NORTH CAROLINA
Wildlife
RESOURCES COMMISSION

2025 North Carolina

WILDLIFE ACTION PLAN

NCWILDLIFE.ORG

Recommended citation:
North Carolina Wildlife Resources Commission. 2025. North Carolina Wildlife Action Plan, 10-Year Comprehensive Review and Revision. Raleigh, NC.

An electronic version of the NC Wildlife Action Plan is available online: http://www.ncwildlife.org/plan.aspx.

This program receives Federal financial assistance from the US Fish and Wildlife Service.

Design and layout by Robert Kern, TIPS Technical Publishing, Inc. (Carrboro, NC)
Cover design by Bryant Cole, NCWRC
Photographs (clockwise, from left) by:
Appalachian Elktoe (Alasmidonta raveneliana), TR Russ, NCWRC
Eastern Painted Bunting (Passerina ciris ciris), Kenneth Cole Schneider
Prescribed burning (an important land management tool), Melissa McGaw, NCWRC
Bog Turtle (Glyptemys muhlenbergii), Melissa McGaw, NCWRC

This public document is available for free download as a PDF file from www.ncwildlife.org/plan.

Chapter 1
Introduction

1

Chapter 1. Introduction

For over 80 years, state fish and wildlife agencies across the United States have benefited from federal aid funds provided by the [Wildlife Restoration Act] (Pittman–Robertson or PR), [Sport Fisheries Restoration Act] (Dingell–Johnson or DJ), and the [Wallop–Breaux Act], which support the conservation and management of game fish and wildlife species. These funds are generated through federal excise taxes collected at the manufacturers' level and have been critical to the establishment of long-term agency conservation planning related to game species.

Yet conservation efforts for nongame fish and wildlife species (those that are not hunted or fished) have historically been opportunistic and crisis-driven. This is largely because of limited resources, such as a lack of dedicated funding, and a lack of strategic approaches to species and habitat conservation. Now, with over 700 wildlife species and 940 plant species currently listed nationally on the federal endangered and threatened species list, there continues to be a critical need for a complementary source of funding for nongame species for continued conservation, protection, and restoration of the full array of North Carolina's wildlife species.

1.1 The Origin of State Wildlife Action Plans (SWAPs)

In the mid-1990s, the Teaming With Wildlife Coalition (TWW) was formed to continue a decade-long effort working to secure funding for the conservation of fish and wildlife species that were not covered by other programs or funding strategies. From their work with members of Congress, the Department of the Interior and Related Agencies Appropriation Act was developed and signed into law in 2002. This Act created the Wildlife Conservation and Restoration Program and the State (and Tribal) Wildlife Grants Program (or SWG, https://www.fws.gov/program/state-wildlife-grants), which provides federal matching funds to all 50 states and territories (separate funding is provided to tribes through the Tribal Wildlife Grants Program). The funds are to be used for conservation efforts aimed at preventing wildlife from becoming endangered and ***keeping common species common***.

The SWG program was designed to assist states with the conservation of nongame species by providing annual allocations of matching grants to supplement, not duplicate, existing fish and wildlife programs. These matching funds support work that benefits species in greatest need of conservation; species indicative of the diversity and health of the states' wildlife; and species with low and declining populations, as designated by the states' fish and wildlife agencies.

The Wildlife and Sport Fish Restoration Program, which is part of the US Fish and Wildlife Service (USFWS), administers the SWG program and apportions funds each year to state wildlife agencies. To be eligible for the matching funds, states and territories are required to work collaboratively with partners, stakeholders, and individuals to develop a state wildlife Action Plan (SWAP) that identifies and prioritizes conservation actions.

1.2 State Wildlife Grants Eligibility and Requirements

Each SWAP must address Eight Required Elements designated by USFWS as minimum requirements included in the Plan (Appendix 1-1) .A comprehensive review and revision of the SWAP is required at 10-year intervals. North Carolina's first SWAP, which was developed to provide a foundation for state and federal agencies and other conservation partners to think strategically about their individual roles and coordinate prioritizing conservation efforts, was reviewed and approved by USFWS in 2005. Details about the development of North Carolina's SWAP are available on the internet (www.ncwildlife.org/plan). The NC Wildlife Resources Commission (NCWRC or Commission) is responsible for managing the SWG program and leads statewide efforts to develop and implement the conservation priorities included in the SWAP. (https://www.ncwildlife.gov)

State funds are needed to match the federal SWG and are generated through several opportunities:

- North Carolina State Tax Checkoff for Nongame and Endangered Wildlife
- Wildlife Diversity Endowment Fund donations (https://www.ncwildlife.gov/donate)
- Purchases of the wildlife conservation special license plate from NC Department of Motor Vehicles (https://payments.ncdot.gov)
- State budget allocations
- In-kind contributions produced by the efforts of volunteers and state and local partners

1.3 From 2015 to 2025—Revision of North Carolina's Wildlife Action Plan

To fulfill the 10-year SWAP revision mandate, NC will complete and submit the revision to USFWS no later than the end of September 2025. To accomplish the revision of this Plan, NCWRC staff worked with numerous federal, state, and local partners, stakeholders, and individuals to complete the review process that began in 2022. Interim updates from two addendums to the 2015 SWAP were published in 2020 and 2022 and have also been incorporated into this 2025 SWAP.

1.3.1 Incorporating Climate Change

The USFWS has provided state fish and wildlife agencies with guidance and best practices for review and revision of SWAPs (USFWS 2007, 2022). Additional revision guidance has been provided by the Association of Fish and Wildlife Agencies (AFWA) for evaluating climate change as an impact to fish and wildlife species during revision of SWAPs (AFWA 2009). The recommendations outlined in their report *Voluntary Guidance for States to Incorporate Climate Change into State*

Wildlife Action Plans and Other Management Plans are correlated to each of the eight elements required by USFWS for state SWAPs (AFWA 2009).

Commission staff continue to work collaboratively with climate scientists and biologists to evaluate how climate change may affect North Carolina's wildlife and habitats. For this revision, WRC has worked with Southeast Conservation Adaptation Strategy (SECAS) staff to develop a regional assessment and framework for coordination and collaboration. By using a regional approach, landscape-scale considerations for North Carolina can serve as a means for the State to find potential collaborations to best support the state's SGCN and Southeast Regional SGCN (RSGCN). A copy of the regional assessment report, "North Carolina, a Regional Perspective" is provided in Appendix 1-2.

Additionally, some of the threats that impact SGCN locally (e.g., development, disease) have consequences statewide and regionally. Addressing these threats effectively requires aligning conservation strategies across state boundaries. By using consistent regional information shared by other states to inform our SWAP, North Carolina can better contribute to regional conservation priorities, identify potential landscape-level threats, and help connect the Southeast region's lands and waters.

The first climate change assessment was published in 2010 in the report *Understanding the Impacts of Climate Change on Fish and Wildlife in North Carolina* (DeWan et al. 2010). Most, if not all, of the information in this report remains relevant. An Executive Summary was published in the 2015 SWAP as Appendix A and is provided in this 2025 SWAP as Appendix 1-3.

Information for several taxonomic groups is provided in Chapter 3 North Carolina's Species. Chapter 4 Habitats contains information about aquatic, wetland, and terrestrial natural communities that are important wildlife habitats. Additional information about climate impacts, plus other categories of threats, is discussed in Chapter 5 Threats.

1.3.2 Revision Approach and Methods

This version of NC's SWAP is the result of the collaborative efforts of many federal and state agencies, local organizations, and citizens working on the revision. Similar to the process for developing previous SWAPs and Addendums, early efforts in the process were spent on planning and organization activities, including the development of committees, review of literature and guidance documents, review and revision of the species evaluation and prioritization process, and investigation of technical publication resources.

The collaborative efforts and extensive assistance from biologists and staff from many organizations and agencies across the state were involved in developing and expanding text, identifying supporting materials (i.e., maps, figures, tables, reports), and assimilating existing

conservation planning resources. It is with great appreciation that we acknowledge their contributions.
Appendix 1-4 provides a copy of the USFWS letter acknowledging NCWRC's intent to comprehensively review and revise the SWAP. Appendix 1-5 is a list of individuals and organizations involved in guiding the revision efforts and participants in work groups and teams that were instrumental to the revision and coordination efforts.

AFWA staff and Southeast AFWA (SEAFWA) member state volunteers and work groups developed best practice recommendations for state fish and wildlife agencies to use in revising and implementing their SWAPs.

- The publication *Best Practices for State Wildlife Action Plans* (Best Practice Guide) was first distributed to the states in late 2012 and subsequently updated in 2022. The guidance is intended to increase plan standardization, and enhance plan effectiveness with respect to prioritization, conservation delivery, and collaboration with partners and other states.

- Additional guidance has been published to assist states with developing digital versions of their revised plans, incorporating climate adaptation measures, and adding plants as SGCN. These documents are available online at the AFWA website https://www.fishwildlife.org/afwa-informs/state-wildlife-action-plans.

To the extent possible, NCWRC has incorporated most of these best practices, including use of ranking procedures to characterize risk and assess the conservation status and need of the state's wildlife species; utilizing spatial analysis tools to identify and map areas that offer the best opportunities for conservation of species and habitats and providing GIS data that support these recommendations; and adopting standard language and classification hierarchies in describing threats and discussing conservation actions (AFWA 2012, 2022).

1.3.3 Report Organization and Format

North Carolina's SWAP not only fulfills the requirements set forth by Congress, it also serves as a practical and essential resource for planning and implementing future fish and wildlife conservation statewide. The entire SWAP document has been comprehensively reviewed for this 2025 revision and the content updated where new and updated information is available. It has also been formatted to improve readability and our ability to revise any section as needed. The format will allow readers to access the document across multiple electronic formats.

This revision generally follows the same structure as the 2015 SWAP, with content organized as described below. A format change has been made to move longer tables, generally those with more than 10 rows, to an appendix. Appendices are numbered to match the chapter where it is referenced. This change was made so it is more apparent which chapter and appendices contain relevant information. For example, all appendix items called out in Chapter 1 will be located in Appendix 1 in sequential order of reference, all remaining chapters and appendices follow this same format.

- **Chapter 1** provides background information on the SWG program, explains why we have a SWAP, outlines the revision process used to update the Plan, and describes the required information that is included in the document. A roadmap to document revisions and where to find the Eight Required Elements is provided in Appendix 1-6.

- **Chapter 2** provides a problem-and-need overview and highlights changes to wildlife and natural community resources, summarizes success stories resulting from steps taken toward addressing conservation needs identified in past SWAP documents, and outlines the goals and objectives of this revised Plan along with recommended strategies and priority actions that can be taken to achieve those goals. Material in this chapter has been updated where necessary.

- **Chapter 3** focuses on fish, wildlife, and plant species for which there are conservation concerns. This chapter defines wildlife statutes and outlines federal and state statutes governing wildlife resources. There is also an explanation about the process for evaluating and ranking wildlife to identify Species of Greatest Conservation Need (SGCN) and other species for which there are research and management priorities. The evaluations focused on both terrestrial and aquatic species in the amphibian, bird, crayfish, freshwater fish, freshwater mussel, mammal, reptile, and snail taxonomic groups. The addition of plants as SGCN, added through Addendum 2 to the 2015 SWAP, has been incorporated into this document. The chapter also provides background information about these groups and individual species, species habitat associations, and conservation needs and recommendations specific to each group. Information provided by partners is included for marine species, pelagic birds, and certain rare and declining arthropods (hereafter 'insects').

- **Chapter 4** contains descriptions of aquatic, wetland, and terrestrial communities based on four primary ecoregions with a list of priority natural communities for conservation. Descriptions cover 12 aquatic communities, **9** wetland communities, **22** terrestrial communities as well as the 17 river basins in the state. The descriptions provide information on SGCNs associated with each community, the problems and threats that affect the communities, anticipated climate change impacts, and outlines recommendations for surveys, monitoring, research, conservation, or management actions specific to each community.

- **Chapter 5** provides information on several categories of threats that are likely to affect North Carolina's natural communities and wildlife during the 10-year planning horizon addressed by this document. Threat categories are based on the classification scheme supported by the International Union for Conservation of Nature (IUCN) Conservation Measures Partnership (IUCN 2012, 2016) and recommended by AFWA in the Best Practice Guide for states to use during the revision process.

- **Chapter 6** summarizes recommendations for conservation action and management applicable statewide. This information represents only a fraction of North Carolina's conservation needs and is intended to be part of the dialogue for implementing collaborative and cooperative discussions about conservation in the state. Recommendations can be used to guide the prioritization of conservation efforts within the context of a particular agency or organization mission. They can also be used to guide conservation or management decisions about a natural community or particular species in any habitat where that species occurs, no matter the size of the management area. Summary information about the agencies, organizations, and partnerships that have developed programs to address wildlife and habitat conservation issues is also included in this chapter.

- **Chapter 7** identifies monitoring needs and outlines strategies and actions that address those needs and provides information about monitoring activities conducted by NCWRC and many of our partners. The chapter includes information about species-specific and guild-level monitoring activities as well as habitat and natural community monitoring.

- **Chapter 8** discusses the next steps for working collaboratively with partners to accomplish the conservation measures identified in this document, provides information about products currently in development that will need to be incorporated as an addendum to this Plan, and plans to review and revise this Plan in an ongoing manner in an effort to keep the information up-to-date and relevant to current and emerging issues.

- **Appendices** provide supporting information and documents that are referenced throughout the Plan, including tables, figures, and a list of acronyms (Appendix 1-7) and a glossary of definitions (Appendix 1-8). Refer to the Table of Contents for a complete list of all tables, figures, and other materials provided in the appendices.

- **References** for the SWAP have been moved from the end of each chapter and are now provided in a separate section at the end of the document. This was done to reduce redundancy and reduce the size of each chapter.

1.4 Potential SWG Program Changes

Currently, SWG program funding is provided through annual federal apportionments and are therefore subject to fluctuations and inconsistency every year. An initiative for a new funding model for the SWG program was first developed by a Blue Ribbon Panel convened by AFWA and comprised of 26 business and political leaders who support state conservation efforts.

Their recommendations led to the creation of the Recovering America's Wildlife Act (RAWA), bipartisan legislation that would change the funding model to provide consistent annual matching grants to states every year without the need for budget negotiations. Both of North Carolina's current elected Senators are co-sponsors of the Senate version of RAWA, S.1149. Ten of North Carolina's elected House of Representative members are co-sponsors of the House version of RAWA, H.R.2773.

The Alliance for America's Fish & Wildlife was formed out of the Blue Ribbon Panel efforts with the purpose to provide sufficient funding to conserve the diversity of fish, wildlife, and their habitats to help keep common species common and reduce the need for federal protection listing under the Endangered Species Act. The Alliance continues to support passage of RAWA and increased funding for wildlife conservation.

Passage of RAWA as it was presented to Congress in 2022 could secure more than $20 million annually for North Carolina for restoration and conservation of species and their habitats as identified in this NCWAP. Additionally, RAWA would allow the NCWRC, along with partners, volunteers and others, to meet the priority goals described in a report on sustaining our state's diverse fish and wildlife resources (NCWRC 2022). With dedicated RAWA funding, this SWAP will serve as a valuable resource that outlines goals and helps identify projects and partnerships to implement conservation priorities for North Carolina. A Summary of the proposed RAWA legislation is provided in Appendix 1-9.

Chapter 2
The Need for Conservation

2

Chapter 2. The Need for Conservation

2.1 Introduction

Using the best information available, North Carolina's previous versions of the State Wildlife Action Plan (SWAP, Plan) addressed local, regional, and statewide concerns across key terrestrial and aquatic habitats and identified critical knowledge gaps and future data needs. This 2025 revision provides a comprehensive review and update of the need for conservation and problems that are likely to impact wildlife and natural communities. The revised Plan identifies significant wildlife resources and critical habitats (Required Elements 1 and 2) across the state and outlines priority conservation actions (Required Elements 3, 4, and 5) for these resources.

This chapter highlights anthropogenic changes to wildlife and natural community resources that emphasize the need for conservation action. Success stories that focus on implementation of SWAP priorities, leading to positive results from conservation efforts, are provided at the end of this chapter.

2.2 Population Changes

A review of numerous economic forecast and development reports provide trend and prediction information about growth patterns for the southeast region and North Carolina. From US Census data, we know that the national population grew 7.4% from 2010 to 2020. Regionally, the South was the fastest growing area in the country with a 10% growth rate. Similarly, North Carolina's population grew from 9.5 million to 10.4 million, an increase of over 9.5%. Results from analysis of the 2020 U.S. Census data confirmed that North Carolina's population grew sufficiently for the state to gain an additional seat in the U.S. House of Representatives (Carolina Demography 2024).

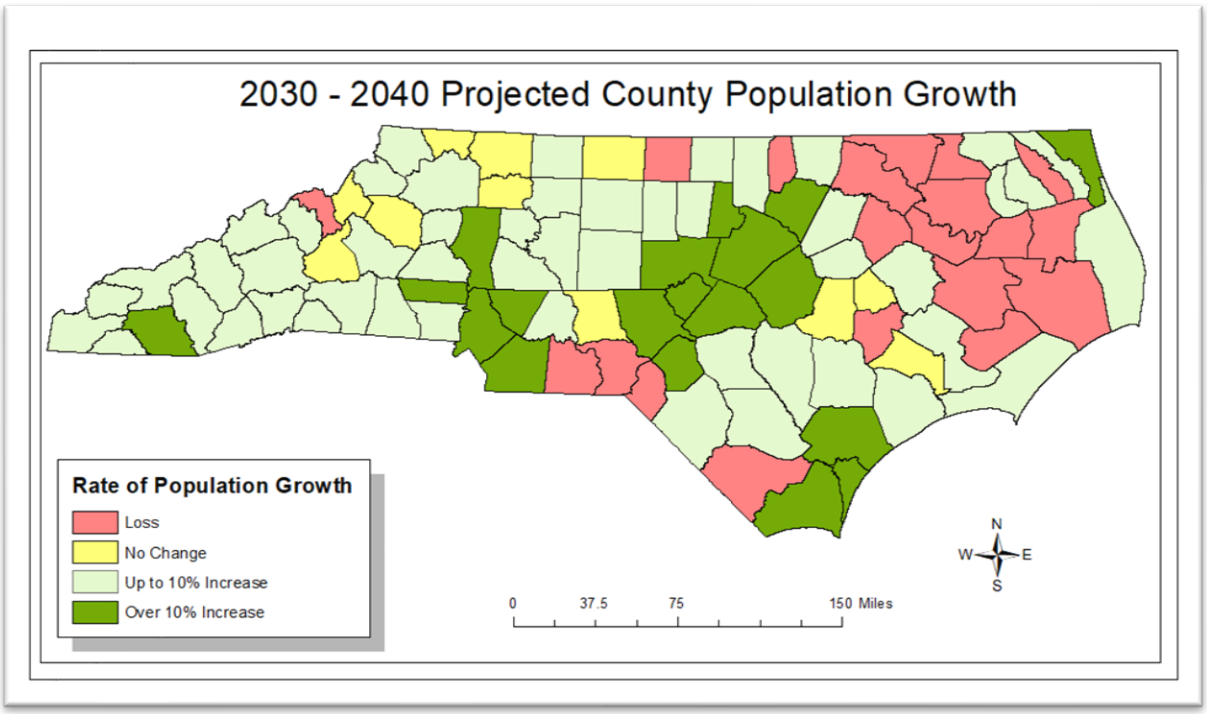
- North Carolina continues to be among the leading states in population growth. Between 2022 and 2023, NC added 140,000 people to its population, ranking it third in state population growth behind Texas and Florida (https://carolinademography.cpc.unc.edu/2023/12/20/north-carolinas-strong-population-growth-continues/)

- If growth continues at projected rates, the state's population will increase by 3.2 million more people by 2050 (USCB 2021).

Other indicators of population growth include commuting patterns that have changed significantly over the last three decades, with more people driving alone and longer distances between home and work and fewer using carpools or walking to work (Jacobsen and Mather 2010). Several reasons have been cited for this trend including increases in car ownership, job growth in suburban and surrounding areas, and an increase in the need to combine trips between home and work with stops at the day care, grocery store, and other locations (Ungemah et al 2007; Jacobsen and Mather 2010).

Much of the current population growth is centered around the state's major urban areas. Figure 2-1 depicts projected population growth rates for 2030 to 2040 in North Carolina by county (OSBM 2024) and supports predictions that growth will center around major metropolitan areas.

Figure 2-1 Projected population growth by county, 2030-2040 (NCOSBM 2024).



Between 2010 and 2020, the top five fastest growing counties in NC were Johnston, Brunswick, Cabarrus, Wake, and Mecklenburg which are counties adjacent to or encompassing the highly urbanized areas of Raleigh, Charlotte, and Wilmington – demonstrating significant growth around urban centers. In 2023, half of NC's population growth occurred in Wake and Mecklenburg counties (NCOBMS 2024). Projections indicate growth trends will continue around large urban centers while rural and less populated areas may experience low growth or population declines. County census data for the 2020 to 2023 period shows the highest percentage of population growth has occurred in coastal counties (Brunswick, Pender, Currituck).

Data for the Raleigh-Durham urban area shows that nearly 70% of the population growth in this urban area occurred in Wake County (USDHUD 2013), which includes the Cary, Wake Forest, Holly Springs, Morrisville, and Apex municipalities. Available housing in the area was projected to meet only 6% of projected demand based on expected population growth. This rate of growth spurred a request by these municipalities for a 38% increase in water withdrawals from the Cape Fear River Basin for drinking water supplies. Growth around these urban areas also resulted in new roads, expanded highway capacity through widening, additional utility infrastructure, and increased commercial, education, and health related development.

The NC Natural and Working Lands (NWL) Action Plan (2020) reports the state's population grew by 27% between 2000 and 2017. With continued population growth we can expect continued changes to land use and for there to be a persistent need for conservation and protection of important natural resources.

2.3 Natural Resources Changes

The Natural Resources Inventory (NRI) periodically conducted by the US Department of Agriculture's (USDA) NRCS reports the status, condition, and trends in soil, water, and other natural resources on non-federal lands in the US (USDA 2020). The 2017 Natural Resources Inventory (NRI) for North Carolina estimates the total surface area of the state, including freshwaters, to be more than 33.7 million acres (USDA 2020). Based on estimates reported in this latest NRI, most land ownership in North Carolina is characterized as non-federal rural lands, which means that nearly all land is private, municipal, state, or tribal owned (see Table 2-1 below) (USDA 2020). The NC Forest Service reports approximately 86% of the farm and forestland holdings in North Carolina are privately owned land (NCFS 2013).

Table 2-1. Surface area of non-Federal and Federal owned land and water areas (USDA 2020)

Federal Land	Non-Federal Land			Surface Waters	Total Surface Area
	Developed	Rural	Total		
2,388	4,916	23,602	28,518	2,804	33,710
All totals are in thousands of acres.					

2.3.1 Land Use and Land Cover Changes

Land use is the term that describes human use of the land, often resulting in some type of modification of the land from its natural or prior state into a developed state (Claggett 2015). Land cover can be defined as the observed biophysical cover on the earth's surface (Di Gregorio 2005, Claggett 2015). The forests, wetlands, farms and fields, and natural communities that cover North Carolina contribute to the health of our ecosystems, the state's economic prosperity, and the quality of life of North Carolina's citizens. However, rapid residential and commercial development in many areas of the state over the last several decades has resulted in the land use change of millions of acres of important land cover (Dutzik, Schneider 2012).

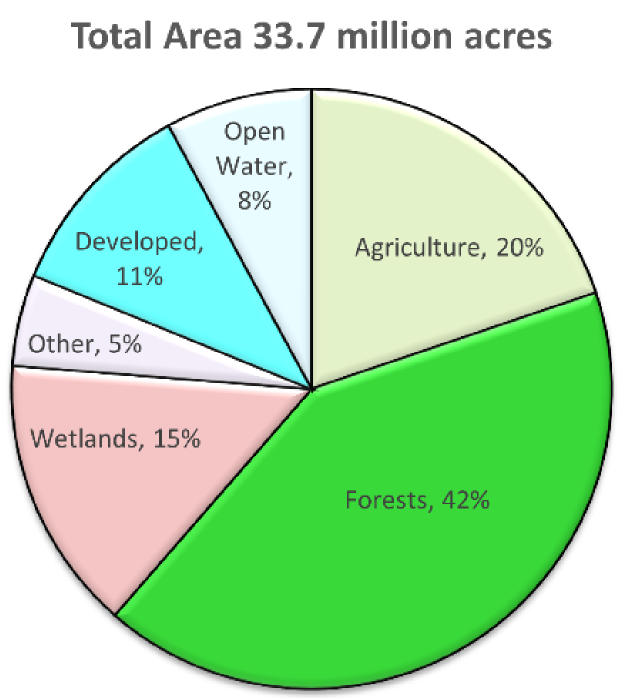
Land use acreage described in the NC Natural and Working Lands (NWL) Action Plan (2020) is summarized in Table 2-2. Figure 2-2 shows land use types by percentage of cover.

Table 2-2 Land Use Types, in millions of acres

(NWL 2020[1], USDA 2022[2])

Land Use	Acres
Forests[2]	18.7
Agriculture[1]	6.9
Wetlands (woody & herbaceous) [1]	4.9
Other Use[1]	1.6
Developed[1]	3.6

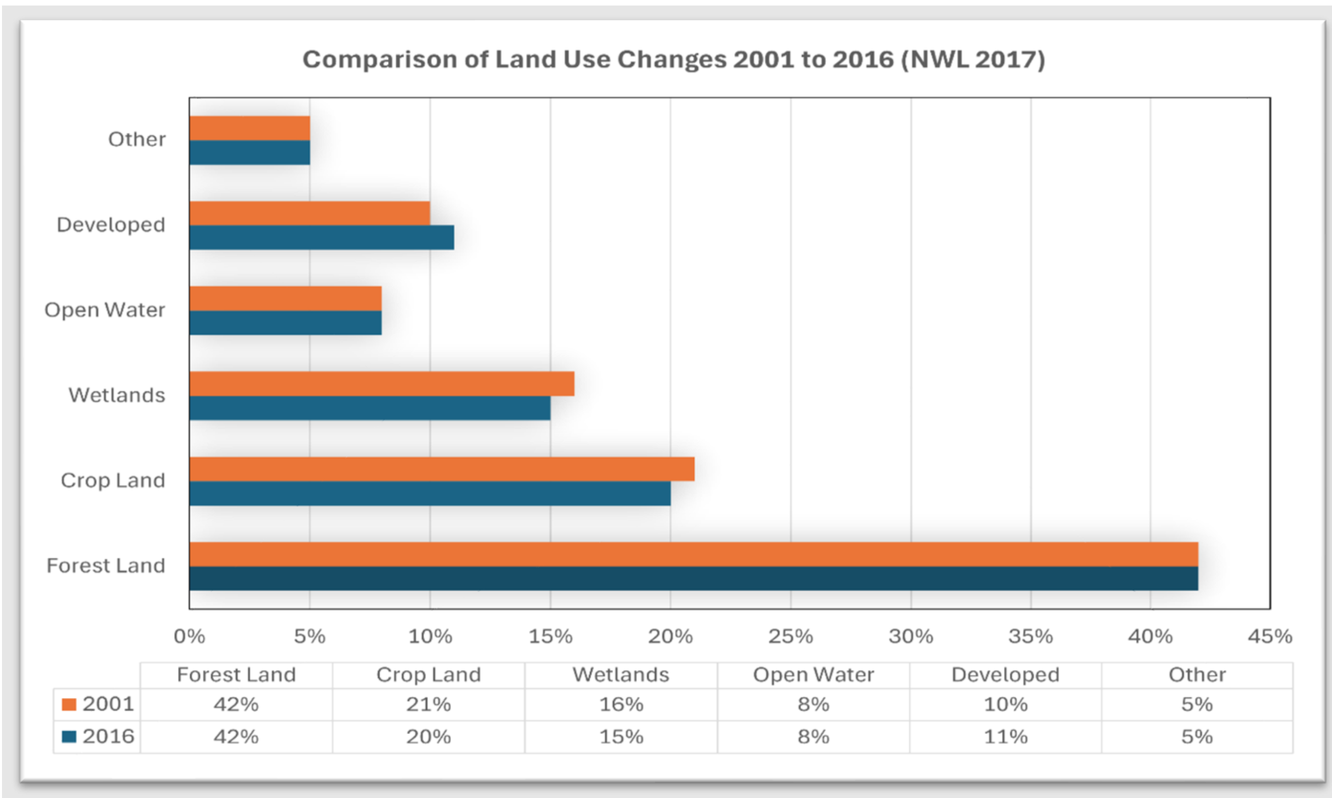
Figure 2-2 Land Use Types, by percentage of cover (NWL 2020)



According to the American Farmland Trust (AFT 2020) agricultural land protection scorecard, North Carolina is among the top states for the conversion of agricultural land to residential development, urban, and highly developed land uses. The American Farmland Trust estimates that NC will lose 12% (nearly 2 million acres) of farmland by 2040, which puts it second in the nation of projected acres of farmland loss (behind Texas) (AFT 2025). Added to the loss of farmland from development conversion is the expected loss of over 17,000 acres by 2040 in coastal areas due to sea level rise (AFT 2022).

The NWL Action Plan notes that developed land use increased by 9% over the period between 2000 and 2017, with a corresponding decrease in cropland and wetland land cover. Figure 2-3 compares land use changes between 2001 and 2016 by land cover types.

Figure 2-3 Comparison of Land Use Changes, 2001 to 2016 (NWL 2020)



2.3.2 Protecting Land

Despite increased land development and population growth, North Carolina has made tremendous progress in protecting valuable and vulnerable watersheds, wildlife habitats, and working landscapes over the past decade. Thanks to a concerted effort by state and local governments, nonprofit groups, land trusts, agricultural organizations, and dedicated citizens across the state, North Carolina has ensured that hundreds of thousands of acres will endure for future generations.

In 2000, then Governor James Hunt, Jr. committed to conserving 1 million additional acres of land by 2010, aiming to have a total of 3.8 million acres conserved. Between 1999 and 2009, more than 680,000 acres of land were permanently protected in North Carolina, increasing North Carolina's stock of protected land in the state by 24%. Between 2009 and 2011, an average of 29,580 additional acres per year was protected. In 2007, there were more than 164,000 acres of farmland in conservation or wetland reserve programs. By the end of 2020, 3.8 million acres of land was conserved in the state, meeting the goal of an additional million acres set by Governor Hunt (Roe 2021).

Beginning in 2021, the state’s Land and Water Fund budget was increased by $49.5 million. From July 2020 to July 2024, 150,396 new acres of land were conserved statewide, bringing the total acreage of land and water protected in North Carolina up to 4,349,267, equaling 12.8% of the state (NWL 2020). To meet the goal of protecting one million new acres by 2040, the statewide rate of protection will need to increase by 35% per year.

In early 2024, then-Governor Roy Cooper committed to conserving an additional 1 million acres by 2040 (Executive Order 305). As reported by the Governor’s office, EO305 is the most significant executive action to protect the state’s ecosystems since Governor Jim Hunt launched the “Million Acre Initiative” in 1999 and sets the most ambitious environmental conservation and restoration targets in the State’s history (NCOG 2024). EO305 was developed based on years of public engagement and seeks to implement transformative recommendations from the 2020 North Carolina Natural and Working Lands Action Plan and other existing efforts (NCOG 2024).

2.3.3 Protecting Endangered Ecosystems

Forest ecosystems that support numerous species and essential ecological processes have high ecological value that might be compromised when the forest is impacted by stressors. The concept of “endangered” forests is based on concerns that continuing losses and impacts from stressors such as land-use changes, invasive species, climate change, and industrial forestry practices will make it increasingly difficult to retain biodiversity in forest ecosystems. These systems may require protection from stressors that threaten their ability to function as complete and natural ecological communities (Forest Ethics et al. 2006).

The IUCN Red List of Ecosystems for North America lists several vulnerable and critically declining terrestrial ecosystems that are found in North Carolina (IUCN 2025). Assessments are based on indicators evaluated over different time frames, including past and historic decline in woodland cover, current extent and trends in tree cover, predicted future changes in climatic suitability, past and historic changes in the intensity of land use, and potential loss of associated wildlife species associated with the habitat (IUCN 2019). These broad ecosystems are temperate systems threatened by increasing population density, intense agriculture, deforestation, and climate change (IUCN 2019, Ferrer-Paris et al. 2019). Overall risk categories for ecosystem types that occur in North Carolina and assessed to be at-risk include critically endangered (CR), endangered (EN), vulnerable (VU), and near threatened (NT) (IUCN 2024).

The following macro group ecosystem types are based on the International Vegetation Classification system (Faber-Langendoem et al. 2014).

- Pond-cypress - Slash Pine Swamp (NT)
- Longleaf Pine woodlands (VU)
- Southern Mesic Mixed Broadleaf forests (VU)
- Southern Floodplain Hardwood Forest (VU)
- Southern Coastal Plain Basin Swamp and Flatwoods (VU)
- South-Central Oak-Hardwood and Pine forests (EN)
- Appalachian and Northeastern Oak - Hardwood and Pine Forest (EN)
- Central Interior and Appalachian Floodplain Forest (EN)
- Southern Coastal Plain Evergreen Hardwood and Conifer Swamp (EN)
- Central and Appalachian Swamp Forest (CR)

According to a recent report on the status of biodiversity in the United States (NatureServe 2023), about 41% of the ecosystems are at risk of range-wide collapse because of an extensive number of threats. The report notes that while tropical ecosystems represent a relatively small proportion of landscapes, they have the highest risk of loss, largely from land-cover change. Temperate ecosystems cover a much larger percentage of the U.S. and are equally at-risk. For example, more than half of the nation's grassland ecosystems are considered at risk of range-wide collapse (NatureServe 2023).

The report also indicates that the largest number of imperiled plant and wildlife species, are concentrated in southeastern and western states. According to the report, the U.S. ecosystems most at risk of range-wide collapse are grasslands (51%) and forests and wetlands (40%). For North Carolina the report shows between 23% and 46% of the state's ecosystems are at-risk of loss (NatureServe 2023).

A study by the Natural Areas Association Science Advisory Committee (Noss et al. 2025) notes that since European settlement, 51 species and 14 subspecies of vascular plants are now extinct in the continental US and Canada (Knapp et al. 2021, Noss et al. 2025). The study recommends species and habitats most in need of conservation action are those determined to be imperiled and vulnerable taxa; endemic taxa and disjunct and peripheral populations; ephemeral habitats for migratory species; representative, under-represented, or imperiled ecosystem types; and areas of high ecological integrity.

2.3.4 Critical Areas for Freshwater Conservation

There have been several aquatic assessments undertaken by conservation organizations during the last several years that address freshwater biodiversity conservation at different scales. These assessments have largely built on the information gathered in previous efforts in order to identify significant regions and priority areas for freshwater conservation.

For example, The Nature Conservancy (TNC) quantified the distribution of freshwater systems and the condition of lands and waters surrounding them to generate a set of priorities for freshwater preservation, restoration, and further exploration (Burns et al.2012; Benner et al. 2014). The Nature Conservancy evaluated streams in the state by applying criteria that considered physical properties and condition characteristics to evaluate their degree of resilience or vulnerability. Resilient stream and river systems are those that have the greatest potential to continue supporting biodiversity into the future despite potentially severe, and often unpredictable, impacts from climate change (Benner et al. 2014). A resilient network is a structurally intact geophysical setting that sustains a diversity of species and natural communities, maintains basic relationships among ecological features and key ecological processes, and allows for adaptive change in composition and structure (Anderson et al. 2012; Benner et al. 2014).

The World Wildlife Fund (WWF) conducted a conservation assessment of freshwater ecoregions of North America (Abell et al. 2000). The Nature Conservancy also assessed small-scale watersheds across the country (Aldrich et al. 1998) and subsequently identified priority areas within four freshwater ecoregions in the Southeast (Smith et al.2002). All three efforts identify the Southeast as a key region for freshwater conservation efforts. Many of the critical areas identified in those efforts overlap North Carolina’s borders:

- The entire South Atlantic freshwater ecoregion (southern Virginia through central Georgia) was identified by Abell et al. (2000) as a key region in which to focus aquatic conservation efforts in North America;

- Smith et al. (2002) identified 70 sites for priority freshwater conservation in North Carolina (14 in the Tennessee-Cumberland Aquatic Region, 56 in the South Atlantic Aquatic Region).

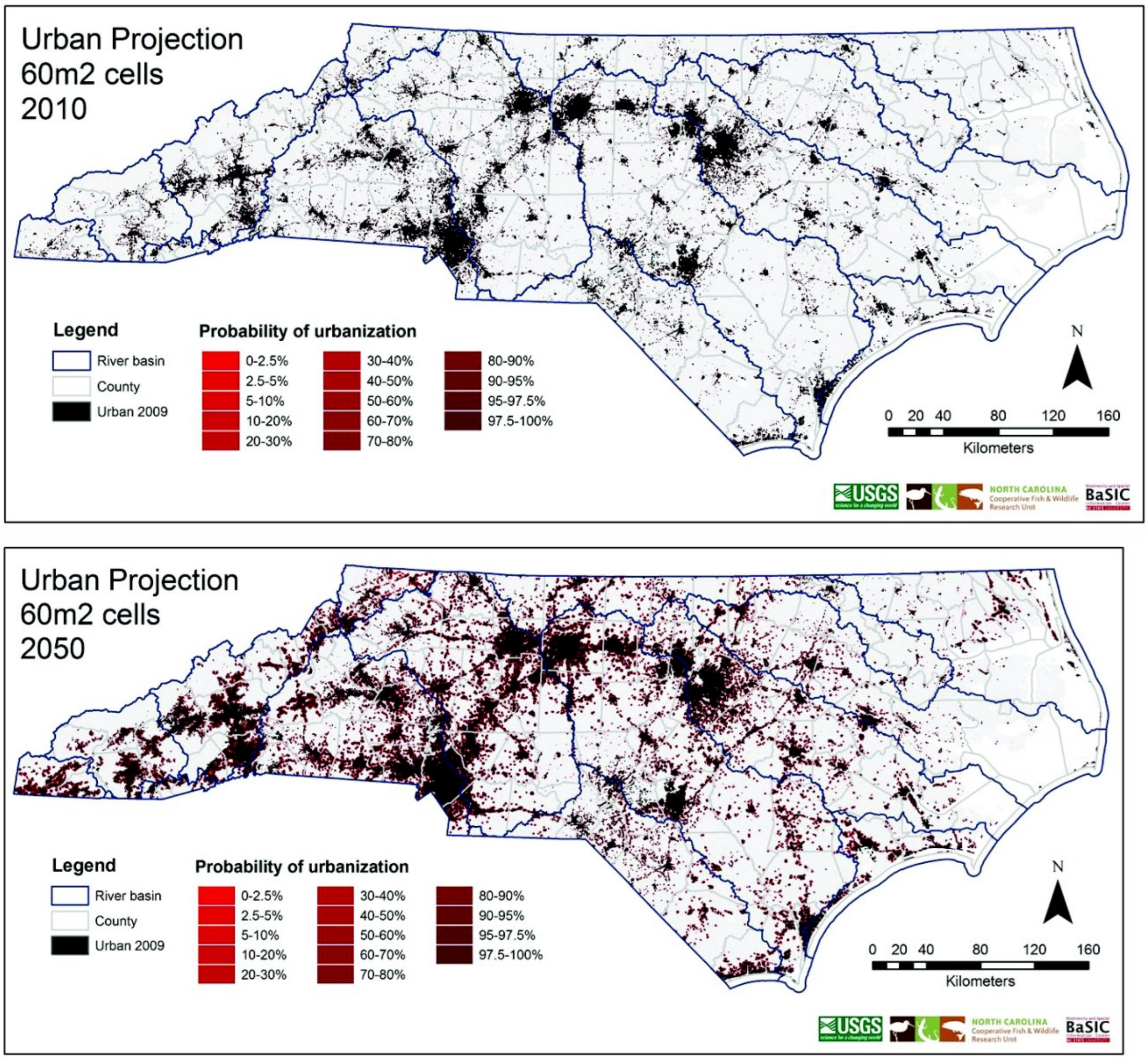
A national water assessment by the U.S. Geological Survey (Stets et al. 2025), surface water provides the largest proportion of public-supply withdrawals. The report also notes the largest category for water use in the Southeast is for thermoelectric power generation. According to the Southeast Aquatic Research Partnership (SARP), southeastern rivers contain the largest number of at-risk aquatic species than any other region of the country (SARP 2025). Projected growth for North Carolina will mean increasing demands for freshwater supplies that will create additional stresses to aquatic resources.

2.4 Uncertainty and Future Conditions

Urban growth probability (as percent change) for the year 2010 to 2050 was projected by means of the Slope, Land use, Excluded, Urban, Transportation and Hillshade (SLEUTH) model, which uses cellular automata, terrain mapping, and land cover change modeling to address urban growth (Jantz et al. 2009; NCGIA 2011). The SLEUTH model incorporates five parameters

(Dispersion, Breed, Spread, Slope, and Road Gravity) into the growth rules that project future urbanization. The model simulates not only the outward growth of existing urban areas but also growth along transportation corridors and new centers of urbanization. Figure 2-4 demonstrates four growth rules (Spontaneous Growth, New Spreading Centers, Edge Growth, and Road-Influenced Growth) to model the predicted rate and pattern of urbanization.

Figure 2-4 Urban growth probabilities (as percent increase) for the period 2010-2020 in comparison with 2010-2050.



Similar results are shown in research conducted by the Spatial Analysis for Conservation and Sustainability SILVIS Lab, a cooperative effort led by the University of Wisconsin Forest and

Wildlife Ecology Department and supported by numerous federal and state agencies and private conservation organizations. The rapid development around the edges of metropolitan areas and expansion into adjacent wild lands and in rural areas is depicted in wildlife–urban interface (WUI) maps. The WUI is the area where houses are in or near wildland vegetation, is the area where wildfires pose the greatest risk to people due to the proximity of flammable vegetation (Radeloff etal 2018). Results of a national assessment indicate one in three houses and one in ten hectares are now a part of the WUI and subject to future wildfire (and likely prescribed fire) impacts.

2.5 Conclusion

A myriad of factors affect the abundance and distribution of species and habitats and many (if not most) are related to human influences. The fact that the management and implementation of conservation measures often fall under the jurisdiction of multiple agencies and organizations presents an obstacle to effective conservation. It also offers opportunities for partnerships as well as the sharing of information and resources. Natural resource agencies must work more closely with private landowners and nongovernmental organizations to identify common conservation goals and to work toward cooperative achievement of those goals.

Considering the persistent limits to funding and manpower resources available for implementing conservation strategies, it is imperative to prioritize efforts and work collaboratively to implement the recommendations outlined in this SWAP. Examples of successful conservation efforts that implement the priorities identified in previous SWAPs are provided in Appendix 2.

The remaining chapters in this document provide information about the conservation and management needs of North Carolina's native species and the natural communities that support them, prioritize recommendations for meeting those needs, and identify important partnerships and programs that work toward achieving conservation goals.

Chapter 3
North Carolina's Species

3

Chapter 3. North Carolina's Species

> ***Required Element 1****: Information on the distribution and abundance of species of wildlife, including low and declining populations as the state fish and wildlife agency deems appropriate, that are indicative of the diversity and health of the state's wildlife.*

3.1 Introduction

Keeping common species common and preventing extinction are important actions, because any loss of species will reduce diversity in natural communities and will have unknown consequences for ecosystems' processes, functions, and services upon which we depend (Mace and Purvis 2008; Diaz et al. 2006). A loss of species diversity can also contribute to constraints in gene flow, which will influence the ability of a species to survive changing conditions and stressors (Mace and Purvis 2008; Myers and Knoll 2001).

Conservation efforts are often necessary to successfully reverse declining population trends and prevent the need for a species to be listed for protection under federal and state laws. While it could be justified to rank every species at the highest priority for conservation and management efforts, there are usually not sufficient resources to implement and achieve this level of effort. Time, staff, and budget constraints are resource limitations that must be factored into conservation planning in an effort to support more effective use of resources. It is important to focus efforts not only on the highest priorities but also on those measures that have the greatest impact, can achieve the most benefits, or are easiest to implement. It is also important to take advantage of opportunities to work synergistically with partners toward achieving common conservation goals.

In most cases, common names are used throughout this document to identify a species. Exceptions include species for which there is taxonomic uncertainty or when common practice is to use a form of the scientific name as the common name; in those instances, the scientific name may be used to identify the species. Lists of all species found in North Carolina that were evaluated by a Taxa Team for identification of Species of Greatest Conservation Need (SGCN) include the common and scientific names, taxonomic information, federal and state protection status, and taxa team evaluation results.

Appendix 3 contains the following list of tables that have designations for SGCN and other priority species for the taxonomic groups discussed in this chapter. The tables also provide the common and scientific names and taxonomic information for species evaluated by taxa teams. Insect SGCN are designated through recommendations from species experts and partners. Plant SGCN are designated through the state listing process by Scientific Council.

All tables are available to download as an Excel file from the 2025 NC SWAP website www.ncwildlife.org/plan.

- Table 3-1 Amphibian SGCN and Priority Species
- Table 3-2 Bird SGCN and Priority Species
- Table 3-3 Crayfish SGCN and Priority Species
- Table 3-4 Freshwater Fish SGCN and Priority Species
- Table 3-5 Freshwater Mussel SGCN and Priority Species
- Table 3-6 Mammal SGCN and Priority Species
- Table 3-7 Reptile SGCN and Priority Species
- Table 3-8 Aquatic Snail SGCN and Priority Species
- Table 3-9 Terrestrial Snail SGCN and Priority Species
- Table 3-10 Insect SGCN and Priority Species
- Table 3-11 Plant SGCN and Priority Species
- Table 3-12 EBCI SGCN and Priority Species

Table 3-13 provides information on the federal and state listing abbreviations and their definitions.In 2022, NC WRC worked with the NC Natural Heritage Program (NHP) and the NC Department of Agriculture and Consumer Services Plant Conservation Program to publish a list of plant SGCN. Addendum 2 to the 2015 SWAP outlines the methodology used to designate plant SGCN. Table 3-14 (Appendix 3) provides a list of common and scientific names for invasive or nonnative species mentioned in this document.

3.1.1 Regulatory Authority for Plants and Wildlife

The idea of wildlife as a "public trust" resource, meaning it is a resource shared as common property amongst all people, was the prevalent perspective during the Roman era. During the Middle Ages, common law tradition that emerged in England stated that wildlife species were legally owned by the king and not for private use (Organ and Mahoney 2007; UCB 2010). However, plants were not owned by the king and fish were subject to limited property rights dependent upon possession (Walrut 2004).

The legal system in the United States is based on English common law (UCB 2010); however, common usage and laws in the United States have reestablished fish and wildlife as public trust resources. By the beginning of the 20th century, overuse and extinctions led to the need for regulation, thus federal laws were established to protect and regulate the use of wildlife resources.

One of the most important protective measures for species conservation is the Endangered Species Act (ESA) of 1973, designed to protect and recover endangered and threatened species of fish, wildlife, and plants within the United States and its territories.

- Information about federal laws regulating wildlife can be found online by visiting the US Fish and Wildlife Service (USFWS) laws and regulations webpage (http://www.fws.gov/laws/lawsdigest/Resourcelaws.html).

- Information about North Carolina regulations can be found online by visiting the North Carolina General Assembly webpage to review General Statutes (GS) https://www.ncleg.gov/Laws/GeneralStatutesTOC.

The first people of the American continent were the original environmental stewards. It is important to recognize the Eastern Band of Cherokee Indians (EBCI, Tribe) is a sovereign nation recognized by the US federal government as being autonomous with its own laws. The Tribe has authority to regulate and manage the species occurring on the Cherokee Public Trust lands (e.g, Qualla Boundary). Tribal governments have a unique legal relationship with the United States and can exercise inherent sovereign governmental powers over their natural resources and tribal members (EBCI 2022).

Conserving natural resources on sovereign tribal lands poses a unique challenge where managers must consider balancing the maintenance of a unique culture and a productive economy with complex natural resource management challenges (EBCI 2022). Federal and state agencies, including NCWRC, work collaboratively with the EBCI on shared priorities and to benefit shared natural resources. The EBCI Natural Resources Program, Fisheries and Wildlife Management Office develops and implements the Tribe's Wildlife Action Plan, which focuses on a social-ecological framework to adaptively manage and conserve fish and wildlife and their habitats (EBCI 2022). Species and habitats representing conservation and cultural priorities of the Tribe have been incorporated into this SWAP.

International protections are provided by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), an agreement between international governments to protect wild plants and animals from becoming threatened or endangered from international trade. The United States is a participating member nation. Protection is afforded through listing of a species in one of three lists, or appendices (UNEP-WCMC 2025).

- Appendix I provides the highest protection, limiting any trade of a species on the list only to exceptional circumstances because they are threatened with extinction.

- Appendix II controls trade of species that are at higher risk when trade could be incompatible with their survival.

- Species included in Appendix III are protected in at least one country that is party to the convention and CITES has been asked for assistance in controlling trade of the species.

3.1.1.1 Wildlife

North Carolina has enacted legislation that states all marine, estuarine, and wildlife resources are public trust resources, establishes state jurisdictions and authorities for their use and management, and assigns stewardship of natural resources to certain state agencies. Legislation states that public trust lands and waters are under stewardship authority of either the NC Wildlife Resources Commission (WRC) (freshwater and inland resources) or the Marine Fisheries Commission (marine and estuarine resources) [NCGS Article 12, § 113-132; .§113-333]

The General Statutes direct the WRC to manage, restore, develop, cultivate, conserve, protect, and regulate the wildlife resources of the state; to determine the requirements for conservation of protected wild animal species; and also grant the WRC authority to conduct investigations to determine whether a wild animal should be on a protected animal list (in GS 113; GS 143).

While not inclusive of all federal and state legislation, Table 3-15 provides a list of important federal and state laws that regulate and protect wildlife resources in North Carolina

3.1.1.2 Plants

The N.C. Nature Preserves Act was enacted in 1985 (NCAC 1985: a.2 c.143B §49-§135.273) and allows the State to obtain and dedicate land as permanently protected nature preserves. North Carolina's Department of Agriculture and Consumer Services, Plant Conservation Program (PCP) was authorized by the Plant Protection and Conservation Act (NCAC 1979: a.19B c.106 §202.12–§.202.22) to manage plant conservation in the State including adopting a state list of protected plant species, adopting and enforcing regulations that protect, conserve, and enhance those listed species, and developing conservation programs for the benefit of listed species.

The PCP is responsible for managing more than 14,500 acres of conservation preserve properties across the state (Friends of Plant Conservation 2021). These preserves provide critical conservation for about 18% of the plant species listed in North Carolina. Additional plant protection is provided by legislation that protects land from criminal trespass (NCAC 2014: a.22 c.14 §126–§159.4) and prohibits taking of certain wild plants from private or public land without a permit issued by the owner.

Table 3-16 provides a list of federal and state laws that regulate and protect plants in the state.

3.1.2 Definitions

North Carolina's General Statutes also provide definitions covering fish, including freshwater, marine, and estuarine species, and wildlife resources, including game and migratory species. These include the following legislative definitions: (defined in NCGS 113, Article 12, §113-129):

- "*Wildlife* [is] all wild animals, wild birds, all fish found in inland fishing waters, and inland game fish".

- "*Wild Animal* means any native or once-native nongame amphibian, bird, crustacean, fish, mammal, mollusk, or reptile not otherwise legally classified by statute or regulation such as game and fur bearing animals, except those inhabiting and depending upon coastal fishing waters, marine and estuarine resources, marine mammals found in coastal fishing waters, sea turtles found in coastal fishing waters, and those declared to be pests under the Structural Pest Control Act of North Carolina of 1955 or the North Carolina Pesticide Law of 1971.".

- "*Wildlife Resources* [are] all wild birds; all wild mammals other than marine mammals found in coastal fishing waters; all fish found in inland fishing waters, including migratory saltwater fish; all inland game fish; all uncultivated or undomesticated plant and animal life inhabiting or depending upon inland fishing waters; waterfowl food plants wherever found, except that to the extent such plants in coastal fishing waters affect the conservation of marine and estuarine resources the Department (Department of Environment and Natural Resources) is given concurrent jurisdiction as to such plants; all undomesticated terrestrial creatures; and the entire ecology supporting such birds, mammals, fish, plant and animal life, and creatures.".

- "*Marine and Estuarine Resources* [are] all fish, except inland game fish, found in the Atlantic Ocean and in coastal fishing waters; all fisheries based upon such fish; all uncultivated or undomesticated plant and animal life, other than wildlife resources, inhabiting or dependent upon coastal fishing waters; and the entire ecology supporting such fish, fisheries, and plant and animal life."

- "*Nongame animals* are all wild animals except game and fur-bearing animals; all wild birds except game birds; and all fish found in inland fishing waters other than inland game fish. Wildlife that are considered to be 'game' species are regulated and subject to special license requirements for harvesting them (e.g., fishing, hunting, trapping)."

In some instances, an animal may fall into more than one regulation or license category. For example, bobcats are classified as a fur-bearing animal subject to trapping regulations and as a game animal subject to hunting regulations. Information about which species are game animals in North Carolina and the regulations and license requirements for fishing, hunting, or trapping wildlife can be found in the Commission's rules and regulation digest, which is published annually online at the WRC webpage https://www.ncwildlife.org/hunting/fishing-hunting-trapping-regulations.

- "*Plant*" means any member of the plant kingdom, including seeds, roots and other parts or their propagules.

- "*Resident plant or resident species*" means a native species or higher taxon of plant growing in North Carolina

- "*Protected plant*" means a species or higher taxon of plant adopted by the North Carolina Plant Conservation Board (Board) to protect, conserve, and/or enhance the plant species and includes those the Board has designated as endangered, threatened, or of special concern.

- "*Endangered plant species*" means any species or higher taxon of plant whose continued existence as a viable component of the State's flora is determined to be in jeopardy by the Board; also, any species of plant determined to be an "endangered species" pursuant to the ESA.

- "*Threatened plant species*" means any resident species of plant which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range, or one that is designated as threatened by the Federal Fish and Wildlife Service.

- "*Special concern plant species*" means any species of plant in North Carolina which requires monitoring but which may be collected and sold under regulations adopted under the provisions of the Plant Protection and Conservation Act.

3.1.3 Permit Requirements

With few exceptions, collection and possession of live animals from the wild is illegal and can be prosecuted under state law; with the exception authorizing the WRC to issue permits for wildlife collectors. This applies to all wildlife species and allows collection and possession when a permit has been issued by WRC. Permits are also required for scientific collection of any federal or state protected species for any reason (e.g., research, propagation). However, when a scientific collection permit is issued, possession of the animal must be temporary and the animal must be returned alive to the site where it was collected.

Another exception has been made for collection and possession of amphibian or reptile species which allows for an individual to collect a limited number of animals without the need for a permit (GS 113-21). Regulations for nongame species possession and collection and other regulations can be found on the WRC webpage for fishing, hunting, and trapping regulations.

For plants, a certificate or permit must accompany the movement of pests designated as regulated articles. Limited permits may be issued by a state regulatory official for the movement of non-certified regulated articles to specified destinations for limited handling, utilization, processing or treatment when the official determines no hazard of spread of noxious weeds exists. Scientific permits may be issued by the North Carolina Department of Agriculture and Consumer Services' (NCDA&CS) Plant Pest Administrator to allow the movement of noxious weeds in any living stage and any regulated articles for scientific purposes under such conditions as may be prescribed in each specific case.

A protected plant permit is required for scientific collection or rescue of a protected plant species (including seeds, leaves, rhizomes, or other parts) on land you do not own, with or with landowner permission. A permit is needed to acquire and relocate a protect plant species in a non-garden setting, including rescuing plants; propagating plants; or the sale, auction, or give away of protected species. Commercial operations that purchase a protected species must have a certificate or origin for protected species. For more information, visit the NCDA&CS Plant Industry, Plant Conservation Program permits web page https://www.ncagr.gov/divisions/plant-industry/plant-protection/plant-conservation-program/permits.

3.1.4 Taxa Team SGCN Evaluation Process

Conservation priorities need to include the greatest variety of biological diversity possible as a means of ensuring that genetic diversity and ecosystem services remain viable as our environment is changed by natural and man-made forces. One way to determine where to focus our conservation efforts is to evaluate what we know about the status of a species and prioritize where best to direct our efforts.

In preparation for the first comprehensive review and revision of North Carolina's SWAP (2015), a work group comprised of WRC biologists developed recommendations for an evaluation process that was peer-reviewed by species experts and research authorities. The evaluation process and methodology are described in a white paper found in Appendix 3 as Reference 31.

A new work group was convened in 2022 to review the 2015 SWAP evaluation process and recommended the method be retained for application in the 2025 SWAP comprehensive review and revision. Taxa Teams of species experts were convened in 2023 and tasked with evaluating eight taxonomic groups of fish and wildlife based on the jurisdictional authority outlined in Section 3.1 and traditional programmatic boundaries. These eight taxonomic groups are: amphibians, birds, crayfishes, freshwater fishes, freshwater mussels, mammals, reptiles, and snails.

The 2025 SWAP revision Taxa Teams used three evaluation categories to measure what we know about the status of North Carolina's fish and wildlife species. The categories are described in Reference 3-1 and include the following:

1. **Conservation Concerns** (Metrics 1 through 9). This category is designed to evaluate biological vulnerability by considering the global and regional status and trends of a species range-wide (wherever it occurs) as well as its local status (wherever it occurs in North Carolina). The species that scored above a threshold established by each Taxa

Team for the Conservation Concern evaluation category have been designated as Species of Greatest Conservation Need (SGCN).

2. **Knowledge Gaps** (Metrics 10 through 14). This category is similar in scope to the 'Research Needed' classification scheme outlined in the IUCN Red List Categories and Criteria (IUCN 2012). This category was developed to identify and prioritize survey, monitoring, and research needs of species in North Carolina.

3. **Management Needs** (Metrics 15 through 20). Ranking scores developed for this category can be used to identify and highlight population sustainability issues and areas where management action may be needed to mitigate impacts on both game and nongame species.

Following the evaluations, each Taxa Team established threshold scores for each evaluation category using the Delphi method (Linstone and Turoff 2002) and considering statistical quartiles and weighting factors as deemed appropriate for the taxonomic group. The ranking scores were then used to prioritize levels of concern for species within each taxonomic group. Copies of the Taxa Team evaluation tables are available in the appendices (refer to Section 3.1) as well as online; they can be downloaded in Excel format from the SWAP webpage (http://www.ncwildlife.org/plan).

The eight Taxa Teams had the option to exclude some species from their evaluations because they may occur at the extreme periphery of their range in the state; occur as accidentals or sporadic migrants that do not normally occur in the state; or have a conservation status or management objectives that have been developed through cooperative efforts of specific conservation partnerships (e.g., North American Bird Conservation Initiative) or are mandated under Federal authorities (e.g., regional Fisheries Management Councils, endangered and threatened species recovery plans).

This 2025 SWAP also includes several groups of species in the phylum Arthropoda for which there is statewide or national concern regarding conservation status. Not all species in this phylum are true insects, but we use the common term "insects" in this document to collectively refer to them. Generally, there is a significant lack of knowledge about insects in the state (e.g., population size, distribution, life history, and more), which increases the complexity and difficulty in determining conservation status or needs. Except for those identified as serious agricultural pests, there is also some ambiguity about which state agencies have regulatory or conservation authority over insects in North Carolina.

3.1.5 Species of Greatest Conservation Need (SGCN)

Element 1 of the Eight Required Elements (see Appendix 1) directs states to identify low and declining populations that are indicative of the diversity and health of the state's wildlife. In

North Carolina, lists of SGCN are determined by Taxa Teams using the evaluation methodology described in Appendix 3 (Reference 3-1 White Paper).

Sections 3.2 through 3.13 in this chapter provide information on fish, wildlife, and plant SGCN and other priority species by taxonomic group. Each section addresses one of the eight fish and wildlife taxonomic groups (listed in alphabetical order) traditionally managed by NCWRC as well as marine, pelagic birds, and insects recommended by conservation partners or identified in federal and state agency conservation plans.

Additionally, any species newly listed for federal protection under the ESA, or that are petitioned for listing and for which the USFWS issues a positive 90-day finding, and newly described species will be considered SGCN without need for evaluation by a Taxa Team. All wildlife SGCN are considered a priority for use of State Wildlife Grant (SWG) Program funds.

Insects recommended as SGCN include those listed for federal ESA protections; that are important to pollination and certain food web cycles; being tracked by the North Carolina Natural Heritage Program (NCNHP); or were identified by biologists, researchers, and other knowledgeable experts to be of cultural, national, or state conservation concern. The insects identified as conservation and research priorities include important pollinator species (bees, wasps, butterflies, and moths) and species with significant aquatic life stages that are important indicators of water quality and are part of aquatic food webs (dragonflies, mayflies, stoneflies, and caddisflies).

Plant SGCN were added to the 2015 SWAP through Addendum 2 (published in 2022). Plant SGCN are those species designated by the state for protection under North Carolina's state listing process. A complete list of all plant SGCN and their federal and/or state listing status and NatureServe global (G rank) and State (S rank) ranking is provided in Table 3-11 (Appendix 3). It should be noted that the regulations governing the use of SWG funds clearly states that funds cannot be used for plant SGCN.

3.1.5.1 Cherokee Species of Concern

All native organisms found within Cherokee's aboriginal homelands are tied to Cherokee identity and culture. The simple act of seeing the diversity of life within streams and a forest can provide a spiritual connection and is provides an economic value as a view-scape (EBCI 2013, 2022). Determining where to focus limited resources in the face of accelerating threats to ecological integrity is a challenging task. The EBCI works to identify and prioritize conservation targets through the integration of both cultural values and modern scientific perspectives. In turn, EBCI Natural Resources focuses its conservation strategies on biological conditions that will affect prioritized conservation targets (EBCI 2022).

Specific biological conditions receiving management attention consist of species, assemblages, and habitat-specific conservation targets based upon a variety of cultural, economic, legal, and ecological factors (EBCI 2022). The Cherokee prioritize species for cultural significance based on an expression of community value as documented in the EBCI Legacy Plan (EBCI 2013), contemporary and historic public input, and historic documentation verified by the EBC Tribal Historic Preservation Office (EBCI 2022). The EBCI Wildlife Action Plan (2022) is available in Appendix 3 as Reference 3-2.

Tribal prioritization considers cultural and ecological significance and the biodiversity of species and natural systems.

- Cultural Significance recognizes that plants and animals often possess multiple cultural values and uses, including consumptive and recreational subsistence purposes, artisan and traditional cultural practices, and spiritual and aesthetic values (EBCI 2022).

- Ecological Significance recognizes the legal and regulatory factors for species, range-wide and EBCI conservation status, and relative importance to ecosystem processes. This includes species with federal protection under the ESA, at-risk species being evaluated for potential listing under the ESA. Species known to be rare or declining on EBCI Trust lands and native (or non-native) species that threaten ecological or cultural values through changes to the environment or impacts to native species are also considered. Also included are species that perform critical ecosystem functions and species that are either rare or unknown (knowledge gaps) as defined by EBCI Natural Resources (EBCI 2022).

- Biodiversity is a critical part of ecosystems and maintaining a great diversity of species ensures essential roles in the environment are fulfilled. Conservation targets prioritized for biodiversity include species assemblages that perform critical ecosystem functions and whose status is either rare or unknown as defined by EBCI Natural Resources. Species assemblages facing existing and impending threats also receive prioritized management attention. (EBCI 2022).

3.1.5.2 Regional Species of Greatest Conservation Need (RSGCN)

The Southeast Association of Fish and Wildlife Agencies (SEAFWA) Wildlife Diversity Committee developed a list of Regional SGCN (RSGCN) in 2018 through collaboration of the 15 member states (Rice et al. 2019). Currently, the SEAFWA RSGCN report and associated data are hosted on the Georgia Department of Natural Resources (GADNR), Wildlife Resources Division's Biodiversity Portal website https://georgiabiodiversity.org/portal/sersgcn. North Carolina's SGCN lists (see Section 3.1) includes notations for RSGCN designations for North Carolina species on the RSGCN list.

The Southeastern Plant Conservation Alliance, Atlanta Botanical Garden, NatureServe, and Terwilliger Consulting, and SEAFWA's member states worked collaboratively to evaluate vascular plant taxa to create a RSGCN list of plants (Rice et al. 2019, Radcliffe et al. 2023). North Carolina's Plant SGCN list includes notations for SEAFWA plant RSGCN designations.

The SEAFWA Wildlife Diversity Committee recommended improvements to the identification, assessment, and prioritization of SGCN by member states. Final recommendations were published in a report published in September 2022 (SEAFWA 2023). A Southeastern SGCN evaluation database was developed by GADNR, with assistance from Arkansas Game and Fish Commission, and NC WRC (available online https://georgiabiodiversity.org). The project was funded through a competitive SWG grant awarded in 2021. North Carolina partnered with the NC Natural Heritage Program to enter 2025 Taxa Team evaluation results into the new SEAFWA SGCN database along with NatureServe Biometrics data tracked by NHP. NC WRC will use the SEAFWA SGCN database to generate reports for comparison with evaluation ranking scores generated by the 2025 SWAP Taxa Team SGCN evaluation process.

3.1.7 Knowledge Gaps and Research Needs

One of the obstacles to wildlife conservation and management is often a lack of scientific information about a species or taxon. A lack of information inhibits the ability to assess the risk of extinction for a species based on its distribution, population status, or other metric (IUCN 2012). A lack of data can also preclude preventative measures that protect a species or result in failure to restrict actions that will have a negative consequence for a species. The knowledge gap category (evaluation Metrics 10 to 14) is used to prioritize research needs over the next 10 years based on what can be achieved under existing programs or given available resources to develop new programs.

Changes that occur over long time periods may be hard to detect without monitoring data and the reasons for a species' decline may be difficult to discern when data are insufficient. The lack of long-term data coupled with a need to develop policies that are often short-term responses can contribute to inefficient and ineffective conservation measures (Mace and Purvis 2008). Identifying where information is lacking or where uncertainty exists about the information available will improve decisions made about conservation needs and actions. Survey, monitoring, and research data are needed before we can develop conservation actions that benefit species and preserve biodiversity and ecosystem services (Arponen 2012).

Knowledge Gap research priority species were identified by the 2025 SWAP Taxa Teams and are listed in the SGCN and priority species tables provided in Appendix 3.

3.1.8 Management Needs

The Management Concern evaluation category (Metrics 15 through 20) was developed to evaluate both game and nongame species. The evaluation results can be used to identify populations with sustainability issues and areas where there may be a need for management action to mitigate impacts on a species.

There may be reasons, other than conservation concern or research needs, for a species to be considered a priority for some type of action. For example, one may be a species of recreational, commercial, or tribal importance that is vulnerable to local threats but has stable populations elsewhere. It may be a species for which we are unable to determine true status in the state because it is not monitored or is very difficult to monitor. Or it may be a species for which there are concerns about the potential for disease to occur within a population, but for which there are no programs for disease monitoring or management.

In some cases, when population densities of common species (those found throughout the state) are concentrated to the extent they exert competitive pressures on local populations of rare species, intervention measures may be deemed necessary. Sometimes a species for which we have lower conservation concerns can be impacted by emerging threats or the synergistic effects of multiple threats can cause rapid declines to their populations and management action must be taken to mitigate the impacts.

Species that scored above the ranking score thresholds set by the Taxa Teams have been recommended as a priority for decisions about habitat management, land protection, or other management actions. The management priority species are identified in the SGCN and priority species tables provided in Appendix 3.

As noted in the EBCI Wildlife Action Plan (Appendix 3, Reference 3-2) they group management actions into conservation strategies and information transfer and processing.

- Conservation strategies focus on altering biological conditions to enhance ecosystem services. This is accomplished through inventory and monitoring and management and research efforts.

- The Tribe develops reports by organizing and disseminating inventory and monitoring data and sharing it with collaborators and funding agencies. The data is interpreted and management recommendations are developed.

3.1.9 Species and Habitat Associations

A discussion about species will necessarily require consideration for the natural communities that provide the habitats they occupy. To aid the discussion about conservation and management actions, we have developed species–habitat association information for SGCN. The resulting species–habitat matrix is organized by ecoregions of the state (Mountain, Piedmont, Sandhills, and Coastal Plain) for the aquatic, wetland, and terrestrial communities and the state's major river basins described in Chapter 4 Habitats.

Habitat associations between SGCN from the eight taxonomic groups evaluated by Taxa Teams and the aquatic and terrestrial habitats and major river basins are provided in the following appendices. Excel tables can be downloaded from the 2025 SWAP website (www.ncwildlife.org/plan).

- Table 3-17 (Appendix 3) provides terrestrial habitat associations for SGCN, by ecoregion and taxonomic group.

- Table 3-18 (Appendix 3) provides aquatic habitat associations for SGCN, by major river basins and taxonomic group.

Since natural communities are composed of many different species and trophic levels, information about the functional relationships between and amongst the species found in these communities is also discussed in Chapter 4. Groups of species that use the same resources but are not taxonomically related are often referred to as an ecological guild. The guild concept is often used to provide a framework for discussions about survey, research, and monitoring needs and conservation recommendations that benefit multiple species, such shorebirds and colonial waterbirds, and the natural communities they occupy. A few important species' guilds and associations are discussed in Sections 3.2 through 3.13.

3.1.10 Population Objectives

As noted in the 2005 and 2015 SWAPs, specific population objectives are difficult to assess for the majority of fish and wildlife in North Carolina due to data limitations and knowledge gaps that need to be filled. Survey, monitoring, and research efforts have since contributed to improving our knowledge base, but with little more than 10 to 20 years of data accumulated for many species, there is still much we do not know or understand about many of the species found in North Carolina.

Due to the mostly strategic (and not operational) nature of this Plan, we have not identified specific population objectives for each species mentioned herein. However, for some species, such as birds and marine fish, data to assess population level objectives developed through the cooperative efforts of specific conservation partnerships may be available. Examples of these partnerships include the North American Bird Conservation Initiative, Atlantic Coast Joint Venture, and the regional Fisheries Management Councils. Recovery plans for species on the federal ESA protected species list include population objectives related to species recovery thresholds.

Table 3-19 (Appendix 3) provides a list of recovery plans, conservation plans, and management plans that include population targets; links to the appropriate websites to download plan information are included in the table.

The remaining sections of this chapter provide information about each of the eight taxonomic groups reviewed by the Taxa Teams plus information on marine, pelagic bird, and "insect" species that are conservation priorities for other agencies and partners. A few species of particular concern have been highlighted and recommendations specific to species or guilds are noted in a subsection with recommendations for each taxonomic group.

The EBCI's Wildlife Action Plan (2022) outlines conservation targets for several priority species in the Plan's appendices. Each of the conservation targets provides the Tribe's management goals and actions, biological conditions of the species and its habtats, ecosystem services, conservation strategies, and the history and adaptive processes the Tribe uses for each species. The following species are conservation targets:

- Aquatic Species: stream fish assemblages, mussels, Sicklefin Redhorse, wild trout
- Birds: Wild Turkey, Ruffed Grouse, Bald Eagle, Golden Eagle
- Herps: Hellbender, Eastern Box Turtle, Timber Rattlesnake, reptile and amphibian herpetofauna
- Mammals: Black Bear, bats, Carolina Northern Flying Squirrel, Feral Swine, Elk, Coyote, White-tailed Deer
- Communities: bird and anuran communities
- Other targets: human/wildlife conflicts, habitat management, wildlife dissease

3.2 Amphibians

3.2.1 Introduction

Taxonomic Class Amphibia represents salamanders (including sirens and newts) and anurans (frogs and toads). Amphibians and reptiles are collectively known as herpetofauna and are commonly referred to as "herps", for short. They are often discussed as a group because they are ectothermic (i.e. cold-blooded) and occupy many of the same habitats. In this document they are discussed as separate groups in order to present information about conservation and management concerns that are unique to each class of animals.

Currently, the NC Biodiversity Project's list of amphibians includes 107 species and 5 lesser taxa documented in the state (https://nc-biodiversity.com/tax/amphibians) (NCBP 2025). Previously, the North Carolina Museum of Natural Sciences (NCMNS) documented 94 species of amphibians on their checklists of amphibians in the state (NCMNS 2025). The increase in number of species is a result of genetic studies that established multiple new distinct species from what was previously considered a single species.

The southern Appalachian region is the world's center for plethodontid salamander diversity (Ricketts et al. 1999). Gradients in elevation, aspect, slope, and rainfall contribute to a range of available niches and habitats. According to the Southern Appalachian Biodiversity Institute, nearly 10% of global salamander diversity and 10% of freshwater mussel diversity occur in this region.

Amphibians hold a special place for the Cherokee, both culturally and ecologically. The old saying "don't drink from a branch unless it has rolled over 5 rocks and a lizard's back" describes how these animals, colloquially known as "lizards," but formally known as salamanders, are important as water quality indicators. The Cherokee lands of today and historically are right in the center of salamander biodiversity for the planet and host key environments for many amphibians with prodigious water sources and microclimates. EBCI work varies from opportunistic sampling and citizen science to effort-based monitoring and management of habitat. Methods vary from non-invasive sampling, like environmental DNA and acoustics, to more invasive methods like drift-fence bucket traps and netting, trapping and hand-capture.

Many amphibians depend on fishless ponds for breeding and, in many cases, breeding sites are restricted to upland ephemeral pools. Because of the porous nature of their skin, and the fact that many species require both terrestrial and aquatic habitats, amphibians are often considered indicator species of general environmental problems such as water pollution and habitat fragmentation. For many species, transitioning from aquatic to terrestrial habitat results in high mortality. This is due to high predation rates of juveniles, changing metabolic processes, and difficulty crossing roads.

The following paragraphs provide information about a few of the amphibian species identified by the Taxa Team as SGCN or a priority species for research or management and for which work has been conducted to implement conservation and management recommendations. Conservation recommendations for the habitats associated with amphibian SGCN have been incorporated into the natural community descriptions in Chapter 4.

3.2.1.1 Salamanders

The southeastern United States has the largest diversity of salamander species in the world. North Carolina is home to 81 species of salamanders and sirens (NCBP 2025), many of which are located only in specific isolated habitats and a few that are endemic to North Carolina.

- The Eastern Hellbender, one of only three giant salamanders from the family *Cryptobranchidae*, is one of the largest salamanders found in North Carolina and the United States. It was once more common throughout the mid-eastern United States but has since disappeared from many streams because of declining water quality, over-collecting, connectivity barriers such as dams, and persecution. This species is state listed as Special Concern and is a SGCN. Hellbenders are fully aquatic salamanders (they do not leave the water) that are found in habitats with swift running, fairly shallow, highly oxygenated waters. They feed on crayfish, fish, aquatic insects, and other amphibians (Mayasich et al. 2003). Because Hellbenders are sensitive to silt, sediment, and other pollution in their aquatic habitat, they are considered a biological indicator of water quality. Regional efforts have been undertaken to establish captive breeding programs to assist with recovery efforts through augmentation and restoration of populations in the wild (Reeves and Pfaffko 2013). The USFWS has proposed listing the Eastern Hellbender for ESA federal protection as an Endangered species.

- The Neuse River Waterdog is another fully aquatic salamander that has been Federally listed as Threatened and is a species for which there are management concerns. Conservation recommendations include the need for survey, research, and monitoring efforts to determine the status and distribution of this salamander in the two river basins (Neuse, Tar-Pamlico) where it was historically found. During the last several years, status surveys have involved winter trapping to collect information for use in determining status trends for the species.

Documenting species occurrence on tribal trust lands is important to retain cultural relationships, so the EBCI prioritize inventory needs. In addition, several species that occur within the Cherokee ancestral landscape that are either rare on tribal trust lands, like the Mudpuppy or do not occur within these Trust lands, like the Alleghany Mountain Dusky Salamander are prioritized by the Cherokee. Because the current Trust lands are in less than 1% of the aboriginal landscape, it is important for Cherokees to have a chance to see and interact with salamanders, toads, and frogs that occur throughout ancestral homelands.

Some Tribal projects might include both invasive and non-invasive sampling methods, like passive surveys for Hellbender salamanders across 11 sites followed by staggered years of invasive sampling to decrease habitat damage. EBCI biologists have verified the capture of 22 of a possible 28 salamander species within the current tribal Trust landscape. Of less concern are species that are widespread elsewhere, so they are not prioritized. There are many species not yet documented on tribal Trust lands, but they could still occur, like the marbled salamander.

3.2.1.2 Frogs and Toads

North Carolina has 31 species of native frogs and toads (NCBP 2025), which includes a recently identified species, the Atlantic Coast Leopard Frog (Feinberg et al. 2014). Molecular DNA analysis, morphology, and bioacoustic identification techniques were used to examine the genetics and mating calls of related leopard frogs to positively determine the frog as a distinct species (Feinberg et al. 2014). Surveys have confirmed populations of the new species occur in North Carolina.

- The Gopher Frog is state listed as an Endangered species and is under review by the USFWS for listing under the ESA for protection. The Gopher Frog is listed on the International Union for Conservation of Nature IUCN Red List as "vulnerable" (IUCN 2024). It is listed as endangered, threatened, or of special concern in all states within their range. In North Carolina, the Gopher Frog is an uncommon species found only in high quality Longleaf Pine forests where they live in stumphole cavities in upland forests and breed in high quality isolated ephemeral ponds during late winter.
    - Historically, they are known from over 50 sites that represent over 30 populations. Extensive surveys throughout the known range of Gopher Frogs in North Carolina have shown substantial declines. Currently, only seven populations remain active. Degradation, fragmentation, and outright loss of both wetlands and associated uplands are the causes.
    - Prescribed fire on the landscape is an extremely important factor for this and many other coastal amphibians (and reptiles). Seasonally appropriate fires (hot, summer fires) are important to both maintain open grassy upland habitat, as well as open-canopy, herbaceous wetlands.
    - The Gopher Frog is a SGCN and the Taxa Team evaluation indicates it is one of the highest priority amphibian species. It is a management priority due to concerns for loss of breeding habitat and risk of mortality from potential diseases or other pathogens. The USFWS considers the Gopher Frog as an at-risk species; it is under review for potential listing for ESA protection.
- Collinses' Mountain Chorus Frog is a state Special Concern species and a SGCN for which there are also knowledge gaps and management concerns. Little is known about the use

of upland habitat by Collinses' Mountain Chorus Frogs and their movements when away from breeding habitats. Nighttime visual encounter surveys conducted at aquatic breeding sites have been used to collect morphological data. Audio surveys for calling frogs, conducted since 2008, have collected distribution information in western North Carolina, and more than 20 new breeding habitats in south-central Cherokee County and western Clay County have been detected. Telemetry techniques could be used to find out more about their movements and habitat use in these areas.

- Populations of the River Frog in North Carolina appear to have been extirpated (Beane 1998, NCBP 2025). Historically, it was found in the southeastern Coastal Plain, with the historic range extending from the Lumber and Cape Fear river systems in the southern Coastal Plain and southward into SC, GA, FL, AL, and MS. (NCBP 2025).

For the last few years, EBCI biologists have continuously inventoried for up to 12 anuran species through acoustic devices with five species recorded acoustically (6 visually over 10 years). EBCI biologists look to opportunistically inventory for new areas, focusing on wetlands within Tribal Trust lands, and documenting frog species number and activity over time. Our local questions include the assessment of peak breeding to determine if it shifts while our climate changes.

3.2.2 Comparison of 2015 and 2025 Priority Species

The 2025 Amphibian Taxa Team evaluated 98 species and identified priority species for SGCN, knowledge gaps, and management concerns as noted below. The following table provides a comparison of changes to the number of SGCN and priority species between the 2015 SWAP, the 2020 Addendum 1, and the 2025 SWAP.

Amphibian Priority Species by Evaluation Categories and Comparison between SWAPs

SWAP Date	SGCN	Knowledge Gaps	Management Needs
2025	53	62	44
2020 Addendum 1	51	58	42
2015	49	56	42

Some species are a priority in more than one of the three evaluation categories. These changes do not necessarily indicate a change in the concern status of these species; they are more likely to reflect an increase in our knowledge base for the species.

There have been significant scientific advances in direct DNA sequencing methods that enabled tests of previous hypotheses of phylogenetic relationships (Amphibiaweb 2015). This new information has led to suggestions for taxonomic revisions such as those proposed by Frost et al. (2006) and others. However, newly published taxonomy should not be interpreted as a formal, mandatory change; it is simply an alternative that should be evaluated alongside other such proposals (Amphibiaweb 2014). In some cases, published literature will use both genus names in use to refer to the same species (*Rana* [*Lithobates] pipiens* Northern Leopard Frog).

There were three *Desmognathus* salamander species described in recent years (Pyron & Beamer 2022) that use species names from the Cherokee language: *D. adatsihi*, *D. gvnigeusgwotli*, and *Necturus dunisdatlvi.* These salamanders are endemic to the Great Smoky/Plot Balsam and Great Balsam Mountains (Pyron & Beamer 2022).

We highlight specific conservation issues related to SGCN and their habitats in the following sections. This is not an exhaustive list of species-specific conservation concerns but rather highlights some of the concerns in the state. Recommendations for priority survey, monitoring, and research studies, conservation actions, and partnerships are outlined in Section 3.2.8.

3.2.3 Conservation Concerns

Table 3-1 provides a list of Amphibian SGCN (see Appendix 3). River basin and habitat associations for these species are provided in Table 3-17 (terrestrial species) and Table 3-18 (aquatic species).

According to Adams (et al. 2013) "documenting the rate of change in population parameters requires intensive studies that separate true changes in populations from changes in the probability of capture or detection when amphibians are present." Long-term population and distribution trends can be difficult to assess. Actual declines can sometimes be difficult to separate from natural fluctuations in population numbers. Surveys and monitoring efforts often focus only on breeding sites (Storfer 2003, Adams et al. 2013) and may not be able to determine survival or recruitment information. However, scientists have been concerned with apparent worldwide declines in amphibian populations since the 1980s (Adams et al. 2013).

A primary hypotheses in Adams (et al. 2013) explains that global amphibian declines are from a number of factors, especially land use change, disease, global climate change, and interactions of these factors with each other or with other stressors like contaminants or habitat degradation (Collins and Crump 2009; Adams et al. 2013). Climate change is recognized as a major threat to amphibian biodiversity and the Amphibian Conservation Action Plan identifies gaps in scientific knowledge and general management actions for amphibians in response to climate change (Gascon et al. 2007; Shoo et al. 2011).

- The Taxa Team evaluation results indicate that distribution information is uncertain for Cope's Gray Treefrog, Northern Gray Treefrog, and River Frog (which is believed to be extirpated in the state). Current levels of knowledge about these amphibians are generally limited to published range maps or have been extrapolated from a few known population locations in the state. These species are high priorities for new status surveys to collect data that can be used to develop monitoring programs and future conservation recommendations.

- The North Carolina Partners in Amphibian and Reptile Conservation (NCPARC) program coordinates the North Carolina Calling Amphibian Survey Program (CASP). Frog call monitoring conducted by WRC biologists, partners, and citizen science volunteers has provided distribution information on many species of anurans, including Oak Toad, Barking Treefrog, and Ornate Chorus Frog. Monitoring results are used to understand occupancy of available wetlands, as well as guide future surveys and inventory efforts for target species.

- Priority Amphibian and Reptile Conservation Areas (PARCAS) have been designated in North Carolina by NCPARC (https://ncparc.org/parcas-priority-amphibian-and-reptile-conservation-areas). These areas are nonregulatory designations meant to raise public awareness about population declines and to encourage complementary voluntary conservation action by landowners and conservation organizations. GIS data layers are available for the 20 different PARCAS designated in North Carolina

3.2.4 Knowledge Gaps

Inventories of amphibian species have been conducted statewide to help build datasets and improve understanding of population abundance and distribution in North Carolina. Knowledge gained from this work contributes to the design of research and conservation measures that support persistence of all amphibian species.

- Studies are needed to assess the effectiveness of specific actions and application of general adaptation management principles (Shoo et al. 2011). Efforts should be targeted at high-risk areas and species as well as resilient locations where species are most likely to persist or migrate toward new sites following impacts from threats (Lawler et al. 2009; Blaustein et al. 2010; Killeen et al. 2007; Klein et al. 2009; Reilly et al. 2009; Shoo et al. 2010, 2011).

- Studies are needed to increase understanding of microhabitat requirements of amphibians and to investigate artificial shelter or burrow use (Lettink and Cree 2007; Arida and Bull 2008, Shoo et al. 2011). Logs, tree falls, and other woody debris can provide microhabitat and shelter that can protect amphibians from high temperatures and govern dehydration rates that can occur during the hottest and driest times of the year (Shoo et al.2011). Retention of downed wood reduces desiccation and promotes amphibian survival in modified landscapes such as harvested forests (Rittenhouse et al. 2008, Shoo et al.2011).

3.2.5 Management Needs

The Taxa Team indicated current levels of management for some species are not sufficient to maintain long-term viable populations. For example, when prescribed burns cannot be used to maintain ephemeral pools for breeding habitat they can be encroached by woody shrubs and invasive plants, thereby reducing the number and quality of breeding pools. Vegetation removal and maintenance of these areas will maintain and improve the condition of existing breeding habitats

An example of successful amphibian habitat restoration is work being conducted by WRC biologists and partners in the Sandhills and Coastal Plain ecoregions targeting SGCN species such as Gopher Frogs, Ornate Chorus Frogs, and Eastern Tiger Salamanders, although many other amphibian and reptile species also benefit. These SGCN require open-canopied, herbaceous ephemeral ponds for successful reproduction. Some upland ephemeral pools are maintained as open-canopy emergent wetlands because of naturally long hydroperiods that prevent the colonization of trees and shrubs (e.g. limestone sinks with a groundwater connection).

However, many upland, isolated wetlands would have historically been maintained as open, "grassy" ponds through a combination of hyrdoperiod and fire regime processes (DeSteven and Toner 2004). Because of historic fire exclusion, or problems with the timing of prescribed fire, many isolated ponds that were once open-canopied have become forested. Dense canopy in these ponds reduces herbaceous vegetation needed for amphibian egg attachment, changes the pond's pH, and can drastically alter the hydroperiod such that ponds dry out too early in the year for amphibian larval development to be completed.

Restoration efforts in wetlands have included removal of organic and woody debris by manual and mechanical means, as well as the use of prescribed fire. Manual removal of woody and invasive vegetation can also be effective. Typically, greater numbers of species of amphibians use ponds following restoration. For example, two wetlands restored in the Sandhills exhibited greater numbers of species after restoration than before. One pond supported only three species of amphibians prior to restoration efforts, and none were SGCN. After management work was conducted, twelve species of amphibians were detected using the wetland, including two SGCN species (Pine Barrens Treefrog and Eastern Tiger Salamander). Another pond also supported only three species (none SGCN) prior to work, and nine species after, including two SGCN species (Pine Barrens Treefrog and Oak Toad).

Management recommendations include the need to protect known breeding sites as well as nearby and surrounding uplands; restore degraded sites and maintain existing sites through application of prescribed fire during appropriate seasons and at required intervals; protect corridors connecting nearby and adjacent breeding sites; investigate captive breeding methods and opportunities for population augmentation and translocation; restore existing wetlands and create new ponds; and monitor populations for evidence of disease and pathogens so that protective measures can be designed and implemented when needed.

Additional management information can be found in a PARC technical publication on habitat management for amphibians and reptiles in the Southeast (Bailey et al. 2006) and is available online: http://separc.files.wordpress.com/2013/04/se-hmg.pdf.

3.2.6 Threats and Problems

Chapter 5 describes 11 categories of threats the Mammal Taxa Team considered during evaluation and ranking process to identify SGCN. Evaluation results for Metric 9 about the expected scope and severity of these threats are available in Appendix 3. The most likely threats to have very high impacts on amphibian populations in North Carolina over the next 10 years include the following:

- Climate extremes and severe weather
- Residential and commercial development
- Agriculture and aquaculture
- Natural system modifications (e.g., fire suppression, land management activities)

Research related to these threats and their impacts on certain amphibian species was ranked during Taxa Team evaluations as a high priority.

Anthropogenic impacts that result in habitat loss and degradation are one of the most important threats to amphibian populations (Willson and Dorcas 2003). Amphibian declines may correlate with declines of other species, especially those utilizing wetlands. Amphibians are also indicators for anthropogenic stressors that can have broader health and biodiversity implications to an ecosystem (Lannoo 2005; Bosch and Rincon 2008).

3.2.7 Additional Information

The USFWS has added the Eastern Hellbender to Appendix III of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), including both live and dead whole specimens, and all readily recognizable parts, products, and derivatives. Listing in Appendix III of CITES allows for adequate monitoring of international trade in the taxon; to determine whether exports are occurring legally with respect to state laws; and to determine whether further measures under CITES or other laws are required to conserve the species (and any subspecies) (Congressional Record 2011).

The US Geological Survey (USGS) established the Amphibian Research and Monitoring Initiative (ARMI) to document changes in the number of amphibian populations rather than the change in species abundance (Adams et al.2013). The ARMI analysis indicates a trend in amphibian declines that includes common species for which there has traditionally been low conservation concern and these declines are occurring on lands protected and managed for conservation.

Another online database is the Carolina Herp Atlas, developed by the Davidson College Herpetology Laboratory. This program tracks county-level distribution information for native species in North and South Carolina and is available online at www.carolinaherpatlas.org.

NCPARC also maintains an online identification and information guide, Amphibians and Reptiles of North Carolina (www.herpsofnc.org).

Important conservation measures that benefit amphibian species include protection and restoration of ephemeral ponds and wetlands across the Sandhills and Coastal Plain. Encroachment by woody shrubs and invasive plants in areas not subject to prescribed burns has reduced the number and quality of ephemeral pools. Vegetation removal and maintenance of these areas has resulted in additional breeding sites being available and has improved the condition of existing breeding habitats. Success of these restoration projects has been demonstrated by the increase in number and diversity of species of amphibians using these sites after restoration work was begun.

Taxonomic classification and agreement on naming conventions for some species is likely to be unsettled until scientific evidence supporting any recommended changes becomes widely accepted. Resources for information about changes in classification include The Society for the Study of Amphibians and Reptiles (SSAR) and The Center for North American Herpetology (CNAH).

- SSAR is a nonprofit organization established to advance research, conservation, and education concerning amphibians and reptiles; is the largest international herpetological society; and is recognized worldwide for having the most diverse program of publications, meetings, and other activities. SSAR's Committee on Standard English and Scientific Names produces a circular every few years with suggestions for standard taxonomy and can be found here: http://ssarherps.org/publications/north-american-checklist/.

- CNAH is an organization that serves as a data bank for information about North American amphibians, turtles, reptiles, and crocodilians. Published research literature documenting taxonomic changes is available online (http://www.cnah.org). The CNAH webpage also provides a link to peer-reviewed articles published in the Journal of North American Herpetology and access to articles in the Contemporary Herpetology journal archives. Another resource for amphibian taxonomy is the American Museum of Natural History Amphibian Species of the World online reference database: http://research.amnh.org/vz/herpetology/amphibia.

3.2.8 Recommendations

In general, protection and restoration of natural community composition and function and protection of surrounding natural areas under current conditions are the best ways to ensure that suitable habitats are available for amphibian species. Measures that protect a large and diverse pool of populations are the best way to ensure that species are able to survive future stressors and adapt to changing climate conditions.

Riparian buffers and forest habitats adjacent to streams and wetlands provide cool and moist microclimate conditions which are beneficial to amphibians (Shoo et al. 2011). Other conservation recommendations for the habitats associated with amphibian species have been incorporated into the natural community descriptions in Chapter 4.

Implement conservation measures and recommendations in protected species conservation plans.

- State protected species conservation plans are available online https://www.ncwildlife.gov/wildlife-habitat/species-conservation-plans.
- Federal protected species recovery plans are available online https://www.fws.gov/program/recovery/recovery-plans.

Implementation of recommendations for surveys, monitoring, and research should follow best practices and protocols established by recognized authorities (see Chapter 6 for a list of protocols). The following recommendations should be considered appropriate to implement for all amphibian species.

3.2.8.1 Surveys

Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Conduct distributional surveys for priority species.

Four-toed salamander	Longtail Salamander	Mudpuppy
Junaluska Salamander	Mole Salamander	Neuse River Waterdog
		Wehrle's Salamander

- Conduct surveys (and monitoring) on all amphibian species associated with small wetland communities.

Wetland habitats	Four-toed Salamander	Oak Toad
	Gopher Frog	Ornate Chorus Frog
Dwarf Salamander	Mabee's Salamander	Pine Barrens Treefrog
Eastern Tiger Salamander	Mole Salamander	Southern Chorus Frog

- Deploy passive acoustic detectors to record frog calls during the spring and summer months (EBCI 2022)

Anurans

- .Use eDNA for non-invasive sampling and evaluate the effectiveness of the method in comparison to electroshocking (EBCI 2022).

  Aquatic species

3.2.8.2 Monitoring

Long-term monitoring is critical to assessing species and ecosystem health and gauging the resilience of organisms to a changing climate. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. These efforts will inform species and habitat management decisions. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Use inventory and monitoring efforts to build historical data that can be compared over time to identify population trends.

- Conduct herpetofauna monitoring to track population trends for species of concern. Particular attention should be paid to Four-toed Salamanders.

  Four-toed Salamander

- Continue to support CASP and other monitoring programs and participate in partnerships where possible.

- Monitor populations for evidence of disease and pathogens so that protective measures can be designed and implemented when needed. For example, WRC biologists and partners have been collecting and analyzing skin swabs from more than 30 different salamander and six frog species in the Mountain ecoregion as a means of detecting the presence of the *Batrachochytrium dendrobatidis* (Bd) chytrid fungus. Additional disease monitoring will focus on the salamander equivalent of *Bd*, called *B. salamandrivorans* (*Bsal*), as well as ranaviruses.

  Mountain ecoregion

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Continue annual inventory and monitoring surveys for all SGCN and develop new surveys for other priority species. Eastern Tiger Salamander, Gopher Frog, Mabee's Salamander, Mole Salamander, Neuse River Waterdog, Ornate Chorus Frog, Pine Barrens Treefrog, Southern Chorus Frog

3.2.8.3 Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.
• WRC is working cooperatively with the NC Zoo to propagate Eastern Hellbenders at fish hatchery facilities. Support and expand captive breeding and propagation programs that benefit hellbenders and other priority species. Eastern Hellbender
• Investigate sites and identify opportunities for population augmentation and restoration for all priority species. Gopher Frogs, Ornate Chorus Frogs, Pine Barrens Treefrogs, Tiger Salamanders
• Determine minimum upland buffers required to sustain at-risk amphibian populations.
• Investigate meta-population dynamics and land management effects on Green Salamanders. Green Salamander
• Investigate Collinses' Mountain Chorus Frog upland habitat use.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
Collinses' Mountain Chorus Frog
• Investigate land use and urbanization effects, habitat augmentation and restoration effects, and larval ecology of Eastern Hellbender.
Eastern Hellbender
• Conduct genetic investigations and species' range delineations for plethodontid salamanders, particularly for the endemic Gray-cheeked Salamander complex and Slimy Salamander complex.
Blue Ridge Salamander Chattahoochee Slimy Salamander Cheoah Bald Salamander Northern Slimy Salamander South Mountain Gray-cheeked Salamander Tellico Salamander
• Conduct genetic work on Gopher Frog populations to determine extent of genetic diversity within each population.
Gopher Frog

3.2.8.4 Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats. In addition, education, regulation, and prevention of the introduction and spread of exotic or invasive species are vital.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Restore, create, and protect habitats for all priority species, especially seasonal wetlands, degraded wetland systems, and riparian zones, and maintain habitat connectivity with uplands.
Wetland habitats
• Protect known breeding sites as well as nearby and surrounding uplands.
• Protect corridors and hydrologic connections between nearby and adjacent breeding sites.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Restore degraded sites and maintain existing sites through application of prescribed fire during appropriate seasons and at required intervals.
• When feasible, remove populations in immediate danger of destruction from land use changes (e.g., transportation projects, development).
• Where fish have invaded amphibian breeding sites, such as from flooding from nearby streams, remove them as a means of protecting amphibian eggs and juveniles.
• Manage high-elevation forests for old growth vegetation. Mountain ecoregion
• Develop legal protections for Hellbenders against moving rocks because they may be crushed or killed (EBCI 2022). Hellbender

3.2.8.5 Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protection measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change but overall can promote ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Identify high quality examples of habitat for SGCN and attempt to acquire or seek alternative conservation actions.
• Continue to support programs that limit collection of priority species, including permit requirements, law enforcement oversight, and legislative action that protects species.
• Implement the state listing process by routinely evaluating conservation status and recommending legislative updates to revise the state species lists.

- Support land trusts and conservation easements as a means to protect amphibian habitat.
- Utilize programs such as the Wildlife Conservation Lands Program and others to protect, manage, and restore habitat on private lands.
- Support citizen science and volunteer efforts to monitor species and habitats.
- Utilize partnerships and research collaborations with local universities and education programs to implement conservation, research, and management actions.
- Develop education, outreach, and technical guidance programs for the public.

References are located at the end of the document.

This page intentionally left blank for double-sided printing

3.3 Birds

3.3.1 Introduction

North Carolina hosts at least 475 species of migratory and resident birds (Ratcliffe and Wojcik 2022), most of which are seen by biologists at some point during the year. Managers and researchers have better knowledge and understanding of many of our bird species compared to other taxonomic groups, largely because of the popularity of bird-watching and subsequent ability to collect data from researchers and the public alike. Citizen science is a continuing force in the collection of bird data (e.g., eBird, Nest Watch, Christmas Bird Count, Great Backyard Bird Count, and Yard Map). Much of the population trend data driving conservation priorities are derived from nationwide citizen science programs like eBird, the USGS Breeding Bird Survey (BBS) (Sauer et al. 2013) and the Audubon Christmas Bird Count (CBC) (Dunn et al. 2005).

The conservation needs of birds in North Carolina center mainly on habitat management, restoration, and protection, especially of Spruce–Fir forest, bottomland hardwood forest, quality early successional habitats, quality old growth/mature forest, Longleaf Pine communities, riparian and wetland habitats, and coastal beach and estuarine habitats.

Information on pelagic bird species is provided in Section 3.11 of this chapter. Natural community descriptions and priority conservation actions are provided in Chapter 4 for important bird habitats. Conservation recommendations for aquatic and terrestrial habitats have been incorporated into the natural community descriptions in Chapter 4.

The following sections provide information about birds the Taxa Team identified as SGCN or a priority for research or management. Recommendations for priority survey, monitoring, and research studies, conservation actions, and partnerships are outlined in Section 3.3.8.

3.3.2 Comparison of 2015 and 2025 Priority Species

The 2025 Bird Taxa Team evaluated 281 species to identify priority species for SGCN, knowledge gaps, and management concerns. The following table provides a comparison of changes to the number of SGCN and priority species between the 2015 SWAP, the 2020 Addendum 1, and the 2025 SWAP.

Bird Priority Species by Evaluation Categories and Comparison between SWAPs

SWAP Date	SGCN	Knowledge Gaps	Management Needs
2025	85	76	69
2020 Addendum 1	77	82	77
2015	99	77	76

Several species are a priority in more than one of the three evaluation categories. These changes do not necessarily indicate a change in the concern status of these species; they are more likely to reflect an increase in our knowledge base for the species.

When research data improves scientific understanding about relationships among and between species, the taxonomic classification of a species may warrant change. The prevalence of genetic research has contributed to expanded knowledge about species taxonomy. This new information often leads to suggestions for taxonomic revisions, such as those published in the American Ornithological Society's Checklist of North American Birds (Chesser et al 2024). WRC biologists refer to recognized authorities for naming species when updating taxonomy.

We highlight specific conservation issues related to SGCN and their habitats in the following sections. This is not an exhaustive list of species-specific conservation concerns but rather highlights some of the conservation concerns in the state. Recommendations for priority survey, monitoring, and research studies, conservation actions, and partnerships are outlined in Section 3.3.8.

3.3.3 Conservation Concerns

Table 3-2 (Appendix 3) provides a list of Bird SGCN and other priority species. Habitat associations for these species are provided in Table 3-17 (terrestrial species). Habitat descriptions and associated conservation priorities are located in Chapter 4.

3.3.3.1 Shorebirds

North Carolina's 3,375 miles of tidal shoreline (NOAA 1975) plays a key role in the life cycle of many migratory shorebirds; thus, conservation activities directed at shorebird stopover, wintering, or breeding habitats (primarily beach, dune, estuarine, and coastal marsh habitats) can have a substantial impact on shorebird conservation throughout the Atlantic Flyway (Winn et al. 2013). In addition, coastal areas are often heavily populated, and balancing the needs of conservation and tourism can be challenging without accurate life history data.

There is national concern about the decline of many shorebird populations, including species found in North Carolina. Smith et al. (2023) reports shorebirds are declining to a greater extent than other avian taxa worldwide. The International Shorebird Survey protocol is followed biannually to obtain population estimates of these and other migratory shorebirds (Howe et al. 1989). The American Oystercatcher, Wilson's Plover, Red Knot, and Piping Plover are shorebird species with stabilized or declining populations in North Carolina.

- In response to recent monitoring and research attention on American Oystercatcher, its population has stabilized over the last 20 years (personal correspondence, Schulte 2013, 2014, unpublished data). Specific projects have been completed to estimate numbers of American Oystercatcher and Wilson's Plover during the breeding season (Davis et al.

2001; DeRose-Wilson et al. 2013), and of American Oystercatcher during winter (Brown et al. 2005), but more detailed information is needed on breeding habits to inform coastal management where species conservation and tourism interests often conflict.

- Wilson's Plover is much less studied; hence, its population trend is less well understood in North Carolina but is declining elsewhere (Butcher and Niven 2007; NABCI 2009).

- Red Knot was federally listed as threatened in 2014 (USFWS 2014), and its abundance and distribution in North Carolina during migration periods and winter are poorly understood.

- Piping Plover is a state listed threatened species and is federally listed for both ESA protection as endangered (interior population) and threatened (Atlantic coast population) species. Piping plovers are well monitored and studied, and its population trend is stabilized, but not meeting USFWS recovery goals (USFWS 2023).

3.3.3.2 Colonial Waterbirds

Long-legged wading birds often nest in multispecies colonies in trees and shrubs, referred to as rookeries (or heronries). Terns, pelicans, gulls, and skimmers nest on the ground in colonies. Since the mid-1970s, multispecies surveys have been conducted to collect information on colonial waterbird nesting sites (Hunter et al. 2006). In North Carolina, surveys are conducted every two to three years to collect data on the location and status of existing colonies and document new colonies.

Ground surveys of colonial waterbirds have also been conducted in North Carolina every two to three years since the late 1970s (Wilson and Henson 1993). Colonial waterbirds nest on North Carolina's barrier islands, dredged-material islands, and marsh islands in estuaries. Aerial surveys of inland heronries are conducted every 10 years within select portions of river basins located in Coastal Plain and Piedmont regions. . Data from surveys are stored in the online colonial waterbird database and used to assess population trends, status, and distribution.

- Least Terns nest on bare sandy beaches, dredged-material islands, or gravel rooftops by making a small scrape in the sand where they lay eggs. Since 2016 ground surveys of nesting Least Terns have been conducted annually. Survey data from 2023 was compared with previous years, with results showing an increase of 30% in number of Least Tern nests. Conservation measures such as posting beach closure signs to protect nesting waterbirds and placement of shelters for chicks has contributed to the success. A partnership with the Town of Emerald Isle and monitoring of protected nest sites at local beach sites by volunteers from a local stewardship group has also contributed to the nesting success.

- Aerial surveys of Wood Stork colonies and potential sites have been conducted annually since 2005. Wood Storks nesting in NC are the farthest north of the nesting population in the US. This northward expansion and their adaptability led to down-listing by USFWS from endangered to threatened in 2014. They were considered for de-listing in 2024.

- The Snowy Egret, Tricolored Heron, Little Blue Heron, and Glossy Ibis are small long-legged wading birds that nest in North Carolina's coastal region. Population trends of these species indicate a decline in numbers of nesting pairs, and nesting population sizes do not meet the state's management goals (Shields and Parnell 1990; Kushlan et al. 2002; Hunter et al. 2006). These species use estuarine salt marsh and dredge spoil islands for nesting and coastal marshes for foraging. Erosion of waterbird islands and loss of coastal marsh foraging habitat from sea level rise is a concern. Coastal marshes in North Carolina are not gaining in elevation at a pace sufficient to keep up with sea level rise (Bost et al. 2024, North Carolina SET Community of Practice 2024).

- The Common Tern, Gull-billed Tern, and Black Skimmer also nest in the coastal region, selecting nearly bare sandy areas on barrier and dredged-material islands. Numbers of nesting pairs of all three species have declined for more than five years, and their populations continue to remain below the state goals.

3.3.3.3 Marsh Birds

Many secretive birds, such as rails, are dependent on coastal marshes. The Eastern Black Rail in particular has experienced significant population declines in North Carolina and elsewhere. Their populations have experienced a 90% decline since the 1990s. They are declining at a rate of 9% per year likely due to loss of high elevation coastal marsh habitat from a high rate of sea level rise, flooding from more frequent and intense storms, and loss of shallow, herbaceous freshwater marsh (USFWS 2019, ACJV 2020).

- The Eastern Black Rail was listed for federal ESA protection as threatened; North Carolina protection status matches the federal status (NCAC 10I .0104). The Eastern Black Rail Call-Response Survey Protocol for Range-Wide Monitoring was adopted by the USFWS and is available on their website https://www.fws.gov/media/eastern-black-rail-call-response-survey-protocol-range-wide-monitoring.

- The King Rail can tolerate deeper water levels than Black Rails and relies mainly on freshwater or oligohaline marshes. They are declining in many areas where freshwater marshes are receiving increased saltwater intrusion (Cooper 2007). Relatively little is known about the limiting factors of these species because of the hidden and inaccessible nature of their nesting habitats.

The North American Marsh Bird Monitoring Program was designed to develop and beta-test standardized protocols to be used in a national or continental monitoring effort. Information about the status and population trends of many species of secretive marsh birds is limited. This general lack of knowledge is the product of inconsistencies in survey methodology that make it difficult to compare data from local and regional survey efforts and current broad-scale monitoring efforts (e.g., BBS) lack adequate coverage of wetland habitat to provide statistically significant results on marsh bird trends. Currently data available through the program is managed by the USGS Patuxent Wildlife Research Center (Maryland), in cooperation with the University of Arizona and the USFWS Office of Migratory Birds. Access to data is through the Marsh Birds Population Assessment and Monitoring Project http://www.pwrc.usgs.gov/point/mb/.

3.3.3.4 Songbirds

North Carolina plays a key role in the life cycle of many migratory songbirds for all stages of their life cycle (breeding, wintering, and migration stopover habitats). Songbirds comprise the largest bird species group and accordingly are found in every habitat type across the state.

Breeding bird surveys and monitoring of priority species and habitats have been conducted on state-owned game lands and other public lands, on conservation partnership lands (e.g., WRC's CURE program) and on private lands, especially on early successional habitats. Data from these survey efforts have improved our understanding of distribution, relative abundance, and population trends for migratory songbirds, but are not adequate to assess larger population parameters for some species such as Cerulean, Golden-winged, and Wayne's Black-throated Green Warbler, Louisiana Waterthrush, Prairie Warbler, Rose-breasted Grosbeak, Vesper and Henslow's Sparrow, and others.

- Henslow's Sparrow is considered one of the most vulnerable nongame species found in eastern North America (Hunter et al. 2001). One of the only breeding locations in the southeastern US for this species is in eastern North Carolina at the Voice of America Game Land (VOAGL). Consistent growth of Henslow's Sparrow population at the VOAGL over the last decade has been attributed to active habitat management using prescribed fire as well as mechanical and chemical control of woody stems (Nastase 2024). Henslow's Sparrow is currently listed for state protection as an endangered species (WRC 2021).

- The Golden-winged Warbler has experienced one of the steepest declines of any North American songbird (GWWG 2013; Sauer et al. 2013) and is currently being petitioned for ESA protection. It is threatened by loss of high-elevation successional community habitats; genetic changes are exacerbated by hybridization with the Blue-winged Warbler. In North Carolina, a range-wide spatially balanced monitoring effort led by Cornell Laboratory of Ornithology and supplemental surveys and monitoring have improved overall understanding of the species. The Golden-winged Warbler Working Group (GWWG 2013) developed best management practices for Golden-winged Warbler which identifies habitat and population goals and includes habitat supplements dedicated to specific habitat types most important to Golden-winged Warbler in the Appalachian Mountains (e.g., Deciduous Forests, abandoned farmlands). Biologists are also concerned about the decline of Blue-winged Warblers and their habitats.

- The Cerulean Warbler is declining at a rate of 3% annually (Sauer et al. 2013) and current population estimates represent more than 75% decline compared to population estimates in 1966 (Buehler et al. 2008). Western North Carolina's core populations have been monitored biennially since 2012, and efforts have begun in the black- and brownwater floodplains of eastern North Carolina to delineate populations and track relative populations trends. Resources developed for managing habitat for the Cerulean Warbler in the Appalachian Mountains include Management Guidelines for Enhancing Breeding Habitat in Appalachian Hardwood Forests (Wood et al. 2013) and Enhancing Cerulean Warbler Habitat in the Appalachians: A Guide for Foresters (AMJV n.d.).

- The Wood Thrush is on the Partners in Flight (PIF) Yellow Watch List and is a Road to Recovery (R2R) Tipping Point species list. It requires large tracts of intermediate to mature aged forests with mostly closed canopy for nesting but also requires early seral forest for the post-fledging phase. It is highly vulnerable to human land use and activities. Declines are linked to forest loss and fragmentation on both the breeding and wintering grounds. Wood Thrush nesting in more fragmented forested areas, such as in the Piedmont ecoregion, face higher rates of nest predation and Brown-headed Cowbird parasitism.

- Red Crossbill and Southern Appalachian Black-capped Chickadee (also referred to as Black-capped Chickadee) inhabit the imperiled Spruce–Fir forests of western North Carolina. Red Crossbill's nomadic habits make it difficult to monitor. The Black-capped Chickadee occurs in the Great Smoky Mountains and Plott Balsam Range and hybridizes with Carolina Chickadee in the Great Balsam Range. The logging boom of the 1880s–1930s reduced the southern Blue Ridge's Spruce–Fir forests by half, and Balsam Woolly Adelgid subsequently caused extensive mortality of mature Fraser fir forest.

- Wayne's Black-throated Green Warbler (or Wayne's Warbler), first described in the early twentieth century (Bangs 1918), breeds along the coastal regions of southern Virginia, North Carolina, and northern South Carolina. Throughout its limited North American range, Wayne's Warbler is distributed along a narrow band of Atlantic White Cedar stands, cypress swamps, and non-riverine forested wetlands (Sprunt, Jr. 1953) and separated by more than 400 km and a 1200 m elevation difference from the Appalachian nominate race. In addition to differences in habitat use, Wayne's Warbler is genetically distinct from (Carpenter et al. 2022) and smaller than Black-throated Green Warbler populations, especially in bill dimensions, including individuals from the same latitude (Morse et al. 2024). The species' presumed last population stronghold at Alligator River National Wildlife Refuge is predicted to suffer from substantial forest cover loss and fragmentation due to climate change (Ury et al. 2021, White, Jr. et al. 2021). The Wayne's Warbler was petitioned for federal ESA protection in 2023 (status pending) and is listed for state protection as an endangered species (WRC 2021).

- Saltmarsh Sparrow is the rarest marsh-endemic sparrow species that overwinters along the North Carolina coast. Despite an increase in the number of observers and a consistent number of count circles reporting Saltmarsh Sparrow presence, there was a persistent decline in the number detected during Christmas Bird Count surveys from 1997-2019 (National Audubon Society 2020). The species is expected to continue losing suitable habitat from sea level rise and extreme weather events. The USFWS considers the Saltmarsh Sparrow an at-risk species and is evaluating it for potential listing for federal ESA protection.

It is estimated that bird collisions with glass kill over 1 billion birds annually, with over 99% of collisions with homes and low-rise buildings. Daytime collisions are often associated with bird feeders near buildings. There is a need to treat glass to reduce daytime reflections and potential collisions. Nighttime collisions happen because birds are attracted to light and become disoriented. The darkness of the night sky is an important resource for many animals and the impact of lighting on buildings and other tall structures on nocturnal migrating songbirds is a great concern. There is a need to address problematic lighting through use of programs such as Lights Out, Fatal Light Awareness Program, and other initiatives.

Non-native invasive plants reduce habitat quality for nesting birds by supporting fewer native insects and creating monocultures or otherwise unsuitable vegetation structure for nesting birds. There is concern for loss of suitable nest cover for ground-nesting species such as Kentucky Warbler.

A few species that nest in North Carolina are threatened on their wintering grounds in international locations by collection from the wild for the illegal pet trade or singing competitions. These include Indigo Bunting, Painted Bunting, and Rose-breasted Grosbeak. Though the exchange of cage birds traditionally took place on the street, the advent of social media for advertising has led to a surge in the cage bird trade, particularly in the Caribbean (McBride 2012).

Migratory songbirds can also face predation threats from feral and free-ranging domestic cats (Loss et al. 2013, Herrera et al. 2022). Cats are obligate carnivores that are efficient hunters of small vertebrates (Bradshaw 2006), especially in open landscapes and forest edges (Herrera et al. 2022). The results from studies conducted on predation by cats introduced to island habitats has been used to extrapolate predation impacts in other landscapes. It is estimated that outdoor cats (both feral and outdoor pets) kill over a billion birds every year (Patronek 1998, Cornell Lab 2025).

3.3.3.6 Other Land Birds

The Red-cockaded Woodpecker is a federally listed Endangered species native to Longleaf Pine habitats in the Sandhills, Piedmont, and Coastal Plain ecoregions. It also uses other natural communities such as the wet pine stands found in Dare, Tyrrell and Hyde counties and pond pine dominated pocosins found on Holly Shelter Game Land. Intense recovery efforts, including annual monitoring and excavation of supplemental artificial cavities, have allowed many managed lands to meet their goals for population recovery. However, continued management of Longleaf Pine and other habitats where it is found is necessary to continue recovery of this species.

The Eastern Whip-poor-will has averaged a 2.8% annual decline since 1966 (Sauer et al. 2013). Because of its nocturnal habits, this species is not well documented through traditional surveys, and thus little is known about its current status. In 2007, the Nightjar Survey Network (nightjars.org) began monitoring this species and other nightjars using volunteers to run survey routes. These data will be important to better assess the status of these cryptic species. In addition to the Whip-poor-will, other aerial insectivores have experienced significant declines in North America. The global decline in insect abundance and in quality of insect prey is a concern.

3.3.3.7 Birds of Prey

Birds of prey include various species of hawks, falcons, eagles, vultures, and owls that occur in North Carolina. Since the conclusion in 1996 of North Carolina’s efforts to reintroduce the Peregrine Falcon, a subset of nests has been monitored annually. Territory occupancy, nest success, and productivity remain at or below the national average. A total of 16 territories have been documented; however, a dozen territories are documented most years.

- Barn Owls and American Kestrels are two raptor species of open habitats with suspected declines in North Carolina and documented declines elsewhere (Smallwood et al. 2009). Loss of nesting and foraging habitat has been attributed to development and clean farming practices. Both species have responded to installation of nest boxes in western North Carolina.

- Understanding of the Golden Eagle’s migration and winter range in the Appalachians has greatly improved with efforts of the Eastern Golden Eagle Working Group. Since 2013, studies of Golden Eagles using camera surveys and GPS tracking have revealed the importance of the North Carolina mountains as overwintering grounds for this species. Golden Eagles are threatened by habitat loss (particularly remote openings in forested landscapes in the mountains), collisions with wind energy infrastructure, lead poisoning, and bycatch in furbearer foothold traps.

- The Northern Saw-whet Owl breeds in North Carolina’s spruce–fir and northern hardwood forests but its population trends are unknown. The logging boom of the 1880s–1930s reduced North Carolina’s spruce–fir forests by half, and Balsam Woolly Adelgid subsequently caused extensive mortality of mature Fraser Fir forest. The species also occurs in Coastal Plain habitats in the winter, but the importance and extent of this area is unknown.

- The Bald Eagle continues its recovery after being delisted from the endangered species list by the US Fish and Wildlife Service in 2007. Periodic efforts to monitor populations are continuing to ensure future positive population trends.

3.3.4 Knowledge Gaps

Much of our distribution and population trend knowledge gaps stem from those species that are not well-surveyed by traditional road-based methods (i.e., USGS Breeding Bird Surveys, Audubon Christmas Bird Count). In many cases, more research into the life history traits and habitat requirements of species is required to properly inform habitat management practices, identify areas for conservation, and resolve human–animal conflicts.

Table 3-2 (Appendix 3) includes knowledge gap priority species; the following information provides highlights about species for which there are research needs.

- There have been few studies of the Wilson's Plover population in North Carolina; thus, the population trend is poorly understood, although survey data have been collected during surveys focusing on other species such as American Oystercatcher and Piping Plover (Ray 2011; DeRose-Wilson et al. 2013), and a triennial count of American Oystercatcher and Wilson's Plover pairs that was established in 2004.

- Other beach-nesting species exhibiting declines, including Common and Gull-billed Terns, have not been studied to identify threats to their nest-site selection and nesting success. Erwin (2005) and others provide suggestions for buffer or setback distances that reduce impacts of human activities to nesting colonies of terns and skimmers. No studies of this threat have been completed in North Carolina, however a study by the University of North Carolina Wilmington of buffer distances in North Carolina is currently underway at Cape Hatteras National Seashore and Pea Island National Wildlife Refuge which will provide information specific to those sites.

- North Carolina provides foraging grounds for the Red Knot during fall and spring migrations, as well as during winter. There has been no systematic survey protocol developed to monitor Red Knot distribution and abundance in North Carolina. Further, although it is known that Red Knots specialize in foraging on small clams such as *Donax spp*. found in the intertidal zone, impacts of continued beach nourishment (fill) projects and beach driving along the North Carolina coast on the forage base for Red Knots has not been studied (Cohen et al. 2010; Sturbois et al. 2015).

- The decline of nesting populations of Snowy Egret, Tricolored Heron, Little Blue Heron, and Glossy Ibis in North Carolina has not been examined to elucidate threats and causes.

Recent surveys of colonial waterbirds in Virginia also detected declines in these nesting populations (Watts and Paxton 2014). Better management of regional data for migratory colonial waterbirds will allow better assessment of populations at the flyway scale. Currently, however, it is unknown what factors are bringing about declines in these small, colonially nesting wading birds.

- Each shorebird and colonially nesting waterbird SGCN in North Carolina is dependent on coastal estuaries and beaches. Modeling studies of potential sea level rise (SLR) and climate change indicate change and loss of these habitats (Morris et al. 2002; FitzGerald et al. 2008). The challenges these species will face, especially given areas of hardened structures on the coast (e.g., commercial and residential buildings, roads, groins, jetties), are not fully understood. Data for modeling studies is available and additional data can be obtained to populate informative, predictive models.

- Secretive marsh birds (e.g., Black Rail) will also benefit from informative models and increased monitoring efforts. The Black Rail Species Status Assessment (USFWS 2019) and the Atlantic Coast Joint Venture Black Rail Conservation Plan (ACJV 2020) stress the need to facilitate the migration of high salt-marsh landward and to create and restore non-tidal herbaceous marsh, including in non-tidal impoundments near existing breeding habitat. This will likely benefit all marsh bird and wading bird SGCN. Considerable knowledge gaps exist regarding this habitat creation and restoration in North Carolina.

- Among raptors, there is need for further study of Barn Owl, American Kestrel, and Peregrine Falcon's post-fledging dispersal, adult and juvenile survival, migratory habits, and vulnerability to contaminants. Very little is known about the abundance and distribution of several of North Carolina's raptor species. There is a need for further study of the Barn Owl, American Kestrel, and Northern Saw-whet Owl's use of habitat and population trends and of Golden Eagle winter abundance and distribution.

Several birds listed as knowledge gap priority species have been added to a PIF Watch List, list of Common Birds in Steep Decline, or the Road to Recovery's list of Tipping Point species. These include Black-billed Cuckoo, Kentucky Warbler, Blue-winged Warbler, and others.

While it is assumed that habitats throughout North Carolina are likely to be significant to species that migrate through, the importance of these habitats has yet to be determined, making prioritization of habitat conservation, especially in the rapidly urbanizing Piedmont, difficult. More effort into monitoring migrating and post-breeding songbirds is warranted.

There is a lack of understanding of predator communities and the increase of many species found along the coastline (e.g., Ghost Crabs, large gulls, Raccoons, foxes, Coyotes) about the effect they are having on coastal bird populations. However, species-specific vulnerability is unknown, as is their overall impact of predators to bird populations.

3.3.5 Management Needs

Bird populations are affected by human activities, predator populations, and habitat characteristics. These factors are not independent from one another, thus, management actions on one are likely to affect another and this interaction must be understood. Recommendations for priority management actions are outlined in Section 3.3.8.

Depending on species, timing, type of disturbance, and habituation to human activities, many shorebirds and colonial waterbirds are sensitive to disturbance from human-related activities (Erwin 2005; Meyers 2005). Many of the colonial waterbirds found in North Carolina that are SGCN are also management-need priority species. Posting nesting areas with symbolic fencing, which consists of informative signs placed 50 meters apart with string tied between posts, reduces disturbance to nesting colonies by recreationists (Erwin 1989). The addition of education and outreach programs during the nesting season, and enforcement of leash and trespass laws, provides greater protection.

- Buffer or setback distances between nests and recreationists that prevent impacts to nesting colonies differ by species, stage of nesting (territory establishment, courting, nest initiation, egg-laying, incubation, hatching, and brooding chicks), and type of disturbance activity (e.g., pedestrian, all-terrain-vehicle, off-road-vehicle, boat, UAV). Buffer distances between nests and posted signs (and, therefore, recreationists) are recommended by Erwin (2005) for Least Tern, Black Skimmer, Common Tern, Gull-billed Tern, Royal Tern, and Sandwich Tern. For American Oystercatcher, buffers are also recommended (Sabine et al. 2008). Once chicks are present, they are particularly vulnerable to recreationists until they have fledged. Alternatively, stewards or seasonal technicians should identify and protect broods from pedestrian and vehicular traffic that might travel closer than the optimal buffer distance.

- In North Carolina, shorebirds and colonial waterbirds nest and roost on many state-owned dredged-material islands in rivers, sounds, and the Atlantic Intracoastal Waterway. The type and percentage of cover provided by vegetation on these islands should vary to provide habitat for diverse waterbird species. Vegetation management should be implemented using varied tools such as wetland-approved herbicides, prescribed burning, hand-pulling, mechanical equipment, and placement of beach-quality sand from dredging operations. Such vegetation management should be used to enhance land, marsh, and waterbird habitats on state-owned lands and on private lands enrolled in conservation programs.

- Continued collection of population data from standardized survey protocol (e.g., colonial waterbird nesting surveys, Piping Plover census window counts, winter Piping Plover surveys, International Shorebird Surveys, point count surveys, Black Rail and marsh bird surveys, etc.) will provide critical data for population status, trend, and distribution evaluation. These data will demonstrate effectiveness of conservation management in North Carolina for SGCN.

- Shorebird and colonial waterbird data are managed in online databases managed by WRC; however, for migratory bird species, knowledge of population status at flyway and regional scales is necessary for conservation decision-making. Migratory bird data should be shared among conservation partners using the East Coast node of the Avian Knowledge Network data management system. The Eastern Avian Data Center is available online at data.pointblue.org/partners/eadc. As part of an Atlantic Flyway-wide survey of colonial waterbirds data from randomly selected survey sites are being entered into the Avian Knowledge Network.

- Continued management of game lands and other conservation lands for Successional habitats (particularly Longleaf Pine Savanna, herbaceous freshwater marsh, and high salt marsh) through fire and other disturbance methods appears to be vital to the continued persistence of many species (e.g., Bachman's Sparrow, Northern Bobwhite, Prairie Warbler, Black Rail). Recent studies indicate that lands managed for conservation harbor the bulk of occurrences in North Carolina (Taillie et al. in review). Development of alternative habitat management practices suitable for both timber or pine straw management and nesting habitat for Bachman's Sparrow may help expand the already contracted range of this species.

- Management of disturbance at Peregrine Falcon nest sites is accomplished through technical guidance to landowners and should continue. Examples of disturbance at a nest site include rock climbing, manned or unmanned (e.g., drone) aircraft operation, and building construction near a nest site.

- Where the Barn Owl and American Kestrel are nest-site limited, nest boxes can be posted. Land management practices that support rodent populations provide foraging habitat for these two raptors.

- Restoration of high elevation forests used by Northern Saw-whet Owl, Red Crossbill, and Black-capped Chickadee is underway through the efforts of the Southern Appalachian Spruce Restoration Initiative and should continue.

- Monocultures of nonnative, invasive plant species such as Japanese stilt grass are unsuitable for species that nest on or near the ground. Kentucky Warbler, for example, requires a dense but heterogeneous woody understory. There is a need to control or eradicate NNIS that form monocultures, particularly in vulnerable floodplain forest. Furthermore, projects that introduce disturbance to closed canopy forest should carefully consider the risk of introducing or encouraging the spread of NNIS.

3.3.6 Threats and Problems

Chapter 5 describes 11 categories of threats the Mammal Taxa Team considered during evaluation and ranking process to identify SGCN. Evaluation results for Metric 9 about the expected scope and severity of these threats are available in Appendix 3. The most likely threats to have very high impacts on bird populations in North Carolina over the next 10 years include the following:

- Climate change and severe weather
- Natural system modifications
- Human intrusions and disturbance
- Agriculture and aquaculture
- Invasives, problematic species and genes

North Carolina is expected to be the seventh most populous state in the country by the early 2030's, with most development expected to be in the Piedmont ecoregion and on the coast. In addition to traditional conservation land protection, development patterns can be affected through local and regional land managers. In 2010, the WRC initiated the Green Growth Toolbox program, designed to proactively educate and inform development planning to minimize the impact of human development on wildlife. The WRC will continue to evaluate and modify this program as needed.

In 2012, the WRC published "Conservation Recommendations for Priority Terrestrial Wildlife Species and Habitats in North Carolina," a guide to development and habitat management practices to best protect priority species and habitats (WRC 2012). Simple recommendations are accompanied by an extensive appendix of backing research for each. The WRC will continue to promote these practices and update the guide as needed. The guide can be downloaded from the WRC website
https://www.ncwildlife.org/conserving/conservingterrestrialhabitatsandspeciespdf/download?attachment.

Conversion of farmlands to residential developments is a particular threat to Barn Owl and American Kestrel. Fragmentation of large forest blocks by conversion to non-forest is an increasing threat to a variety of songbirds and raptors in the Mountains and can exacerbate problems with hybridization (e.g., Golden-winged and Blue-winged Warbler) and nest parasitism.

Because North Carolina provides important nesting, migration stopover, and wintering habitat for numerous shorebird and waterbird species, any loss of this important habitat is a threat that can have significant impacts on populations. Loss of habitat can occur from land-use impacts (e.g., development, inlet relocation and management, beach nourishment projects, recreation activities) and climate change (e.g., sea level rise, more intense and frequent storm events, saltwater intrusion) (NABCI 2009; Delany, Nagy, and Davidson 2010, Sweet et al. 2022, North Carolina SET Community of

Practice 2024). Waterbird rookeries are vulnerable to development activities, especially land clearing and construction activities that destroy nesting habitat and intrusion or disturbance impacts from development sites that are located near rookeries.

High winds or other severe weather events can uproot trees and impact entire nesting colonies. Saltwater intrusion can cause die-off of forest vegetation that needs freshwater resources. Information on the loss of freshwater herbaceous marsh on which many marsh bird SGCN depends on is lacking. However, currently only four percent of freshwater wetlands in North and South Carolina could be classified as herbaceous (Carolina Wetlands Association 2022). The lack of Black Rail detections outside of high elevation coastal marsh and the decline in King Rail demonstrate the need to create and restore this habitat type.

Increased human population density within North Carolina's coastal region increases challenges associated with garbage and pet food that attract mammalian and avian predators in larger numbers. Raccoons, foxes, free-ranging cats, coyotes, crows, and gulls all prey on bird adults, eggs, chicks, and fledglings. Such predation pressures have population-level impacts on bird species, and especially significant effects on small, declining populations.

Energy development from wind farms, solar panels, or offshore oil rigs may affect migratory bird populations directly through collisions with infrastructure or being coated with oil from spills. Indirect effects may include avoidance of large areas used by energy development, thus loss of habitat. Buildings and glass, especially in urban areas where multi-story buildings have numerous windows, are collision risks because the glass reflects open sky, plants, or other components of natural habitat. Several toolkits to reduce bird collisions are available online https://www.fws.gov/story/threats-birds-collisions-buildings-glass.

Climate change and SLR will alter coastal environments. Coastal marshes in North Carolina are not gaining in elevation at a pace sufficient to keep up with sea level rise (Bost et al. 2024, North Carolina SET Community of Practice 2024). Loss of freshwater marsh habitat to saltwater intrusion will adversely affect several rail species, many of which we know little about already. Loss of marsh islands in estuaries will affect Forster's Tern, Willet, Clapper Rail, American Oystercatcher, and other species dependent on these sites for nesting, feeding, and roosting. Strong coastal storms create overwash pans and inlets that benefit many shorebirds, terns, and skimmers. Barrier islands may decrease in area, thus, dredged-material islands may play an increased role in providing nesting, roosting, and feeding habitats.

Habitat management on private lands continues to be important to maintaining viability of bird populations in the Piedmont and Coastal Plain. In particular, providing and administering programs to discourage clean agricultural practices, and promoting field borders of native herbaceous and shrub species should continue to be supported through the WRC Wildlife Conservation Lands Program and similar programs. In other landscapes, increase the use of fire as a management tool, mitigate loss of canopy cover in key dispersal corridors (for species like the Red-cockaded Woodpecker), and manage invasive species causing reduction of insect prey populations.

3.3.7 Additional Information

3.3.7.1 North Carolina

The NC Bird Atlas (https://ebird.org/atlasnc/home) is a statewide community science project sponsored by WRC to map birds during the breeding and wintering seasons. The Atlas is a data collection portal associated with Cornell Labs' eBird program. eBird is a worldwide online platform for birdwatchers to document their sightings and observations, allowing birdwatchers to organize and share information about their sightings in one place. Observation records entered into the Atlas are merged with data entered into other eBird portals to provide distribution, abundance, and potential breeding bird information that can be searched to find information relevant to North Carolina.

Audubon has identified 95 Important Bird Areas (IBAs) in North Carolina, 30 of which are recognized as globally important. The IBA program is a global effort to identify and conserve areas that are vital to birds and other biodiversity. The IBA reports associated with each site provide a description of habitats available and a list of species occurring in the IBA, identifies threats likely to impact the site or species, and provides recommendations for conservation action. A map of BCR regions and IBAs is provided in Appendix 3.22 and are available online at http://netapp.audubon.org/iba/Reports.

The Carolina Bird Club (http://www.carolinabirdclub.org) maintains well-documented records of birds in North and South Carolina, and through a quarterly ornithological journal, *The Chat*, publishes scientific articles, reports of bird counts, and general notes about bird sightings. An online searchable database of material published in *The Chat* provides occurrence data spanning 1971 to present day.

In 2012, the WRC published "Conservation Recommendations for Priority Terrestrial Wildlife Species and Habitats in North Carolina," a guide to development and habitat management practices to best protect priority species and habitats (WRC 2012). Simple recommendations are accompanied by an extensive appendix of backing research for each. The WRC will continue to promote these practices and update the guide as needed. The guide is available to download https://www.ncwildlife.org/conserving/conservingterrestrialhabitatsandspeciespdf/download?attachment.

3.3.7.2 National

Road to Recovery (R2R) is an independently funded enterprise focused on the recovery of the most rapidly declining birds in the US and Canada by supporting species-focused teams. The four guiding principles are: a focus on proactive recovery of species, integration of social and biological sciences, co-production of sustainable solutions, and engagement and empowerment of species working groups. R2R uses data in the Avian Conservation Assessment Database (ACAD) to assess urgency so that efforts and resources can be focused on the recovery of species listed as Tipping Point species. Tipping Point species are those that require immediate, focused scientific action to pinpoint causes of declines and need strategies developed for recovery. An example is a range wide survival study of Golden-winged Warblers.

Information on waterfowl and other migratory birds is collected through work conducted under cooperative agreements such as the Atlantic Coast Joint Venture (ACJV), Appalachian Mountains Joint Venture (AMJV), South Atlantic Migratory Bird Initiative (SAMBI), Atlantic Flyway Council, and South Atlantic Landscape Conservation Cooperative, and through management of PIF Bird Conservation Regions (BCRs).These efforts provide long-term trend data that are critical to assess population changes.

The AMJV currently focuses their conservation efforts on three main natural communities. Bird species that are closely associated with these communities have been identified as priorities for their conservation work. The AMJV priorities include Golden-Winged Warblers and their association with young forests and old fields (successional community types); Cerulean Warbler and Wood Thrush and their association with mature deciduous forests (cove, montane, and oak forests); and Saw-whet Owl, Black-capped Chickadee, and Red Crossbill and their association with high elevation forests (northern hardwood and spruce–fir forests). Conservation of open pine communities and wetlands are another priority area for the AMJV.

North Carolina contains portions of three Bird Conservation Regions (BCRs)—Southeastern Coastal Plain BCR27, Piedmont BCR29, and Appalachian Mountains BCR28—as defined by the North American Bird Conservation Initiative (NABCI). The conservation regions encourage and facilitate conservation with ecological rather than political boundaries. Each BCR has conservation plan(s) outlining conservation actions specific to the species and habitats contained therein. Each year, the NABCI, in partnership with 18 other organizations, issues a "State of the Birds" report, which combines information from eBird and other sources to illustrate a high-level view of bird conservation across the country (NABCI 2014).

Partners in Flight (PIF) (https://partnersinflight.org) is a cooperative venture of government agencies, businesses, non-governmental organizations, researchers, and many others whose common goal is the conservation of North American birds. While PIF is concerned primarily with landbirds, it works in conjunction with other bird partners to promote coordinated conservation of all birds.

3.3.7.3 International

North Carolina's Wildlife Resources Commission is committed to the full life cycle conservation of migratory bird species. Through the Southern Wings Program of the Association of Fish and Wildlife Agencies, WRC is supporting conservation work for the Piping Plover on its wintering grounds in the Bahamas. The Bahamas National Trust (BNT) and National Audubon Society

(NAS) are conducting surveys of wintering Piping Plover to determine abundance and distribution, and to locate significantly important habitat. The BNT is working to put such habitat into conservation protection status. Additionally, current banding programs will provide further information about the migration of Piping Plover between the North Carolina coast and the Bahamas.

The International PIF organization is developing full life cycle plans for habitats across North America and associated wintering grounds in Central and South America. The WRC and other partners will continue to work on these plans to develop flyway-wide conservation priorities (e.g., Caribbean/Eastern Upland Hardwoods Conservation Business Plan). Partners in Flight maintains a color-coded Watch List that identifies species of highest conservation concern at the continental scale. The purpose of the PIF Watch List is to foster proactive attention to the conservation needs of the continent's most vulnerable species. Red Watch List includes species with extremely high vulnerability due to small population and range, high threats, and range wide declines (example, Golden-winged Warbler). The Yellow/Prevent Decline Watch List includes species not declining but vulnerable due to small range or population and moderate threats (example, Henslow's Sparrow). The Yellow/Reverse Decline Watch List includes species with population declines and moderate to high threats (examples, Eastern Whip-poor-will, Wood Thrush, Kentucky Warbler, Cerulean Warbler, and others).

3.3.8 Recommendations

In general, protection and restoration of natural community composition and function and protection of surrounding natural areas under current conditions are the best ways to ensure suitable habitats are available for bird species. Measures that protect a large and diverse pool of populations are the best way to ensure that species are able to survive future stresses and adapt to changing climate conditions. Data needs to be collected using standardized, accepted protocols that can be used by others and should be entered into the Avian Knowledge Network (appropriate node).

Implement conservation measures and recommendations in protected species conservation plans.

- State protected species conservation plans are available online https://www.ncwildlife.gov/wildlife-habitat/species-conservation-plans.

- Federal protected species recovery plans are available online https://www.fws.gov/program/recovery/recovery-plans.

Implementation of recommendations for surveys, monitoring, and research should follow best practices and protocols established by recognized authorities (see Chapter 6 for a list of protocols). The following recommendations should be considered appropriate to implement for bird species.

3.3.8.1 Surveys

Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Determine the breeding distribution of and develop and ground truth occurrence models; extend surveys to include hardwood forests for the owl.

  Northern Saw-whet Owl   Eastern Whip-poor-Will

- Use autonomous recording units (ARUs) for vocal species with brief survey windows to extend surveys across a broader geography than is otherwise reachable by limited personnel, especially during the peak survey windows. ARUs that can be programmed with a delayed start can be deployed and retrieved outside of the narrow, busy survey window.

- Build out infrastructure statewide for the Motus Wildlife Tracking Network to support migration studies. NC's Motus stations can fill in knowledge gaps about migration timing, especially for birds that move through North Carolina, and about important stopover sites.

  Migratory species

- Survey for birds on the PIF Watch List, Common Birds in Steep Decline, and Regional Stewardship lists.

American Black Duck	Chuck-will's-widow	Loggerhead Shrike
Bank Swallow	Grasshopper Sparrow	Northern Bobwhite
Black Skimmer	Little Blue Heron	Savannah Sparrow

- Survey for Road to Recovery (R2R) and Tipping Point species (indicated by *)

Red Watch List (SGCN)`	Yellow Watch List (SGCN)	Orange Watchlist (SGCN)
Bachman's Sparrow*	American Oystercatcher*	Black-bellied Plover*
Black Rail*	Cerulean Warbler*	Bobolink*
Saltmarsh Sparrow*	Eastern Whip-poor-will*	Chimney Swift*
Wilson's Plover*	Golden-winged Warbler*	Great Black-backed Gull*
	Henslow's Sparrow*	King Rail*
	Kentucky Warbler	Least Tern*
	Marbled Godwit	Long-tailed Duck*
	Nelson's Sparrow	Piping Plover*

Priority Conservation Action, Examples of Focal Species or Focal Habitats

	Prairie Warbler*	Red Knot*
	Prothonotary Warbler	Sanderling*
	Red-cockaded Woodpecker*	Whimbrel*
	Seaside Sparrow	
	Willet	
	Wood Thrush*	
	Yellow Rail*	

- Survey for priority species identified by Migratory Bird Joint Ventures:
  - Appalachian Mountains Joint Venture (AMJV)
  - Atlantic Coast Joint Venture (ACJV)
  - Black Duck Joint Venture
  - Sea Duck Joint Venture

Landbirds	Waterbirds
Shorebirds	Waterfowl

- Conduct surveys to estimate population status, trends, and distribution of all marsh birds; surveys of secretive marsh birds are especially needed.

Freshwater Marsh	Black Rail	American Bittern
Brackish Marsh	King Rail	Least Bittern
Salt Marsh	Virginia Rail	

- Conduct surveys of SGCN birds in riparian habitats that are not covered well by traditional surveys (e.g., Breeding Bird Survey, Christmas Bird Count).

Riparian habitats	Acadian Flycatcher	Louisiana Waterthrush
Inland Floodplains	Cerulean Warbler	Prothonotary Warbler
Blackwater Floodplains	Kentucky Warbler	Swainson’s Warbler
Brownwater Floodplains		

- Survey for grassland birds that are considered to be steeply declining, are not tracked well by typical survey methods, or have poorly understood distribution and status in the state.

Grassland habitats	Barn Owl	Grasshopper Sparrow
	Bobolink	Lark Sparrow
	Dickcissel,	Loggerhead Shrike
	Eastern Kingbird	Savannah Sparrow
	Eastern Meadowlark	Vesper Sparrow

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Survey for birds that may be declining in Longleaf Pine habitats.		
Longleaf Pine	Bachman's Sparrow	
• Determine distribution and breeding status for species not covered well by traditional surveys.		
American Kestrel Barn Owl Cooper's Hawk Loggerhead Shrike Merlin	Nelson's Sparrow Northern Harrier Northern Saw-whet Owl Rusty Blackbird Saltmarsh Sparrow	Seaside Sparrow Sedge Wren Sharp-shinned Hawk Short-eared Owl Worm-eating Warbler
• Conduct migration surveys statewide to determine the extent of use of successional and other habitats by post-breeding and migratory birds.		
Successional habitats	Post-breeding birds	Migratory Birds
• Determine the breeding and roosting status and distribution of birds in natural conditions along major floodplains with appropriate habitat conditions (e.g. older, hollow trees).		
Inland Floodplains Blackwater Floodplains Brownwater Floodplains	Chimney Swift	
• Survey for potential nesting birds in caves and on cliffs and rock outcrops.		
Caves Rock Outcrops and Cliffs	Common Raven Black Vulture	Peregrine Falcon Turkey Vulture
• Determine the status and distribution of Wayne's Black-throated Green Warbler.		
Wayne's Black-throated Green Warbler		
• Determine the status and distribution of Swallow-tailed Kite and Mississippi Kite.		
Mississippi Kite	Swallow-tailed Kite	
• Determine the status and distribution of inland nesting wading birds.		
Anhinga	Little Blue Heron	Yellow-crowned Night Heron

3.3.8.2 Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. These efforts will inform species and habitat management decisions. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Develop and implement a long-term occupancy monitoring program using bioacoustics for breeding populations.

  Northern Saw-whet Owl

- Expand the range wide Nightjar Survey Network (https://www.nightjars.org) across North Carolina to meet scale requirements for a population estimate or trend index. This supports priorities for Atlantic Flyway Council's Landbird Committee work on Aerial Insectivores.

  Chuck-will's-widow Common Nighthawk Eastern Whip-poor-will

- Continue regular colonial waterbird surveys during the breeding season (currently conducted coast-wide every three years on average).

  Coastal Plain Ecoregion Colonial waterbirds

- Establish long-term monitoring for all marsh birds; conduct monitoring that incorporates detection of marsh bird SGCN to the maximum extent possible.

Freshwater Marsh	Black Rail	American Bittern
Brackish Marsh	King Rail	Least Bittern
Salt Marsh	Virginia Rail	

- Evaluate whether Breeding Bird Survey routes or point counts need to be established in selected areas or habitats and more attention paid to the migration period and wintering ecology of birds using early successional habitats.

  Early Successional

- Add more Monitoring Avian Productivity and Survivorship (MAPS) stations and migration banding stations.

  Migratory birds

- Monitor Henslow's Sparrow population and distribution at Voice of America (VOA) sites in eastern North Carolina to determine population trends.

  Grasslands Henslow's Sparrow

Priority Conservation Action, Examples of Focal Species or Focal Habitats

Early Successional

- Continue annual monitoring of Peregrine Falcon nest cliffs to assess population status.

High Elevation Rocks and Cliffs Peregrine Falcon

- Continue long-term monitoring and banding work on Eastern Painted Bunting in support of the USGS Painted Bunting Working Group multi-state efforts

Eastern Painted Bunting

- Continue long-term monitoring of active territories, successful breeding pairs, and fledged eagles.

Bald Eagle

- Continue long-term monitoring of birds that use early successional and mature habitats habitats on game lands, national and state forests and parks, and National Wildlife Refuges.

Early Successional
Mature forests

- Address monitoring needs for montane bird populations particularly for species that may be found at the upper or lower ranges of this habitat.

Montane forests	Canada Warbler	Northern Saw-whet Owl
	Cerulean Warbler	Pine Siskin
Alder Flycatcher	Chestnut-sided Warbler	Red Crossbill
Black-billed Cuckoo	Golden-crowned Kinglet	Rose-breasted Grosbeak
Blackburnian Warbler	Golden-winged Warblers	Veery
Brown Creeper	Hermit Thrush	Yellow-bellied Sapsucker

- Continue regular, periodic aerial heronry surveys in the Coastal Plain ecoregion. Return to a subset of heronries to conduct ground counts for nests of long-legged wading bird SGCN.

Coastal Plain ecoregion Long-legged wading birds

- Continue to monitor Wood Stork nest abundance.

Wood Stork

- Continue shorebird surveys for breeding, wintering, and migratory birds throughout the year to document population status, trends, and distribution. Document distribution, past and present, using survey data and mapping efforts.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
American Oystercatcher, Red Knot, Piping Plover, Wilson's Plover
• Continue support for long-term monitoring of SGCN landbirds. Piedmont Ecoregion, Longleaf Pine, Early Successional, Riparian habitats
• Expand monitoring frameworks to account for species that are not suited to traditional long-term monitoring protocols or for species missed under systematic monitoring due to small population sizes or limited ranges in North Carolina. Hawks, Chuck-will's-widow, Alder Flycatcher, Owls, Common Nighthawk, Black-capped Chickadee, Eastern Whip-poor-will, Brown Creeper
• Initiate long-term monitoring of breeding and wintering birds in pocosin habitats on public lands and industrial forestland. Pocosin
• Initiate long-term monitoring related to snag ecology and cavity-nesting birds during different seasons. Brown-headed Nuthatch, Northern Flicker, Red-headed Woodpecker
• Monitor status and reproductive success of shorebirds. Black Skimmer, Common Tern, Least Tern, Caspian Tern, Gull-billed Tern, Piping Plover
• Continue current monitoring of marsh nesting colonial waterbirds, especially the Laughing Gull. Laughing Gull
• Continue monitoring beach-nesting species due to their high vulnerability from habitat loss due to sea level rise and coastal erosion.

3.3.8.3 Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Utilize data collected through the NC Bird Atlas to generate distribution and abundance maps and related metrics for species breeding and over-wintering in North Carolina.

- Fill critical knowledge gaps such as density, diet, nesting performance, use of roosting, nesting, and foraging habitat. Investigate prey availability, and determine if insect abundance or changes in insect diversity are limiting factors.

  Eastern Whip-poor-will Northern Saw-whet Owl

- Study movements, particularly post-breeding dispersal, of several raptor species. Determine if these species remain year-round residents or shift altitudinally or latitudinally for the winter.

  Raptors American Kestrel Northern Saw-whet Owl
  Peregrine Falcons

- Study nest ecology and movements, autumn flock formation, and particularly post-breeding dispersal of several mountain songbird species.

  Black-capped Chickadee Hermit Thrush Veery

- Document nest sites and ecology, record songs for type identification, and document movements with respect to cone crop availability.

  Red Crossbill

- Assess response of disturbance sensitive species to recreation development and activities.

  Eastern Whip-poor-will Northern Saw-whet Owl Peregrine Falcon

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Study response to forest management or alteration; investigate use of forests altered by pests (for example, use of young, regenerating Fraser Fir stands), storm damage (use of forest patches impacted by hurricanes), or by silviculture. Much is already published about the response of Golden-winged Warbler, Wood Thrush, and other species to forest management in the form of silviculture or prescribed burning, but there may be a specific need for additional studies based in North Carolina.

  Cerulean Warbler, Kentucky Warbler, Eastern Whip-poor-will, Northern Saw-whet Owl, Golden-winged Warbler

- Determine the extent of use of successional and other habitats by post-breeding and migratory birds using the Motus Wildlife Tracking Network and other methodologies.

- Advance understanding of breeding and wintering ground linkages and migratory pathway in support of AMJV strategic plan goals.

  Mountain Ecoregion, Eastern Whip-poor-Will, Wood Thrush, Cerulean Warbler, Golden-winged Warbler, Kentucky Warbler

- Support studies addressing the decline of aerial insectivore species.

  Swallows, Flycatchers, Warblers, Swifts, Nightjars

- Identify causal factors responsible for low beach-nesting bird reproductive success; initiate predator impact studies (e.g., ghost crabs, fire ants, gulls, foxes, raccoons, feral cats, coyotes, crows, Gull-billed Terns).

- Conduct monitoring to estimate American Oystercatcher, Gull-billed Tern, Black Skimmer, and Wilson’s Plover reproductive success, especially needed for the Wilson’s Plover due to scant data available. Studies should examine direct and indirect factors affecting reproductive success, including effects of different levels of human disturbance.

  American Oystercatcher, Gull-billed Tern, Black Skimmer, Wilson’s Plover

- Conduct life history studies of colonial waterbirds, especially SGCN.

  Colonial waterbirds

- Examine the effectiveness of diverse vegetation control methods for beach-nesting birds that require early successional habitat.

  Early Successional

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Examine impacts of coastal engineering actions on benthic macro-invertebrates on which migratory shorebirds feed, especially the Red Knot.

Active Shoreline	Red Knot
Beach	Migratory Shorebirds

- Assess the impacts of changes mandated by the Federal Energy Regulatory Commission (FERC) in water releases at hydroelectric dams on high-priority species.

Reservoirs
Riverine systems

- Conduct bird nest productivity studies, including nest-searching and spot mapping, and studies of predator effects on bird nest productivity.

- Conduct genetics research on Worm-eating Warbler (to determine if the coastal population represents a separate subspecies), breeding American Kestrels in the Sandhills ecoregion, and Black-capped Chickadees and Golden-winged Warbler (to assess hybridization with Carolina Chickadee and Blue-winged Warbler, respectively).

Mountain ecoregion	American Kestrels	Carolina Chickadee
Sandhills ecoregion	Black-capped Chickadees	Golden-winged Warbler
	Blue-winged Warbler	Worm-eating Warbler

- Conduct survival studies, examining adult and juvenile survival.

American Kestrel	Peregrine Falcon

- Conduct study of vulnerability to contaminants.

American Kestrel	Barn Owl
Bald Eagle	Peregrine Falcon

- Conduct studies of small wading birds using miniature GSM transmitters to obtain habitat selection, migration, energetics, and survival estimates.

Glossy Ibis	Snowy Egret
Little Blue Heron	Tricolored Heron

- Study past and predicted change in coastal bird habitats, especially relative to sea level rise and storm events, including natural barrier islands, marsh islands, and dredged-material

Priority Conservation Action, Examples of Focal Species or Focal Habitats

islands. Use models to provide guidance for long-term habitat restoration and management for continued population viability.

Coastal habitats	Natural islands	Dredge spoil Islands

- Evaluate and prioritize restoration of coastal marshes and waterbird habitats to reduce sea level rise impacts to breeding habitats.

Coastal marsh habitats		

- Conduct research on habitat management techniques to maintain suitable habitat for disturbance-tolerant species.

Early successional	Golden-winged Warbler	

- Conduct studies on the nesting ecology of Mountain birds.

Mountain ecoregion	Hermit Thrush	
	Red Crossbill	

- Conduct studies on post-fledging dispersal, adult and juvenile survival, migratory habits, and vulnerability to contaminants.

American Kestrel	Peregrine Falcon	

- Conduct studies of habitat use, population trends, and winter abundance and distribution.

American Kestrel	Northern Saw-whet Owl	Wood Stork
Barn Owl	Golden Eagle	

- Conduct studies about nesting success, productivity, and survival of floodplain birds in buffers of different widths; this could provide some insight into population declines and help to guide management recommendations for buffer width.

Inland Floodplains	Acadian Flycatcher	Swainson’s Warbler
Blackwater Floodplains	Cerulean Warbler	Wood Stork
Brownwater Floodplains	Kentucky Warbler	Wood Thrush

- Conduct research into the potential effects of renewable energy development, including species-specific vulnerability and effectiveness of methods to reduce mortality.

Bald Eagle	Waterfowl	
Golden Eagle		

- Determine if southeastern subspecies breed and/or winter in habitats in North Carolina.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
American Kestrel		

- Determine the effects of clear-cut stand size on shrubland birds.

- Document the habitat selection and competition factors related to use of maritime forests and successional communities

Maritime forests Successional habitats	Eastern Painted Bunting Indigo Bunting	

- Examine causes of declines among nightjars on industrial forestland and other habitats.

Managed timber	Chuck-will's-widow Common Nighthawk	Eastern Whip-poor-will

- Examine nest parasitism impacts on bird productivity in small versus large habitat patches.

Cowbird

- Identify lands that can be converted to non-tidal or supratidal herbaceous marsh for the benefit of Black and King Rail and other waterbirds. Evaluate freshwater herbaceous marsh habitat creation techniques and response by marsh bird SGCN.

Freshwater marsh	Black Rail King Rail	Waterbirds Marsh birds

- Examine habitat use and conduct nesting habitat research on marsh birds. Employ UAS with lidar to examine microtopography and vegetation of coastal high marshes relative to Black Rail occupancy. Evaluate, and use if successful, UAS with thermal cameras to identify Black Rail spatial distribution in coastal marshes, relative to microtopography.

Marsh habitats Marsh birds	Black Rail	

- Employ game cameras to evaluate Black Rail reproduction and determine the adult flightless molt period in North Carolina.

Black Rail

- Evaluate water levels and the effects of prescribed fire in marshes where Black Rails are present. Examine the effect of prescribed fire on salt marsh migration. Evaluate the benefit to Black Rails of cutting and / or burning ghost forest.

Marsh habitats	Black Rail	

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Assess the importance of stopover habitats in North Carolina using aeroecology (radar)or other remote sensing technologies.		
• Conduct studies on contaminants in avian populations.		
• Investigate predation of Piping Plover chicks by Gull-billed Terns, population decline in both species, and strategies for both species to meet recovery/management goals.		
Piping Plover	Gull-billed Tern	

3.3.8.4 Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• With the Appalachian Mountains Joint Venture, work with partners to produce, endorse, fund, and promote efficient and effective full annual cycle conservation projects and programs, including conservation within key stop-over and wintering grounds locations.		
Mountain ecoregion		
• Work with land managers and owners to create and maintain high quality nest cover for species that nest in the understory, using a variety of management tools (e.g., herbicide, mowing, brush cutting, seeding, prescribed fire, logging, restoring river cane).		
Mountain ecoregion	Eastern Whip-poor-Will Golden-winged Warbler Kentucky Warbler	Prairie Warbler Swainson's Warbler
• Provide guidance to land managers and owners about optimal timing for mowing woods roads, harvesting hay, and similar activities to minimize impacts to nesting birds.		
• Work with land managers and owners to close public access and post closure signs to cliffs and rock outcrops with Peregrine Falcon nests. Develop effective communications about peregrines, disturbance, and cliff closures, targeting different forest visitors (e.g., rock climbers, recreational drone operators, hikers).		

Priority Conservation Action, Examples of Focal Species or Focal Habitats

Cliffs and Rock Outcrops	Peregrine Falcon

- In landscapes managed for silviculture, develop prescriptions that provide high quality nesting cover and post-fledging habitat.
  - For species that nest in closed canopy forest such as Wood Thrush, ensure sufficient area of high-quality mature forest for nesting in proximity to patches of deciduous saplings, woody shrubs, and native fruit-bearing trees and shrubs for the post-fledging period.
  - For species that nest in openings such as Golden-winged Warbler, ensure high quality nest cover in proximity to young forest for the post-fledging period.

Golden-winged Warbler	Wood Thrush

- Restore native understory vegetation where deer browsing and/or non-native invasive species of plants have degraded habitat by managing deer populations and controlling invasives. Restoring native understory vegetation will benefit Kentucky Warbler, Swainson's Warbler, Cerulean Warbler, Eastern Whip-poor-Will, and more. Particular attention is needed in degraded floodplain forest.

Riparian forest	Cerulean Warbler
Inland Floodplain	Eastern Whip-poor-Will
Blackwater Floodplain	Kentucky Warbler
Brownwater Floodplain	Swainson's Warbler

- Promote and provide technical guidance on the use of native plant species in landscaping.

- Provide guidance to help agencies and organizations, partners, businesses, private landowners, and others to reduce strike hazards to birds because of reflective surfaces of structures. Support and share materials developed by others that provide guidance, such as the US Fish & Wildlife Service's guidance "Reducing Bird Collisions With Buildings and Building Glass Best Practices (https://www.fws.gov/sites/default/files/documents/reducing-bird-collisions-with-buildings.pdf).

- Share Best Management Practices for livestock grazing regarding optimal herd size to maintain high quality openings for Golden-winged Warbler, Vesper Sparrow, and others with willing livestock farmers.

Golden-winged Warbler
Vesper Sparrow

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Annually post signs around perimeter of colonial waterbird nesting sites before the nesting season to prohibit human intrusion; signs should be posted at sufficient distance to minimize disturbance from activities in nearby areas.

  Coastal habitats Colonial waterbirds

- Maintain dredged-material islands with sand dredged from channels to continue viability of nesting sites for colonial waterbirds. Placement of dredged sand on the islands once every seven to 10 years may be sufficient to maintain the habitats.

  Coastal habitats Colonial waterbirds

- Conduct predator management as needed at important bird nesting sites, especially of introduced and invasive species (e.g., nutria, coyotes, red fox, feral cats, large gulls).

- Continue to proactively promote planning efforts incorporating conservation measures for priority species via the Green Growth Toolbox program (https://www.ncwildlife.org/wildlife-habitat/conservation-restoration-programs/green-growth-toolbox) and in accordance with guidance in the WRC's Conservation Recommendations for Priority Terrestrial Wildlife Species and Habitats in North Carolina (https://www.ncwildlife.org/conserving/conservingterrestrialhabitatsandspeciespdf/download?attachment).

- Where appropriate, use prescribed fire to maintain fire adapted communities.

- Provide artificial nest aids, in the form of nest boxes or constructed cavities. Continue to excavate artificial nest cavities for Red-cockaded Woodpeckers. Where appropriate, post nest boxes for owl species and American Kestrel. Consider installing nest aids at those eyries where Peregrine Falcons have experienced chronic nest failure.

  American Kestrel Red-cockaded Woodpeckers
  Peregrine Falcons

- Direct interested parties to resources on bird-safe building policies or legislation. ABC has toolkits and NYC Local law 15 of 2020 is considered the most comprehensive to date.

- Educate homeowners and building owners on the threat posed by glass and artificial light on residential buildings and provide information on how they can reduce that threat.

- Control or minimize the amount of large gull depredation on other beach-nesting birds. These large gulls did not nest in the state until recent decades and are causing pressure on beach-nesting bird populations.

  Beach nesting birds

3.3.8.5 Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Work with owners and managers of buildings on which Least Terns nest to increase reproductive success while allowing owners/managers to maintain good public relations.

  Least Terns

- Work with private lands biologists to identify conservation strategies and programs for important waterbird nesting habitat and roost sites that occur on private lands (e.g., Black Rail, King Rail, Wood Stork, Great Egret, Snowy Egret, Little Blue Heron, Tricolored Heron, Black-crowned Night Heron, Great Blue Heron, Anhinga)

Colonial waterbirds	Black-crowned Night Heron	Little Blue Heron
Anhinga	Great Blue Heron	Snowy Egret
Black Rail	Great Egret	Tricolored Heron
	King Rail	Wood Stork

- Work with the Atlantic Coast Joint Venture and other appropriate partners to facilitate a regulatory framework for coastal marsh protection and restoration.

  Coastal marsh habitats

- Continue participation in Partners in Flight efforts to develop international conservation business plans (e.g., Caribbean/Eastern Upland Hardwoods Conservation Business Plan).

  Coastal habitats
  Hardwood forests

- Continue promotion and participation of private landowner incentive programs (e.g., Wildlife Conservation Lands Program https://www.ncwildlife.org/wildlife-habitat/private-lands-management/wildlife-conservation-land-program, USFWS Partners for Fish & Wildlife Partners for Fish and Wildlife | U.S. Fish & Wildlife Service).

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Continue efforts to improve coordination, collaboration, cooperation between biologists and researchers within the state and regionally through meetings, webinars, newsletters, and other electronic media (NC Partners in Flight Initiative). Continue to support and contribute data to the Eastern Avian Data Center (https://avianknowledge.net/tools/#input), an initiative centered on greater data sharing.
• Continue to support and contribute data to the Eastern Avian Data Center (https://avianknowledge.net/tools/#input), an initiative centered on greater data sharing.
• Empower communities to initiate local action that directly benefits birds and their habitats by promoting bird-friendly community programs, such as Bird City Network.
• Support and uplift bird-friendly initiatives, such as Bird City Network's recognition and incentive programs for communities, businesses, and organizations that demonstrate contributions to bird conservation through the adoption of recommended practices and actions.
• Integrate programs like Bird City Network or Urban Bird Treaty into the state's broader wildlife conservation strategies, providing a pathway for municipalities to contribute to the overall goals of habitat preservation, reduction of urban threats to wildlife, community engagement, and enhancement of biodiversity.
• Encourage owners of communication towers 350 feet Above Ground Level to extinguish side-marker (L-810) lights and reprogramming non-flashing LED lights to flash on towers 150-350 ft Above Ground Level.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Continue active participation in international, national, regional, and species-specific partnerships. Examples include (but are not limited to): ▫ American Oystercatcher Business Plan ▫ American Oystercatcher Working Group (https://amoywg.org) ▫ Appalachian Mountains Joint Venture (https://amjv.org)

- Atlantic Coast Joint Venture (https://acjv.org)
- Atlantic Flyway Council (including the Game and Non-Game Migratory Bird Technical Sections) (https://www.fws.gov/partner/migratory-bird-program-administrative-flyways)
- Atlantic Flyway Shorebird Initiative (https://atlanticflywayshorebirds.org)
- Cerulean Warbler Technical Group
- Eastern Atlantic Painted Bunting Working Group
- Eastern Black Rail working groups
- Eastern Golden Eagle Working Group (https://egewg.org)
- Eastern Working Group, Partners In Flight (https://partnersinflight.org/working_groups/eastern)
- Golden-winged Warbler Working Group (https://gwwa.org)
- Integrated Waterbird Management and Monitoring Program (https://iwmmprogram.org/)
- International Partners in Flight (https://partnersinflight.org)
- Loggerhead Shrike Working Group (https://www.loggerheadshrikes.org)
- NC Waterbird Management Committee and Plan
- North American Bird Conservation Initiative (https://nabci-us.org)
- North Carolina Wood Thrush Conservation Alliance (https://nc.audubon.org/wood-thrush-0)
- Piping Plover Atlantic Coast Population Revised Recovery Plan
- Road to Recovery (https://r2rbirds.org)
- Saltmarsh Habitat and Avian Research Program (https://www.tidalmarshbirds.org)
- Southeast Conservation Adaptation Strategy (SECAS) (https://secassoutheast.org)
- Southern Appalachian Spruce Restoration Initiative
- Southern Wings program of AFWA
- Wood Stork Recovery Plan
- Others as appropriate

References are located at the end of this document

3.4 Crayfishes

3.4.1 Introduction

Within North Carolina, 51 described crayfishes are currently recognized, including 15 endemic species and 7 nonnative species (Simmons and Fraley 2010). Crayfishes, commonly referred to as crawfish or crawdads, are native to every continent except Africa and Antarctica and inhabit a wide diversity of habitats that range from rivers, lakes, streams, and wetlands, to caves, hillside seeps and springs, roadside ditches, and underground burrows in backyards (Taylor and Schuster 2004; Reynolds and Souty-Grosset 2012). Several crayfishes in the state are known from the work of John Cooper at the NC Museum of Natural Sciences during the last two decades (Cooper and Cooper 1995; Cooper 1998, 2000a, 2000b, 2006a, 2006b, 2007, 2010, 2011; Cooper and Schofield 2002; Cooper and Cooper 2003; Cooper and Russ 2013).

North American crayfishes are classified into two taxonomic families, Astacidae and Cambaridae, that contain nearly 390 native species (Simmons and Fraley 2010). Approximately 98% of all the species native to North America are classified as cambarids and the majority of this diversity (90%) occurs east of the Rocky Mountains, primarily in the southeastern United States (Pflieger 1996, Taylor and Schuster 2004) making the southeastern U.S. home to the greatest diversity of crayfish in the world (Schuster 1997; Welch and Eversole 2006).

Crayfishes are large, highly mobile, abundant invertebrates that utilize a wide variety of aquatic habitats and assume important roles in freshwater food webs (Pflieger 1996; Lodge et al. 2000a; Holdich 2002; Nystrom 2002). They are epitomized as keystone species because of their ability to manipulate their physical surroundings, process detritus, change macrophyte biomass, and influence the abundance and structure of invertebrate communities (Chambers et al. 1990; Hanson et al. 1990; Holdich 2002; Statzner et al. 2003; Stenroth and Nystrom 2003). Further, they represent a substantial portion of biomass within streams, thereby providing a forage base for numerous aquatic and terrestrial predators (Rabeni 1992; Rabeni et al. 1995; Pflieger 1996).

Burrowing crayfish spend significant portions of their lives in subterranean burrows ranging from simple linear shafts to elaborate systems of multiple tunnels and chambers (Hobbs Jr. 1981; Taylor et al. 1996). Burrowers may use areas without standing water or inhabit open water during wet seasons (Hobbs Jr. 1942, 1981; Welch 2006). Red Burrowing Crayfish is a primary burrowing crayfish often found in wetlands and bogs. Nonburrowing crayfish live in permanent waters and may make shallow excavations or simple tubes under rocks or in the substrate for refuge (Taylor et al. 1996).

Our described native crayfish fauna is dominated by the genus *Cambarus* (34 species) but also includes species from the genera *Procambarus* (8 species), *Faxonius* (8 species), and *Fallicambarus* (1 species). In addition, North Carolina is home to several undescribed species that await taxonomic resolution and scientific description. Baseline surveys and relatively recent assessments have been completed for many species in the mountains, including two newly described species in the Yadkin Pee Dee River basin: Falls Crayfish and Stony Fork Crayfish. Undescribed and nominally identified species are conservation and research priorities.

In 1996, the American Fisheries Society (AFS) Endangered Species Committee, Subcommittee on Crayfishes assessed the conservation status of crayfishes in the United States and Canada and subsequently reassessed statuses in 2007 (Taylor et al. 1996, 2007). To evaluate conservation status of crayfishes, Taylor et al. (1996, 2007) assessed status based on criteria known to impact aquatic taxa that included (1) existing or potential destruction or alteration of a species' habitat or distribution, (2) over utilization, (3) disease, (4) other natural or anthropogenic factors (e.g., hybridization or invasive species introduction), and (5) restricted range. Results from the reassessment indicate that the overall conservation status of crayfish has changed little since the first comprehensive review.

- Specifically, nearly half of the 363 crayfishes remained categorized as possibly extinct, endangered, threatened, or vulnerable; however, it should be noted that at least 25 taxa were downgraded due to increased research efforts and 27 new crayfish species were described after the 1996 assessment (Taylor et al. 2007).

- Of the described, native crayfishes in North Carolina, the conservation status of 24 species remained the same after reassessment, seven species were downgraded to a lower priority status, 12 species were described after the 1996 assessment, and no species were upgraded to a higher threat category.

- The 2007 assessment ranked the aforementioned 43 species as follows: one (2%) species is listed as Endangered; four (9%) are Threatened; nine (21%) are Vulnerable; 28 (65%) are Currently Stable; and one species was described subsequent to AFS assessments.

Conservation recommendations for the associated habitats have been incorporated into the natural community descriptions in Chapter 4. Additional recommendations can be found in the river basin descriptions (Section 4.5). The following paragraphs provide information about species identified by the Taxa Team as SGCN or as priority species for research or management, and for which work has been conducted to implement conservation and management recommendations.

3.4.2 Comparison of 2005 and 2015 Priority Species

The 2025 Crayfish Taxa Team evaluated 57 species and identified priority species for SGCN, knowledge gaps, and management concerns as noted below. The following table provides a comparison of changes to the number of SGCN and priority species between the 2015 SWAP, the 2020 Addendum 1, and the 2025 SWAP.

Crayfish Priority Species by Evaluation Categories and Comparison between SWAPs

SWAP Date	SGCN	Knowledge Gaps	Management Needs
2025	28	45	56
2020 Addendum 1	22	14	5
2015	19	14	5

Some species are a priority in more than one of the three evaluation categories. These changes do not necessarily indicate a change in the concern status of these species; they are more likely to reflect an increase in our knowledge base for the species.

We highlight specific conservation issues related to SGCN and their habitats in the following sections. This is not an exhaustive list of species-specific conservation concerns but rather highlights some of the concerns in the state. Recommendations for priority survey, monitoring, and research studies, conservation actions, and partnerships are outlined in Section 3.4.8.

3.4.3 Conservation Concerns

Table 3-3 (Appendix 3) provides a list of Crayfish SGCN and other priority species. River basin and habitat associations for these species are provided in Table 3-17 (terrestrial species) and Table 3-18 (aquatic species) (see Appendix 3).

Crayfish are one of the most threatened freshwater taxa assessed according to the 2010 update to the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (Richman et al. 2015; Reynolds and Souty-Grosset 2012). Twenty eight species are SGCN and the majority are either NC endemics, have a small range-wide distribution, or have a nominal part of their distribution in the state. Extinction risk is often attributed to small range size and degradation of freshwater habitats, especially from urban development and pollution (Crandall and Buhay 2008; Richman et al. 2015). Lodge (et al. 2000b) consider invasive nonnative crayfishes as the primary threat facing native crayfish populations. Taylor (et al. 2007) note five broad factors that can affect crayfish populations, including habitat destruction, over-utilization, disease, introduction of exotic species, and restricted range.

Endemic species that are of conservation concern include the Broad River Stream, French Broad River, Grandfather Mountain, Greensboro Burrowing, Pamlico, Tuckasegee Stream, and Valley River crayfishes.

3.4.4 Knowledge Gaps

An understanding of crayfish taxonomy, ecology, distribution, and abundance is necessary for resource managers to determine relative conservation status and to develop effective monitoring and management strategies (Simmons and Fraley 2010). For some North American crayfishes there is a lack of ecological knowledge and contemporary distributional information (Taylor et al. 2007). A recent evaluation of crayfish life history studies by Moore et al. (2013) substantiates the contemporary lack of knowledge and reports that only 12% of North American crayfishes have life history studies that have been published. These statistics are somewhat surprising considering the influence that crayfishes have on aquatic and terrestrial ecosystems. However, much work has been done in North Carolina over the last decade to address knowledge gaps about species in our state (Simmons and Fraley 2010).

In the late 1990s, the WRC began a focused effort to inventory and establish baseline data for the majority of crayfishes in the state. In-depth status assessments have been completed for several species considered SGCN, including Chauga, Grandfather Mountain, Little Tennessee, Hiwassee Headwater, Broad River Stream, French Broad River, Broad River Spiny, and Chowanoke crayfishes (Simmons and Fraley 2010; Thoma 2012; Russ and Fraley 2014). Eleven of the remaining species need baseline or updated status assessments to better understand their contemporary status and improve distributional knowledge within North Carolina. And while the general distribution for many crayfish species in the state is known, additional surveys are needed to refine their range in the state. Updated status assessments are needed for all but one of the species ranked as Knowledge Gap priority species.

Life history research is a conservation priority for all native crayfishes in North Carolina because this research forms the foundational knowledge base for evaluating threats and impacts from non-indigenous species, planning conservation activities, and guiding temporal aspects of environmental impacts. Nine of the SGCN species are high conservation priorities because of their NC endemic status, restricted range, taxonomic relationship, or lack of basic biological knowledge.

Genetic analysis is needed for seven of the SGCN to identify areas with high genetic diversity, resolve taxonomic relationships, and clarify species distributions. The results of genetic analysis studies will provide the knowledge needed to assess long-term monitoring priorities and direct conservation activities. An understanding of genetic diversity at the population level coupled with long-term monitoring will provide better information to conserve species.

Taxonomic descriptions need to be developed for currently undescribed species in the state. Within the past 10 years, the Carolina Foothills, Rocky River, and Sandhills Spiny crayfishes were described out of the *Cambarus (Puncticambarus)* sp. *C* species complex. Currently, there are still several suspected species from 10 different river basins that need to be described in this complex. The Chattahoochee Crayfish is currently considered part of another species complex that includes crayfishes found in the Broad and Catawba River basins and the South Fork Catawba River subbasin. Recently, *Cambarus* (*Cambarus*) sp. *A*, which is found in the Hiwassee and New River basins, was identified as a species that closely resembles the Common Crayfish and Chattahoochee Crayfish.

Six species considered SGCN need long-term monitoring to assess long-term population trends, identify management actions, and update conservation status. A recent status assessment of Broad River Stream Crayfish, Hiwassee Headwater Crayfish, French Broad River Crayfish, and Broad River Spiny Crayfish found that some of these species have restricted ranges or declining populations, and specific monitoring recommendations were suggested (Russ and Fraley 2014), thereby warranting frequent monitoring of these species. For example, the Grandfather Mountain Crayfish is a SGCN for which monitoring is a high priority because it has a small range that is increasingly threatened by development, the presence of the nonnative Virile Crayfish in the lower Linville River is a potential threat, and its population trends are not well known.

Other needs include monitoring to detect the spread of nonnative species and the status of native sympatric species. Species that have a small native range and are threatened by present or foreseeable habitat disturbance and those that may be declining should be monitored to detect population trends. Investigations on the factors associated with global climate change and deposition of atmospheric pollutants that may affect rare and endemic species found at high elevations, and land-use changes occurring in rapidly developing areas are needed. Research on the habitat requirements and the tolerance of individual species to physical and chemical changes to their habitats is another priority (Simmons and Fraley 2010). For instance, the Broad River Stream Crayfish appears to be vulnerable to excess sediment and is a priority for monitoring efforts (Simmons and Fraley 2010).

3.4.5 Management Needs

Five crayfish species considered nonnative and/or invasive have been identified in North Carolina and pose significant threat to native crayfish species: Coosa River Spiny, Kentucky River, Rusty, and Virile crayfishes and the Red Swamp Crawfish. Except for the Coosa River Spiny Crayfish, each was ranked as a management priority by the Crayfish Taxa Team.

One native species, the White River Crawfish, is considered a management priority. It is native to the Piedmont and Coastal Plain but has been introduced to several basins in the Mountain region (likely through bait bucket dumps). Its effect on native crayfish populations is not known. Measures to address impacts from these introduced populations should be considered for the drainages where they have been introduced.

The Red Swamp Crawfish is native to the lower Mississippi River Basin but is currently being raised as an aquaculture product in North Carolina. In 2012, five aquaculture farms in North Carolina produced approximately 8,685 pounds of this crayfish for consumption. It has been introduced to waters throughout the state and could pose a significant threat to native crayfish populations.

The Kentucky River Crayfish has recently been introduced to western North Carolina where it has been found in the Little Tennessee River Basin. The Rusty Crayfish is another introduced species found in the Broad and Catawba River basins. Both species could pose a significant threat to native crayfish populations. The Virile Crayfish has been introduced in the Roanoke, Catawba, and Broad River basins and its effect on native crayfish populations is unknown. Long-term monitoring of the spread of this crayfish should be a high priority.

3.4.6 Threats and Problems

Chapter 5 describes 11 categories of threats the Taxa Team considered during the evaluation and ranking of priority species and provides information about the expected scope and severity of their impacts to wildlife in North Carolina (see Appendix 3). Results of Metric 9 evaluations indicate the threats most likely to have had significant impacts to crayfish populations in North Carolina over the next 10 years include the following:

- Pollution
- Invasive and other problematic species
- Residential and commercial development
- Natural system modifications
- Climate change and severe weather
- Transportation and service corridors
- Biological resource use

Over the next several decades, invasive species are predicted to increase extinction rates of native species significantly (Lodge et al. 2000a; Schochat et al. 2010; Richardson et al. 2015). Introduced nonnative crayfish (i.e., the Coosa River Spiny, Kentucky River, Rusty, and Virile crayfishes, and the Red Swamp Crawfish) are a primary threat, followed by habitat loss, degradation, or alteration (Taylor et al. 2007; Simmons and Fraley 2010). Nonnative crayfish have cleared streams of vegetation, eliminated insect larvae (macrobenthics) and other native organisms through predation, and contributed to problems with turbidity in otherwise clear water in small streams (Davidson et al. 2010). Although eradication or control of invasive species can be economically more expensive than the cost of prevention, measures or programs that address invasive species proactively are usually underfunded (Leung et al. 2002; Allendorf and Lunquist 2003; Ricciardi et al. 2011; Withrow et al. 2015).

Problems and uncertainty with taxonomy for numerous species need to be addressed in order to better understand abundance and distribution better and to develop conservation measures for native species. Research related to these threats and their impacts on certain species was ranked as a high priority.

In their book on freshwater biodiversity management, Reynolds and Souty-Grosset (2012) identify fungal crayfish plague (*Aphanomyces astaci*) as another reason for concern with nonnative crayfish. This pathogen is listed by the IUCN as one of the world's 100 worst invaders (Lowe et al. 2000; Souty-Grosset 2012) because once a watershed is infected, control of its spread is almost impossible. While the disease has not been detected in the United States at this time, indirect evidence from laboratory studies indicates Red Swamp Crawfish can harbor the fungus and act as a vector for translocation of the pathogen (Evans and Edgerton 2002). There have been no investigations conducted in the United States about the fungus' mortality impacts to native species. Porcelain disease, or thelohaniasis has been documented in the Broad, Catawba, French Broad, Hiwassee, Savannah, Yadkin-Pee Dee, Lumber, and Neuse River Basins. In crayfish with thelohaniasis, the muscle tissue is progressively invaded leading to deterioration of muscle function and death. Thelohaniasis has been attributed as a cause of epidemics among crayfish in Europe. Generally, the prevalence is less than 5% but there have been occasional reports of prevalence up to 30% (Evans and Edgerton 2002).

The ecological benefits of dam removal are well documented in research literature, and discussion about negative effects often focuses on downstream transport of sediments, nutrients, and toxic materials and upstream movement of introduced fish (Lieb et al. 2011). Dams may protect imperiled crayfishes by preventing the upstream spread of nonnative or invasive crayfishes, and regulatory agencies that manage dam removals need to consider this potential when considering dam removal projects (Lieb et al. 2011).

Thermal conditions in a watershed may also limit the spread of invasive species (Lieb et al. 2011). However, factors that can increase water temperatures (e.g., urbanization, climate change, increasing groundwater temperatures) can facilitate movement of invasive species into waters not previously occupied (Eggleston et al. 1999; Mohseni et al. 1999; Steffy and Kilham 2006; Kaushal et al. 2010; Lieb et al. 2011).

3.4.7 Additional Information

The AFS Endangered Species Committee, Subcommittee on Crayfishes published a reassessment of the conservation status of crayfishes in the United States and Canada (Taylor et al. 2007) that is available online from the US Geological Survey's Southeast Ecological Science Center website http://fl.biology.usgs.gov/afs_crayfish/index.html. This website provides lists of crayfishes by freshwater ecoregion, state, or province boundary, and plot distributions of crayfishes by ecoregions or political boundaries. Information is provided for both native and introduced species.

The International Association of Astacology (IAA) is dedicated to the study, conservation, and wise utilization of freshwater crayfish. The IAA publishes a peer-reviewed scientific journal *Freshwater Crayfish* to distribute information on aquaculture, life history, conservation, ecology, and research topics.

The WRC webpage http://www.ncwildlife.org/Learning/Species.aspx#5528114-crustaceans provides detailed species information, photographs, and distribution maps for crayfishes found in the state.

3.4.8 Recommendations

In general, protection and restoration of natural community composition and function and protection of surrounding natural areas under current conditions are the best ways to ensure suitable habitats are available for crayfish species. Measures that protect a large and diverse pool of populations are the best way to ensure that species are able to survive future stresses and adapt to changing climate conditions.

Implement conservation measures and recommendations in protected species conservation plans.

- State protected species conservation plans are available online https://www.ncwildlife.gov/wildlife-habitat/species-conservation-plans.

- Federal protected species recovery plans are available online https://www.fws.gov/program/recovery/recovery-plans.

Implementation of recommendations for surveys, monitoring, and research should follow best practices and protocols established by recognized authorities (see Chapter 6 for a list of protocols). The following recommendations should be considered appropriate to implement for all crayfish species.

3.4.8.1 Surveys

Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities, as well as monitoring the expansion of non-native and invasive species

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Continue to update status assessments for the highest priority SGCN specie.
• Conduct surveys prior to dam removal projects and within extant reservoirs and tailraces to detect presence of nonnative species; barrier removal may facilitate movement of introduced crayfish (Lieb et al. 2011).

3.4.8.2 Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. These efforts will inform species and habitat management decisions. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Continue long-term monitoring for state-listed and SGCN crayfish species (see Table 3-3 in Appendix 3).

- Monitoring the spread of nonnative or invasive crayfish species is a high priority. Focal species include:

Kentucky River Crayfish	Rusty Crayfish	Virile Crayfish
Red Swamp Crayfish	Spiny Stream Crayfish	

3.4.8.3 Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, contaminant dynamics and toxicology, impacts of climate change and invasive species, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Perform genetic analysis for species complexes; support publication of peer-review descriptions for nominally identified species. Focal species include:

Cambarus sp. A	Appalachian Brook Crayfish	Devil Crayfish
Cambarus sp. C	Big Water Crayfish	Digger Crayfish
	Chattahoochee Crayfish	White River Crawfish

- Obtain life history and ecology information for nearly all crayfish species in North Carolina, specifically for state-listed and SGCN species.

- Research distribution, taxonomy, and life history of Coastal Plain *Procambarus* species in North Carolina.

  Procambarus species

3.4.8.4 Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Develop programs that emphasize the prevention of nonnative species introductions. Outreach efforts should include anglers, boaters, and people using WRC access areas.

- Utilize education and outreach efforts to make the public aware of problems associated with bait bucket and aquarium (pet) releases.

  White River Crawfish

- Protect and restore native, forested riparian buffers and healthy wetlands.

Riparian buffers	Wetlands

- Enforce and improve existing regulations prohibiting possession of exotic species. A list of WRC prohibited species can be found in the Aquatic Nuisance Species Management Plan Committee (NCANSMP 2015), available online https://www.ncwildlife.org/aquatic-nuisance-species-management-plan-finalpdf/open. Examples include:

Chinese Mysterysnail	Rusty Crayfish	Quagga Mussel
Japanese Mysterysnail	Virile Crayfish	Zebra Mussel

- Update WRC webpage with current information. For example, story maps can be developed with information about genetics work used to understand species complexes or explain aquatic biodiversity and food cycles.

3.4.8.5 Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Implement recommendations developed by the Aquatic Nuisance Species Management Plan Committee (NCANSMP 2015), available online https://www.ncwildlife.org/aquatic-nuisance-species-management-plan-finalpdf/open.
• Work with partners to protect riparian forest and wetland habitats. Riparian forest Wetlands

References are located at the end of this document

3.5 Freshwater Fish

3.5.1 Introduction

The freshwater fish fauna of the southeastern United States is among the most diverse fauna in North America. There are an estimated 260 species of freshwater fish in the state, including both native and nonnative species.

Aquatic habitats are one of the most imperiled because of pollution, flow alteration, habitat loss, and fragmentation of freshwater systems (Ashton et al. 2010). Freshwater communities are likely the most threatened ecosystems in the world, making aquatic organisms important indicators of degraded ecological conditions (Leidy and Moyle 1998; Jelks et al. 2008). Habitat loss, degradation, and fragmentation resulting from anthropogenic activities can have the most significant impact to natural communities at the landscape level. Flow modifications, introduction of nonnative species, and overuse also have significant impacts at the local and regional level.

During the last two decades, several assessments considered the imperilment of freshwater fish species including those found in North Carolina. Previous versions of this SWAP referred to reports published by Etnier (1997) and Warren (et al. 1997) that identified patterns of imperilment of fish by family and major habitat preference and a report by Butler (2002) that assessed conservation priorities for fishes in the Southern Appalachian Ecoregion. More recently, the AFS has published an updated assessment of the conservation status of imperiled freshwater and diadromous fishes of North America (Jelks et al. 2008).

As part of the updated assessment, the AFS Endangered Species Committee (AFS-ESC) developed a map of freshwater ecoregions that represented modifications of earlier ecoregional maps used by Maxwell (et al. 1995), Abell (et al. 2000, 2008), and others. The AFS-ESC map for North America indicates the southeastern United States has three ecoregions with especially large numbers of imperiled fishes. North Carolina is located within two of these ecoregions. The South Atlantic ecoregion (Atlantic Complex) has 34 species considered imperiled and the Tennessee ecoregion (Mississippi Complex) has 58 species considered imperiled. The report noted that the Tennessee River ecoregion has the greatest number of imperiled fishes in comparison with other US ecoregions (Jelks et al. 2008).

The AFS assessment states that approximately 39% of described fish species in North America are imperiled:

- 280 extant taxa are considered endangered,
- 190 are threatened, and
- 230 are vulnerable.

Additionally, though they may survive in captive populations, 61 taxa are presumed extinct or extirpated from the wild (Jelks et al.2008). Habitat degradation and restricted range appear to be the primary factors associated with imperilment of North American fishes.

The National Park Service (NPS) assessed the status of freshwater fish biodiversity in the southeastern United States (Long et al. 2012). The NPS assessment used fish assemblage data for noncoastal park system locations (Long et al. 2012) and included four NPS sites in North Carolina: Blue Ridge Parkway, Carl Sandburg Home National Historic Site, Great Smoky Mountains National Park, and Guilford Courthouse National Military Park. Many of the same species identified by AFS (Jelks et al. 2008) as imperiled have been found within these sites. Human disturbance, especially urbanization, was noted to have the most important impact on freshwater fish in the park units. Linear park units such as the Blue Ridge Parkway have numerous nonnative species that represent a high threat to native species (Long et al. 2012).

In western North Carolina, the Cherokee people have managed fisheries in the southern Appalachians for thousands of years. Fish species within Cherokee ancestral watersheds hold cultural, ecological, and economic value. Traditional practices, such as the construction of stone fishing weirs, supported subsistence harvest while allowing for long-term population monitoring across river systems. The Cherokee worldview, which names rivers the Ganvhidv Asgaya / ᎦᏅᎯᏛ ᎠᏍᎦᏯ or "Long Man," reflects a foundational understanding of watershed function with the importance of clean, flowing, and connected aquatic systems.

The Eastern Band of Cherokee Indians (EBCI), in partnership with the USFWS, formally began fisheries management in 1964 with the creation of a recreational trout fishery program. This initiative marked the beginning of tribal governance in fisheries conservation. Since then, EBCI efforts have expanded to include native species recovery, aquatic habitat management, and long-term biodiversity monitoring. Current work builds on traditional knowledge and scientific methods to conserve fish populations in Cherokee managed lands. These efforts occur within a network of over 180 miles of EBCI-managed streams and rivers.

Conservation recommendations for the associated habitats have been incorporated into the natural community descriptions in Chapter 4. Additional recommendations for aquatic habitats can be found in the river basin descriptions (Section 4.5). The following paragraphs provide information about species identified by the Freshwater Fish Taxa Team as SGCN or a priority species for research or management, and for which work has been conducted to implement conservation and management recommendations.

3.5.2 Comparison of 2015 and 2025 Priority Species

The 2025 Freshwater Fish Taxa Team evaluated 226 species for conservation concern, knowledge gaps, and management concern priorities. The following table provides a comparison of changes to the number of SGCN and priority species between the 2015 SWAP, the 2020 Addendum 1, and the 2025 SWAP.

Freshwater Fish Priority Species by Evaluation Categories and Comparison between SWAPs

SWAP Date	SGCN	Knowledge Gaps	Management Needs
2025	89	79	72
2020 Addendum 1	81	73	65
2015	66	65	64

Some species are a priority in more than one of the three evaluation categories. These changes do not necessarily indicate a change in the concern status of these species. They are more likely a reflection of increases in our knowledge base for the species.

The Freshwater Fish Taxa Team recognized some species propagated in fish hatcheries and released into freshwater systems have naturalized with native populations. For most of these comingled species it is difficult to separate the populations during surveys or monitoring activities. The Taxa Team designated which populations were evaluated by indicating "native" or "naturalized" as the population unit. This applies to Alewife, Blueback Herring, Brook Trout, Brown Trout, Muskellunge, Smallmouth Buffalo, Striped Bass, and White Perch.

The Taxa Team also recognized that some populations should be evaluated based on the ecoregion or river basin where they occur because they are subject to different threats and pressures.

- American Brook Lamprey were evaluated as separate Mountain and Piedmont populations; however, both population segments are SGCN.

- Broadtail Madtom populations in Lake Waccamaw, Cape Fear River and Pee Dee River basins were evaluated and designated as SGCN.

The following sections highlight specific conservation issues related to SGCN and their habitats. This is not an exhaustive list of species-specific conservation concerns but rather highlights some of the concerns in the state. Recommendations for priority survey, monitoring, and research studies, conservation actions, and partnerships are outlined in Section 3.5.8.

3.5.3 Conservation Concerns

Table 3-4 (Appendix 3) provides a list of Freshwater Fish SGCN and other priority species. River basin and aquatic habitat associations for these species are provided in Table 3-18 in Appendix 3. Aquatic habitats and river basin descriptions with associated conservation priorities are located in Chapter 4.

Of the SCGN fish species, 40% are suckers and minnows (order Cypriniformes) and 38% are darters (order Perciformes). According to Jelks (et al. 2008), the Cyprinidae family is the most species-rich of freshwater fishes in North America.

Within this family, Ironcolor Shiner is noted to be one of the most widespread because it occurs in multiple ecoregions (Jelks et al.2008). However, statewide surveys conducted by WRC biologists since the 1960s found this fish in small numbers and noted it to be a vulnerable species. Recent surveys conducted in locations where it was previously found detected only a small number of fish in 2010 (three sites in two river basins). Surveys conducted in 2012 across the Southeastern Coastal Plain at 35 sites where Ironcolor Shiners were found in previous surveys detected none of these fish.

Anadromous and catadromous fish species migrate between inland freshwaters and coastal brackish and salt waters during their life cycles. Many native migratory fish populations have sharply declined over the last several decades.

- A recent assessment of southeastern Atlantic coast diadromous fish stocks (Burke and Rohde 2015) provides information about numerous species for which there are population concerns, including the federally listed Atlantic Sturgeon and Shortnose Sturgeon.

- As noted in the report, American Eel and two river herring species that are found in North Carolina rivers and coastal waters have been petitioned for listing as endangered species (USFWS 2011; NMFS 2011; Burke and Rohde 2015).

Degraded freshwater and estuarine habitats that serve as nursery and spawning grounds and the vulnerability of anadromous fishes to exploitation during migration into coastal rivers contribute to a large number of species being included on lists of marine endangered and threatened fishes (Burke and Rohde 2015). Principle causes of population declines have traditionally been attributed to dammed rivers, habitat loss, overfishing, and pollution but other contributing factors include climate change, nonnative species, and aquaculture (NMFS 2012; Burke and Rohde 2015). In 2015, the EBCI received federal authority to administer its own Water Quality Standards Program under the Clean Water Act. This designation supports fisheries work by aligning water quality goals with aquatic conservation priorities.

Future habitat connectivity projects will further enhance restoration capacity. The planned removal of Ela Dam on the lower Oconaluftee River, a partnership that includes EBCI and NCWRC, is expected to benefit multiple species. These include redhorse species, Walleye, and other taxa targeted for reintroduction, such as Spotfin Chub, Stonecat Madtom, and Blotchside Logperch. Continued collaboration between EBCI and NCWRC, and other regional partners is essential to long-term conservation success across shared watersheds.

Additional information on rare and listed freshwater fishes relevant to the river basin systems where they are found is provided in Chapter 4, including Cape Fear Shiner (Cape Fear River Basin), Robust Redhorse (Yadkin-Pee Dee River Basin), and Ironcolor Shiner (Lumber, Cape Fear, and White Oak river basins).

3.5.4 Knowledge Gaps

There are 79 species identified as research priorities because there are knowledge gaps, of which 29 are also considered SGCN. Table 3-4 (Appendix 3) includes knowledge-gap priority species.

WRC staff conduct rare coastal fish surveys for several species listed as knowledge gap survey and research priorities. Target species are SGCN but species that are also knowledge gap priorities are included, for example Ironcolor Shiner. As noted in the Annotated Atlas of the Freshwater Fishes of North Carolina (Tracy et al. 2020), Ironcolor Shiner populations and distribution have been declining since the first surveys were conducted in the 1960s.

There are fish species complexes that represent closely related species that need genetic and taxonomic review to determine their status as a species. In North Carolina, there are three madtom forms (Family Ictaluridae) that do not have formal descriptions. These madtoms are a complex of species referred to as "Broadtail" madtoms and are found in the Coastal Plain ecoregion: a Cape Fear form from the Cape Fear River; a Lake Waccamaw form in the Waccamaw basin; and a Pee Dee form from the Lumber and Waccamaw River basin (Tracy et al. 2021). Genetic assessments are needed to determine the correct taxonomy before a formal description can be developed (Tracy et al. 2021). McCall (2023) notes that "madtom catfishes are an understudied and imperiled group of fishes, with approximately 20% of the genus under protection of the Endangered Species Act (USFWS, 2018)."

The EBCI supports species identified in the North Carolina State Wildlife Action Plan. Ongoing monitoring targets several fish of greatest conservation need, including the Red/Smoky Dace complex, Wounded Darter, and Olive Darter. Restoration efforts also focus on historically abundant migratory fish, such as Muskellunge, Smallmouth Buffalo, and Lake Sturgeon, which have declined across the French Broad, Little Tennessee, and Hiwassee river basins.

3.5.5 Management Needs

Multiple collaborations and partnerships have formed to design and implement conservation activities that benefit migratory fish species as well as other native aquatic species (CFRP 2013). For example, in 2013, a rock arch fish passage ramp was built at Cape Fear River Lock & Dam No. 1, located 32 miles upstream from Wilmington. The structure improves passage for American Eel, Striped Bass, American Shad, River Herring, and possibly sturgeon species. Although construction of the rock arch ramp is complete, the USACE's Lock and Dams No. 2 and No. 3

remain and continue to block spawning runs to the Smiley Falls area near Erwin in the middle of the Cape Fear River Basin.

Access to the Deep River and historic spawning habitats in the upper Cape Fear River basin is currently blocked by Buckhorn Dam on the Cape Fear River and Lockville Dam near the mouth of the Deep River. Fish passage around these obstructions is needed for migratory fish to reach historic spawning sites in the Deep River. Restoring migratory fish access to historic spawning and nursery habitats will help rebuild currently depressed populations to support healthy ecosystems and sustainable recreational and commercial fisheries (CFRP 2013).

Management activities differ depending on the type of habitat involved. Many large rivers have one or more hydropower operations so a main concern is maintaining a natural flow regime. On small streams, bank stability is a major concern. Fish passage is an issue of both large and small streams. Reservoirs are typically managed differently than natural lakes. Reservoirs are usually managed for sport fisheries to provide recreation. Participation in the Federal Energy Regulatory Commission (FERC) relicensing process will facilitate negotiation of more natural flow regimes in regulated rivers and help identify opportunities to mitigate negative impacts from hydropower development. Natural lakes such as Lake Waccamaw and Lake Phelps are managed for both recreational fisheries and native species.

Advancements in propagation techniques and hatchery facilities have contributed to the successful raising of Robust Redhorse and Spotfin Chub in captivity at WRC fish hatcheries. Partners such as Conservation Fisheries, Inc., have also reared Roanoke Logperch, Spotfin Chub, Sicklefin Redhorse, and Carolina Madtom, and the state of Tennessee is propagating Lake Sturgeon. These captive-raised fish have been used for augmentation stocking in areas with appropriate habitat and extant populations. Management needs include improvements to and expansion of fish hatchery facilities in order to support a successful propagation program.

A core focus of the EBCI fisheries program is using fish diversity as an indicator of water quality. Staff monitor populations using Index of Biological Integrity (IBI) surveys at seven sites, conduct three-pass electrofishing depletion sampling, and apply modern environmental DNA (eDNA) techniques. Since the first formal fish diversity assessment within the Qualla Boundary, conducted in 1978, surveys have documented 50 local species. These collections support the development of molecular tools to refine IBI assessments and track ecological change.

Brook trout is the only native salmonid in the region and is a management priority for both the EBCI and NCWRC. Populations within EBCI watersheds are limited and require active monitoring, habitat restoration, and protection from invasive species. EBCI also collaborates on the conservation of culturally significant and imperiled species, including the Sicklefin Redhorse. Since 2007, translocation efforts have aimed to restore this species to both current and ancestral habitats. First recognized by western science in 1992, Sicklefin Redhorse was identified with its Cherokee name—meaning "wearing a feather"—through consultation with fluent Cherokee speakers, referencing its distinctive dorsal fin (Jenkins et al. 2025).

There are numerous instances of nonnative fish species being introduced into the state's waters and for some of these species there are significant concerns. For example, the Flathead Catfish is an obligate piscivore (fish-eating species) that has been associated with declines and extirpations of native fish populations in areas where it has been introduced.

3.5.6 Threats and Problems

Chapter 5 describes 11 categories of threats the Mammal Taxa Team considered during evaluation and ranking process to identify SGCN. Evaluation results for Metric 9 about the expected scope and severity of these threats are available in Appendix 3. The most likely threats to have very high impacts on freshwater fish populations in North Carolina over the next 10 years include the following:

- Natural system modifications
- Residential and commercial development
- Agriculture and aquaculture
- Pollution
- Energy production and mining
- Invasives, problematic species and genes

There are water quality concerns beyond turbidity and sedimentation. The presence of endocrine-disrupting chemicals (EDCs), even at very low concentrations, can disrupt normal development and lead to reproductive problems. Many fishes, especially piscivores, bioaccumulate and bioconcentrate (retain in tissue) heavy metals such as mercury and arsenic, as well as many chemical pollutants, via predation on other fish that have absorbed these contaminants. Smallmouth Bass can be an environmental indicator and long-term monitoring of populations can identify where there are problems with heavy metals in fish tissue or the presence of EDCs (Brewer and Orth 2015). Immune suppression can be detected through presence of fin and skin erosions, lesions, and partial fish kills (Ripley et al. 2008; Blazer et al. 2010; Brewer and Orth 2015).

Microplastics are persistent organic pollutants that include polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and perfluoroalkylated substances (PFAS) (Melnyk et al. 2023). Emerging concerns have been linked to the presence of microplastic contamination in freshwater habitats, particularly concerning their ubiquitous persistence in aquatic habitats. Bioaccumulation is a concern because it happens at different trophic levels and impacts various organisms, including freshwater fish (Scott et al. 2021). Both humans and wildlife are likely to be impacted by consumption of contaminated fish. Research by the EPA (Melnyk et al. 2023) reports high concentrations of microplastic contaminants in Striped Bass, American Shad, and Sea Lamprey that could have impacts on wildlife that consume these fish. Research needs to include understanding how the bioaccumulation of microplastics impact higher trophic species when they ingest prey species with bioaccumulation of microplastics (Au et al. 2017).

Aquatic weeds and invasive species are serious problems in many freshwater systems, especially reservoirs and lakes. Nuisance species such as Hydrilla and Water Milfoil can be transferred between aquatic habitats when water craft (boats, jetskis) trailers, and gear (rods, tackle) are not washed after being used in a location with these species.

3.5.7 Additional Information

The Robust Redhorse Project is part of a collaborative sampling effort with the Robust Redhorse Conservation Committee (http://www.robustredhorse.com), which collected individuals for use in the captive breeding program that has successfully translocated thousands of young fish in the Pee Dee River Basin downstream of Blewett Falls Dam.

3.5.8 Recommendations

Protection and restoration of natural community composition and function and protection of surrounding natural areas under current conditions generally are the best ways to ensure suitable habitats are available for freshwater fish. Measures that protect a large and diverse pool of populations are the best ways to ensure that species are able to survive future stresses and adapt to changing climate conditions.

Implement conservation measures and recommendations in protected species conservation plans.

- State protected species conservation plans are available online https://www.ncwildlife.gov/wildlife-habitat/species-conservation-plans.
- Federal protected species recovery plans are available online https://www.fws.gov/program/recovery/recovery-plans.

Implementation of recommendations for surveys, monitoring, and research should follow best practices and protocols established by recognized authorities (see Chapter 6 for a list of protocols). The following recommendations should be considered appropriate to implement for freshwater fish species.

3.5.8.1 Surveys

General distribution of most priority species is known; however, surveys are needed to complete distributional status for some priority and invasive species. Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Distribution and status update surveys are needed for all freshwater fish SGCN and other priority species in order to maintain prioritization lists and to inform potential state/federal listing status. Focal species include: Ironcolor Shiner Madtom species
•

3.5.8.2 Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. These efforts will inform species and habitat management decisions. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Focal Species, or Focal Habitats
• Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Dam removal sites Restoration sites Spawning habitats for declining species Sensitive watersheds
• Implement monitoring programs for restoration and augmentation sites where propagated species are released. Examples include release sites for: Roanoke Logperch

3.5.8.3 Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, contaminant dynamics and toxicology, impacts of climate change and invasive species, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration.

Priority Conservation Action, Focal Species, or Focal Habitats

- Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status of species' complexes are needed. Examples include:

'Atlantic' Highfin Carpsucker	'Carolina' Quillback	'Lake Phelps' Killifish
Brassy Jumprock	'Carolina' Redhorse	Sicklefin Redhorse
Broadtail Madtom	Hiwassee/Smoky Dace	'Tessellated' Darter

- Conduct research to facilitate appropriate conservation actions. Research should focus on life history studies of priority species. Examples include:

Brook Silverside	Waccamaw Darter
Carolina Pygmy Sunfish	

- Determine the distribution of nonnative fishes and how they are affecting native species.

Blue Catfish	Green Sunfish	Alabama Bass
Channel Catfish	Redear Sunfish	Redeye Bass

- Conduct surveys using side-scan sonar to assess potential Atlantic and Shortnose Sturgeon spawning habitat above and below existing barriers in Cape Fear River (CFRP 2013).

Atlantic Sturgeon	Shortnose Sturgeon

- Research pathogens and emerging diseases of freshwater fish, including technologies and methods for detecting and isolating or treating infectious diseases. Concerns potentially include:

Whirling Disease	Viral Haemorrhagic Septicaemia	Epizootic Ulcerative Syndrome
Spring Viraemia of Carp Virus	Epizootic Haematopoietic Necrosis Virus	

3.5.8.4 Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources, protect native populations and their habitats, and improve degraded habitats so they support native populations.

Priority Conservation Action, Focal Species, or Focal Habitats		
• Reintroduce or augment rare fish populations in areas where water quality and stream habitats have recovered sufficiently to support them. Examples include:		
Cape Fear Shiner Carolina Madtom	Roanoke Logperch Robust Redhorse	Spotfin Chub
• Support incentive and information programs that help reduce impervious surface and sedimentation/erosion, minimize pesticide and herbicide use, and modernize wastewater treatment facilities.		
• Protect and restore native, forested riparian buffers. Shading reduces water temperatures and provides detritus that is critical to food webs and cover.		
Riparian forest		
• Develop strategies to mitigate Flathead/Blue Catfish impacts (and other exotics) to native species, including education and outreach programs to educate the public about the impacts of introduced species and how to prevent further introductions.		
Blue Catfish	Flathead Catfish	
• Protect and restore fish access to habitat in streams and gene flow, where appropriate, via efforts to prevent and remove lateral blockages, or if blockage removal is not feasible to otherwise provide fish passage (CFRP 2013).		
• Restore fish passage around dams and other barriers to allow migratory fish to reach historic spawning sites. Sites include:		
Buckhorn Dam, Cape Fear River	Lockville Dam, Deep River	
• Protect instream fish habitat from channel impacts caused by activities such as snag removals (CFRP 2013).		
• Update and expand fish hatchery facilities in order to support successful propagation of declining and state protected species.		

3.5.8.5 Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation serves numerous purposes in the face of anticipated climate change, but most importantly promotes ecosystem resilience.

Priority Conservation Action, Focal Species, or Focal Habitats

- Support establishing riparian buffers along streams and implementing low-impact development and better stormwater management (e.g., secondary and cumulative impacts; NCWRC 2012) through program coordination, cooperative projects, and technical guidance.

- Support stream protection/restoration by working collaboratively with other organizations. Reintroduce or augment rare fish populations in areas where water quality and stream habitats have recovered sufficiently to support them.

- Support incentive and information programs that help reduce sedimentation/erosion, minimize pesticide and herbicide use, and modernize wastewater treatment facilities.

- Support targeted protection actions for priority spawning areas identified by the Cape Fear River Partnership, including Smith Creek, Rice Creek, Town Creek, and Smiley Falls (CFRP 2013).

Cape Fear River Basin	Rice Creek	Smiley Falls
Smith Creek	Town Creek	

- Work with partners, including private landowners, to release propagated populations of ESA listed fish species under the Programmatic Safe Harbor and Candidate Conservation Agreement with Assurances agreement with USFWS.

Cape Fear Shiner	Lake Sturgeon	Robust Redhorse
Carolina Madtom	Orangefin Madtom	Spotfin Chub
	Roanoke Logperch	

References are located at the end of this document.

3.6 Freshwater Mussels

3.6.1 Introduction

North America has the richest freshwater bivalve mollusks, also called mussels, fauna with approximately 50 genera that are members of the Family Unionidae representing more than 350 species (Haag 2012, Graf and Cummings 2021, Newton et al. 2023). Currently, there are over 60 species of freshwater mussels found in the wild in North Carolina. The majority are in the Family Unionidae and are the species for which more data is available. There are also native and nonnative species of "pea clams" from the Families Corbiculidae (Basket Clams) and Sphaerlidae (Fingernail Clams) that are found in the state but there is less known about these species.

Freshwater mussels are filter feeders with a diet that varies across habitats and among species but primarily consists of microscopic particulate matter such as phytoplankton, zooplankton, bacteria, and organic detritus (Vaughn and Hakenkamp 2001; Haag 2012). Mussels live most of their lives burrowed in the bottom of a stream or lake, and depending on species and season, they may be closer to the substrate surface (warm seasons) or burrow more deeply during colder seasons (Amyot and Downing 1991, 1997; Watters et al. 2001; Schwalb and Pusch 2007; Haag 2012). When population density is high, mussels can be the dominant biomass and exert control over the structure of an aquatic community (Vaughn and Hakenkamp 2001), as demonstrated in locations that have large populations of the nonnative Asian Clam.

Most mussel species have a complex life history that includes a reproductive process dependent on an obligate larva parasite on fish called a glochidium, which has important ramifications for many aspects of mussel ecology and conservation (Layzer and Scott 2006). Recolonization is dependent on the successful parasitizing of a host fish and subsequent movement of the infected host fish into water that provides suitable habitat for the mussel (Layzer and Scott 2006). Freshwater mussels are one of the most imperiled fauna; many have undergone drastic declines and many are predicted to go extinct in the next few decades (Eckblad and Lehtinen 1991; Bogan 1993; Neves 1993; Shannon et al. 1993; Wilson et al. 1995; Neves et al. 1997; Vaughn and Taylor 1999; Vaughn and Hakenkamp 2001, Newton et al. 2023).

Conservation recommendations for the associated habitats have been incorporated into the aquatic natural community descriptions in Chapter 4 (Section 4.2). Additional recommendations can be found in the river basin descriptions (Section 4.5). The following paragraphs provide information about species identified by the Freshwater Mussel Taxa Team as SGCN and other priority species for research or management, and for which work has been conducted to implement conservation and management recommendations.

3.6.2 Comparison of 2015 and 2025 Priority Species

The 2025 Freshwater Mussel Taxa Team evaluated 52 species for conservation concern, knowledge gap, and management concern priorities. Some species may be considered a priority in more than one of the evaluation categories. The following table provides a comparison of changes to the number of SGCN and priority species between the 2015 SWAP, the 2020 Addendum 1, and the 2025 SWAP. These changes do not necessarily indicate a change in the concern status of these species; they are more likely to reflect an increase in our knowledge base for the species.

Freshwater Fish Priority Species by Evaluation Categories and Comparison between SWAPs

SWAP Date	SGCN	Knowledge Gaps	Management Needs
2025	39	28	26
2020 Addendum 1	39	28	28
2015	31	28	29

The following sections highlight specific conservation issues related to SGCN and their habitats. This is not an exhaustive list of species-specific conservation concerns but rather highlights some of the concerns in the state. Recommendations for priority survey, monitoring, and research studies, conservation actions, and partnerships are outlined in Section 3.6.8.

3.6.3 Conservation Concerns

Table 3-5 (Appendix 3) provides a list of Freshwater Mussel SGCN and other priority species. River basin and aquatic habitat associations for these species are provided in Table 3-18 in Appendix 3. Aquatic habitats and river basin descriptions with associated conservation priorities are located in Chapter 4.

Some North Carolina species are isolated to small geographic areas such as a single watershed. Newton et al. (2023) notes that the reasons for local and widespread decline are mostly unknown, though likely threats include habitat loss and fragmentation, diseases, contaminants, altered flow regimes, migration barriers, nonnative species, and climate change. Haag (2012) notes that because the conservation status of many species remains poorly known, high conservation concern stems from the expectation that future imperilment will exceed current imperilment.

About 75% of those historically found in the southeastern United States are thought to now be extinct or at risk of extinction (Williams et al. 1993; Bogan 1996; Neves et al. 1997; Gangloff et al. 2009). The synergistic effects of numerous point and nonpoint source impacts that affect water and habitat quality are likely causes of these declines, with changes to the physical and chemical variables in a stream believed to be principle factors for this decline (Neves et al. 1997; Brim-Box and Williams 2000; Gillies et al. 2003; Lydeard et al. 2004; Gangloff et al. 2009).

3.6.4 Knowledge Gaps

There are 28 species identified as research priorities because there are knowledge gaps. Progress toward species recovery depends on knowledge about species distribution patterns as well as a clear understanding of habitat and life history requirements of species (Flebbe and Herrig 2000). We have limited knowledge and data regarding freshwater mussels compared to other taxa. Accurate distribution information is still lacking for some species, as is work related to fish host identification, ecology (both of individual species and among communities of organisms), and basic systematics (genetics, taxonomy, and morphology). Extensive monitoring of populations is generally lacking.

Since the first comprehensive list of freshwater mussels for North America was compiled by Turgeon et al. (1988, 1998), rigorous phylogenetic studies based on quantifiable, heritable attributes such as DNA sequence data has been needed for scientifically defensible estimates of North American mussel diversity (Lydeard and Roe 1998). Recent efforts have yielded departures from traditional classifications and molecular studies have uncovered a high degree of cryptic variation not reflected by shell morphology. As noted by Williams et al. (2017), classification and phylogenetic studies will evolve as more data are collected and new genetic techniques are developed and accepted for research.

A revised list of freshwater mussels for the Order Unionida, Families Margaritiferidae and Unionidae resulted from taxonomic studies reported by Williams et al. (2017). This work recognized several revisions to phylogeny, including recognition of new species and subspecies and elevation of numerous species and subspecies being elevated to species from synonomy. Some of the revisions were for species that occur in North Carolina. In summary, the study shows:

- Unionidae has 54 genera represented by 293 species. Revisions for species in North Carolina include the following:
    - Three new genera (*Hamiota, Parvaspina, Reginaia*) (Roe et al. 2005, Campbell and Lydeard 2012, Perkins et al. 2017). Currently only *Parvaspina* occurs in North Carolina.
    - Four genera are elevated to species from synonomy (*Eurynia, Pleuronaia, Theliderma, Utterbackiana*). Of these, *Eurynia, Pleuronaia*, and *Utterbackiana* occur in the state.

These studies show that several currently recognized species include multiple evolutionary units (Mulvey et al. 1997; Roe and Lydeard 1998; King et al. 1999; Jones et al. 2006; Serb 2006, Williams et al. 2017), suggesting that diversity of North American mussels has been underestimated. Taxonomic difficulties have yet to be resolved for several genera, most notably the *Elliptio*. There is an extreme knowledge deficit regarding the pea (or fingernail) clams in North Carolina, primarily in the Family Sphaeriidae. Attaining information on their distributions should be pursued whenever possible.

Protecting a rich fauna of mussels from environmental contamination requires an understanding of mussel sensitivity to diverse toxicants. The vast majority of mussel species remain untested for most toxicants, and estimating safe environmental concentrations is a critical need, especially for the protection of rare, threatened, or endangered species. Freshwater mussel toxicology still lacks full identification of pollutants that may limit mussel survival, recruitment, and recovery. Few of the compounds that mussels encounter in the wild have been evaluated in the lab. Also, toxicity tests seldom address mussel reproduction, and tests are still short relative to mussel lifespans. In particular, there is a need to test previously unevaluated contaminants of emerging concern using long-term exposures that more closely mimic natural conditions, and to evaluate more ecologically relevant endpoints such as mussel health and recruitment.

Several publications over the last decade have noted the absence or under-protectiveness of national water quality criteria for particular pollutants to which mussels are known to be sensitive (Augspurger et al. 2003; Wang et al. 2010; Haag and Williams 2014;; Haag 2012). To facilitate habitat evaluation, work is needed to better characterize chemical and contaminated sediment exposure and provide benchmarks to define acceptable pollutant concentrations. Researchers at NC State University, University of Georgia, and US Geological Survey have started work on testing additional classes of chemicals (Bringolf et al. 2010; Hazelton et al. 2012, 2013; Wang et al. 2012). The US Environmental Protection Agency (USEPA) has been an active participant in designing and funding these studies, but more are needed. Publication of recommended benchmarks for pollutants of concern (e.g., metals, major ions) will be useful in developing water quality regulations.

3.6.5 Management Needs

Restoring mussels into areas where they have been extirpated is a high priority where degraded habitat is being reclaimed and restored in some watersheds. Propagation and release of mussels to augment existing populations will help reduce the risk of extinction and may increase genetic diversity among small populations. It will be important to understand how dispersal limitations of larval hosts affect connectivity of mussel communities (Newton et al. 2023). Removing barriers and other impediments to host fish movement will allow natural recolonization of suitable habitats and facilitate gene flow between populations.

Freshwaters that support populations of SGCN mussels must be monitored to detect changes in water quality. Water quality ratings (poor to excellent) determined by the NC Department of Environmental Quality (DEQ), Division of Water Resources (DWR) Waters Sciences Section inform several other aspects of state water quality programs. For example, some waters with excellent quality can be petitioned for additional protection, and waters rated as poor may be listed as impaired, thereby making them subject to restoration planning. Not all waters are monitored, so having important mussel habitat included in a long-term monitoring program is an important step in having access to other water quality management tools.

The DWR Water Planning Section develops standards, rules, and management strategies to protect water quality. Waters rated as excellent and which have outstanding resources values (as defined in water quality statutes) can be petitioned for designation as Outstanding Resource Waters (ORW) or High-Quality Waters (HQW). Such designations afford additional protections to ensure that water quality and associated resources are maintained. The process is not automatic and starts when DWR is petitioned to provide additional designation and associated protection. Resource agencies should identify the waters important for mussel conservation, which are eligible for ORW or HQW designations, and petition for those protections.

Cooperation between DWR and partners (i.e. state and federal agencies, conservation organizations) is needed to develop site-specific water quality restoration plans under NC Administrative Code (see NCAC 15A 02B.010) which outlines rules for considering federally listed threatened or endangered aquatic species. For example, through collaborative efforts, WRC, along with the NHP, USFWS, and DWR, developed the technical basis for a site-specific water quality management plan for Goose Creek (Yadkin – Pee Dee River Basin) (https://www.deq.nc.gov/water-quality/surface-water-protection/401/riparian-buffers/goose-creek/download). However, there are other waters with federally listed aquatic species and water quality concerns in need of additional site-specific restoration plans.

Advancements in propagation techniques and improvements to WRC hatchery facilities have contributed to the successful raising of freshwater mussels in captivity. The WRC's Conservation Aquaculture Center at the Marion Fish Hatchery has had substantial success in propagating federal and state listed mussel species.

3.6.6 Threats and Problems

Chapter 5 describes 11 categories of threats the Mammal Taxa Team considered during evaluation and ranking process to identify SGCN. Evaluation results for Metric 9 about the expected scope and severity of these threats are available in Appendix 3. The most likely threats to have very high impacts on freshwater mussel populations in North Carolina over the next 10 years include the following:

- Climate change and severe weather
- Residential and commercial development
- Pollution

Invasive and nonnative species can create competitive pressures on food resources. Further, their burrowing activity can uproot native mussels in sandy sediments (Vaughn and Hakenkamp 2001; Bogan et al. 2011). In 2007, the first location in the state of the nonnative Lilliput was discovered at Falls Lake in Wake County and was confirmed through DNA analysis (Bogan et al. 2011). Asian Clam can be found throughout the state, often in such large quantities that they decrease available oxygen (Belanger et al 1990; Leff et al 1990; Bucci 2007) and create high levels of ammonia in streams that can negatively affect native mussels. Knowledge about how mussel species and communities may change in response to invasive nonnative species and pathogens is needed. Development of an early detection and rapid response system for new aquatic invaders (for example, use of eDNA) as a means of targeting problems early (Newton et al. 2023).

Extinction of North American unionoid bivalves can be traced to impoundment and inundation of riffle habitat in major rivers basins of the central and eastern US. Dams are a barrier to host fish and the loss of obligate hosts, coupled with increased siltation, and various types of industrial and domestic pollution have resulted in the rapid decline in the unionoid bivalve fauna in North America (Bogan 1993). Hypolimnion water discharged from behind a dam will be colder and have less oxygen than downstream receiving waters (Neves and Angermeier 1990). Participation in the Federal Energy Regulatory Commission (FERC) relicensing process will facilitate negotiation of more natural flow regimes in regulated rivers and help identify opportunities to mitigate negative impacts from hydropower development.

Contaminants and water pollution are a significant threat to all aquatic species, especially mussels. Point source discharges from municipal wastewater that contains monochloramine and unionized ammonia compounds are acutely toxic to freshwater mussels and may be responsible for glochidial mortality that results in local extirpation of mussels (Goudreau et al. 1993; Gangloff et al. 2009). However, given the transient nature of flowing systems (e.g., a water continuum) and the potential for dilution at any point along the system, it is especially difficult to detect not only origin points but also concentration levels in the water column (Fleming et al. 1995). A die-off event affecting Tar River Spinymussel populations was detected in the Swift Creek watershed (Nash County) as it occurred and was attributed to anticholinesterase poisoning related to organophosphorus and carbamate pesticides used in agricultural applications (Hill and Fleming 1982; Fleming et al. 1995).

Since the publication of Kolpin et al. (2002) on the extent and diversity of chemicals present in the nation's waters, there has been increased concern about the biological relevance of the mix of chemicals to which mussels and other aquatic organisms are exposed, including pharmaceuticals, personal care products, and agrochemicals. Many pollutants detected in streams have never been evaluated for their impacts to mussels (2015 email from T Augspurger to the authors; unreferenced, see "Notes"). Toxicity data for mussels should be integrated into regulatory decisions for existing and new water quality standards (Newton et al. 2023). It would be useful to understand the relative contribution of a suite of environmental contaminants to develop a risk profile and identify the lethal and non-lethal responses of mussels to the full spectrum of environmental contaminants (Newton et al. 2023).

Given their burrowing nature and consumption of detritus and particulate matter, mussels may be more susceptible to trace metal exposure and uptake of contaminants than other aquatic animals (Wilson 2008; Jarvis 2011). Sediments from upstream, especially hydroelectric impoundments, can be a source of sediments laden with trace metals (Jarvis 2011). A decline in Appalachian Elktoe populations in the Upper Little Tennessee River watershed may be related to concentrations of trace metals, especially copper and zinc, found in stream sediments (Jarvis 2011). In urbanized areas, a lack of riparian vegetation and increased impervious areas contributes to higher sediment loads from erosion that carry fertilizers, pesticides, herbicides, and many other chemical compounds (Gangloff et al. 2009).

Lab studies indicate freshwater mussels are more sensitive than most aquatic animals to toxicity from sodium chloride and potassium chloride (Gillis 2011; Wang et al. 2012). As sea levels rise and salt water moves upstream into freshwater habitats, it could be predicted that mussels would be particularly vulnerable. Field confirmation of the estimated limits of tolerance predicted by the lab tests is important in determining the significance of this threat and in design of ameliorative measures (2015 email from T Augspurger to the authors; unreferenced, see "Notes").

Climate change, mining, hydraulic fracturing, and other energy developments will bring additional stressors that need to be evaluated for mussels. In addition to specific pollutants that may be introduced into the aquatic environment, the interactions of pollutants and temperature (from climate change), salinity (related to SLR), and lower dilution (from altered flows) will need to be considered (2015 email from T Augspurger to the authors; unreferenced, see "Notes").

Impervious areas in urbanized watersheds contribute to high water levels, even during short rainfall events, which can result in flash flooding. These high or flashy flow events contribute to increased sediment loads, turbidity throughout the water column, and stream bed movements that stress mussel populations (Gangloff et al. 2009).

3.6.7 Additional Information

The Southern Appalachian Man and the Biosphere (SAMBI) program, in partnership with several federal and state agencies, conducted the Southern Appalachian Assessment, which was designed to be a regional assessment of all resources in 132 counties in mountain areas of North and South Carolina, Georgia, Alabama, Tennessee, and Virginia (Flebbe et al. 1996).

- The ecological, social, and economic data collected and analyzed by the project facilitates an ecosystem-based approach to management of natural resources on public lands within the assessment area and are presented in four separate technical reports (SAMAB 1996a).

- The aquatic technical report compiles existing region wide information on aquatic resource status and trends, riparian condition, impacts of various land management or human activities, water laws, aquatic resource improvement programs, and water uses. The report discusses the distribution of aquatic species, identifies impacts on aquatic resources and water quality, identifies cooperative opportunities for citizens, businesses, and government agencies, and identifies future data needs for aquatic resources (SAMAB 1996b).

The NC Museum of Natural Sciences hosts a collection of aquatic invertebrate specimens focused on mollusks, especially freshwater bivalves. Collection composition is 83% freshwater species (mussels, fingernail clams, and snails), 10% marine species, and 7% terrestrial snails. The Invertebrates Collection is worldwide in scope, with emphasis on localities in the Eastern United States. The holdings are comprised of collections acquired from state agencies (e.g. NCWRC), the Institutes of Marine Sciences (IMS), and a private collection from Herbert D. Athearn, Tennessee which contained over 23,000 lots of freshwater mollusks. The collection contains specimens from over 100 countries and currently contains of over 2.3 million specimens (NCMNS web page).

Research by Graf and Cumings (2007, 2020) was published in a checklist of freshwater mussel species and genera in the order Unionoida. The checklist represents a catalogue compiled from global records of nominal species-, genus-, and family-group level taxa (Graf and Cumings 2020). Their data was synthesized and is available for public access through the MUSSEL Project Database online at http://mussel-project.net.

3.6.8 Recommendations

In general, protection and restoration of natural community composition and function and protection of surrounding natural areas are effective measures to ensure suitable habitats are available for mussels. Measures that protect a large and diverse pool of populations are the best way to improve species survival from future stresses and support adaptation to changing climate conditions. Recommendations specific to aquatic habitats as well as basin-specific recommendations are provided in Chapter 4 Habitats, Sections 4.2 and 4.5 (respectively).

Implement conservation measures and recommendations in protected species conservation plans.

- State protected species conservation plans are available online https://www.ncwildlife.gov/wildlife-habitat/species-conservation-plans.

- Federal protected species recovery plans are available online https://www.fws.gov/program/recovery/recovery-plans.

Implementation of recommendations for surveys, monitoring, and research should follow best practices and protocols established by recognized authorities (see Chapter 6 for a list of protocols). The following recommendations should be considered appropriate to implement for freshwater mussel species.

3.6.8.1 Surveys

General distribution of most priority species is known; however, surveys are needed to complete distributional status for some priority and invasive species. Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities. Distribution and status update surveys are needed for all SGCN and other priority species in order to maintain prioritization lists and contribute to potential state/federal listing status.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Due to increased focus on barrier assessment and removal, continual baseline surveys are needed downstream of barriers in order to inform conservation decisions.
• Obtain information on the distribution, taxonomy, and life histories for many species, including information on larval hosts.
• Identify, develop, and synthesize geospatial data on mussel distributions statewide (Newton et al. 2023).
• Use emerging molecular tools (i.e., eDNA) to improve detection of rare species (Newton et al. 2023).

3.6.8.2 Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. These efforts will inform species and habitat management decisions. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Conduct long-term monitoring to identify population trends for SGCN and other priority species.
• Continue to monitor long-term sites in priority areas.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Monitor populations and habitats to inform natural resource damage assessments (Newton et al. 2023).

- Investigate the use of eDNA as an early detection system for nonnative species and support developing rapid response techniques for new invaders (Newton et al. 2023).

  Apple Snails

3.6.8.3 Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, contaminant dynamics and toxicology, impacts of climate change and invasive species, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Refine knowledge of systematics, taxonomy, and genetic structure of species and populations (Newton et al. 2023). Support taxonomic resolution with completion of species descriptions for undescribed taxa and resolution of species complexes using DNA research. Taxonomic difficulties have yet to be resolved for several genera, most notably *Elliptio*.

  Elliptio species

- Conduct research to facilitate appropriate conservation actions. Research should focus on life history studies of priority species.

- Make pea clam species a research priority because there is little knowledge about them in North Carolina.

  Family Corbiculidae   Family Sphaeriidae

- Determine appropriate areas of suitable habitat for augmentation or restoration activities, in particular for species included in the Programmatic Safe Harbor Agreement (SHA) and a Candidate Conservation Agreement with Assurances (CCAA) approved by USFWS in 2022.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
Appalachian Elktoe	Cumberland Moccasinshell	Longsolid
Atlantic Pigtoe	Dwarf Wedgemussel	Tar River Spinymussel
Carolina Heelsplitter	Green Floater	Tennessee Clubshell
	James Spinymussel	Yellow Lance

- Further refine techniques and protocols and develop best management practices for captive propagation, augmentation, and reintroduction.

- Continue to investigate host fish relationships for all SGCN and priority species.

- Research the impact of chemicals, especially pharmaceuticals, personal care products, industrial/agrochemicals, microplastics and PFAS, and their interactions to all mussel life stages (including survival, recruitment, and recovery). The selection of chemicals to test should be guided by chemical occurrence and class (representative compounds from various classes of pharmaceuticals, for example) (2015 email from T Augspurger to the authors; unreferenced, see "Notes").

- Evaluate the influence of suspended sediment and its associated contaminants, especially metals and microplastics, on mussels. Develop a standard test method for evaluating the quality of sediment on mussel survival, growth, and reproduction (2015 email from T Augspurger to the authors; unreferenced, see "Notes").

- Investigate the interactions of pollutants and temperature (climate change), salinity (SLR), and lower dilution (altered flows)(2015 email from T Augspurger to the authors; unreferenced, see "Notes").

- Support genetic studies to help improve our understanding of mussel taxonomy.

- Determine vulnerability of SGCN to help guide permit regulations and inform the need for moratoria.

- Research to improve our understanding of how mussel species, populations, and communities respond to emerging stressors, including environmental contaminants and climate change (Newton et al. 2023).

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Understand and characterize the role of pathogens and diseases in mussel declines (Newton et al. 2023).
• Use climate change models to develop predictions of the effects of altered thermal regimes on mussel communities; identify habitats that may be resilient to changing climates; explore how variability in temperature and water levels (for example, flood and droughts) affect risk of extirpation (Newton et al. 2023).
• Investigate thermal tolerance for freshwater mussels. Research has shown that many species of mussels are already living close to their upper thermal limits and that there are physiological and behavioral effects of climate change on mussels (Pandolfo et al. 2010; Archambault et al. 2013; Ganser et al. 2013, FMCS 2016.)

3.6.8.4 Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Continue to improve propagation techniques and production capacity for SGCN and other priority fish and mollusk species.
• Conduct population augmentations and restorations using hatchery-reared and translocated mussels.
• Protect and restore native, forested riparian buffers on all waterways.
• Promote use of BMPs on all state owned lands (wildlife, parks, recreation areas, forests, preserves).

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Ensure that freshwater mussel populations are considered in the evaluation of all projects, including impacts during activities such as dam removal or stream restoration activities.
• Resource agencies should identify the waters important for mussel conservation, which are eligible for ORW or HQW designations, and petition for those protections.
• Assess how upstream land-management activities affect mussels (for example, through sediment and contaminant inputs) and how mussels could contribute to sediment stability (Newton et al. 2023).

3.6.8.5 Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Continue to work with partners, such as NCSU and propagation facilities from other states, to facilitate a robust production and augmentation program.
• Pursue voluntary approaches or local, regional, and state land-use ordinances to encourage riparian buffers, because not all waters of the state have buffer rules. Riparian buffers are recognized as important in maintaining suitable in-stream physical and chemical habitat quality.
• Work with outreach partners to raise awareness of and support for the existence and importance of mussel populations on the landscape and their connections with healthy drinking water and human communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Work with appropriate partners to understand how current management practices for water quality and water quantity affect mussels and their habitats.
• Identify priority locations for installation of new stream flow gauges to improve collection of streamflow data and use it to identify streams and rivers with stable flow regimes (Newton et al. 2023).
• Collaborate with USGS, North Carolina DOT and DWR, and other partners to fund and install, monitor, and maintain new stream flow gauge locations. Streamflow data can inform conservation efforts that are beneficial for all aquatic species and help local governments responsible for communities subject to flooding. Streams and Rivers

References are located at the end of this document.

3.7 Mammals

3.7.1 Introduction

North Carolina has an impressive diversity of mammalian fauna and they are an important component of the natural landscape. Currently, there are about 126 species of mammals that occur in the state, including both native and nonnative species. Mammals are key contributors to ecosystem processes through herbivory, predation, seed dispersal, and as prey (Littlewood et al. 2020).

North Carolina is ranked 11th in the country in mammalian diversity (Stein 2002). The general public is often familiar with our larger, more visible species, like the White-tailed Deer and American Black Bear, but it is our species of bats, shrews, rodents, and other small mammals that comprise most of our mammalian diversity. The majority of mammal species in North Carolina are terrestrial or freshwater species.

According to the North Carolina Biodiversity Project (https://nc-biodiversity.com/tax/mammals), North Carolina has a variety of marine mammals most likely due to the warm Gulf Stream waters from Cape Hatteras southward and the colder Labrador Current waters off the northern coast. Around 38 species of whales and dolphins, and four seals, yield one of the higher lists of such marine mammals of any state (NCBP 2025).

Natural community descriptions and priority conservation recommendations for aquatic and terrestrial habitats used by mammals are provided in Chapter 4. The following paragraphs provide information about a few of the species identified by the Mammal Taxa Team as SGCN or other priorities. This is not an exhaustive list of species-specific conservation concerns but rather highlights some of the concerns in the state.

3.7.2 Comparison of 2015 and 2025 Priority Species

The 2025 Mammal Taxa Team evaluated 88 species for conservation concern to identify SGCN, knowledge gaps to identify research priorities, and management concerns to identify management priorities. Some species may be considered a priority in more than one of the evaluation categories.

The following table provides a comparison of changes to the number of SGCN and priority species between the 2015 SWAP, the 2020 Addendum 1, and the 2025 SWAP. These changes do not necessarily indicate a change in the concern status for these species; they are more likely a result of an increase in our knowledge base for the species.

Mammal Priority Species by Evaluation Categories and Comparison between SWAPs

SWAP Date	SGCN	Knowledge Gaps	Management Needs
2025	29	30	33
2020 Addendum 1	23	24	26
2015	21	24	26

The following sections highlight specific conservation issues related to SGCN and their habitats. This is not an exhaustive list of species-specific conservation concerns but rather highlights some of the concerns in the state. Recommendations for priority survey, monitoring, and research studies, conservation actions, and partnerships are outlined in Section 3.7.8.

3.7.3 Conservation Concerns

Table 3-6 (Appendix 3) provides a list of Mammal SGCN and other priority species. River basin and habitat associations for these species are provided in Table 3-17 (terrestrial species). Habitat descriptions and associated conservation priorities are located in Chapter 4.

The conservation needs of mammals in North Carolina are addressed mainly through habitat management, restoration, and protection. Mammals have the ability to influence vegetative communities, play a significant role in nutrient cycling, and contribute to ecosystem integrity. They can occupy a variety of habitats and are distributed from the mountains to the coast, including marine habitats. Some species, such as the nonnative Coyote, are extremely adaptable and are found in a variety of habitat types throughout the state. Other species, like the Carolina Northern Flying Squirrel, are more restricted in their distribution, occurring only at the highest elevations where its habitat is isolated as "sky islands."

However, disease and pathogens, particularly White-Nose Syndrome (WNS) in bats and Chronic Wasting Disease (CWD) in White-tailed Deer, are major conservation issues in North Carolina that require ongoing surveillance and research. Many of our bat species within North Carolina are of conservation concern due in large part to the relatively recent spread of WNS, a fungal disease affecting hibernating bats that has devastated many bat populations in the eastern US. The WRC has developed a WNS Surveillance and Response Plan (2016) to coordinate a strategy for monitoring bat populations, documenting the occurrence and spread of this disease, and conducting research (NCWRC and USFWS 2013).

3.7.4 Knowledge Gaps

Species for which the Mammal Taxa Team determined there are research priorities because of knowledge gaps are included in Table 3-6 (Appendix 3). In general, most of the species noted as knowledge-gap priorities are listed because we lack information regarding statewide distribution and abundance, we have few programs in place to monitor the species, or there are questions regarding what factors affect the population size and distribution of these species. For example, studies are needed to assess the occurrence of Allegheny Woodrat and Eastern Woodrat (coastal and mountain populations) to discover if there is any overlap in the distribution of the mountain populations.

Additionally, similar information is needed for the Eastern Spotted Skunk due to concerns regarding the suspected decline of this species in North Carolina. Suspected factors impacting Eastern Spotted Skunk populations may include habitat alteration associated with modern agricultural and forestry practices, predation, and disease (i.e. rabies) but it is unclear if or how these factors have impacted the abundance of this species.

Research is needed to better understand bat presence, abundance, and distribution in the Piedmont and Coastal Plain, especially for those mountain species that are at-risk due to WNS and have populations living in other parts of the state that may serve to rescue mountain populations in the future. There is a need to identify where these Coastal and Piedmont populations are roosting and foraging, so that we can protect these habitats. Long-term survey sites for mist-netting bats have been established in the Mountain region of North Carolina, but much less information is known about the distribution and abundance of bats in the Piedmont, Sandhills, and Coastal Plain.

There is a knowledge gap regarding the abundance and trends in abundance of Carolina Northern Flying Squirrel due to low captures and recaptures. Acoustics surveys are relatively new and a protocol is still being developed. An acoustic call filter and classifier are needed. A robust, long-term monitoring approach using appropriate survey techniques (e.g., nest box surveys and acoustic surveys to monitor occupancy over time) is needed. Research is needed to test for heavy metals and other contaminants in Carolina Northern Flying Squirrel (USFWS 1990). It is also not known how pervasive the *Strongyloides robustus* nematode is in the Carolina Northern Flying Squirrel population.

3.7.5 Management Needs

The Mammal Taxa Team indicated that current management levels for many of our bat species are not sufficient to maintain long-term, viable populations. Many laboratories and state and federal biologists are investigating the cause of bat deaths to document the spread of WNS. Research is currently being conducted to investigate the dynamics of the fungal infection and transmission in order to determine a way to control the disease.

Carolina Northern Flying Squirrel populations have been monitored annually since 1996 via winter nest box surveys. Data are stored in WRC's flying squirrel database. Acoustic surveys have been underway since 2009 and take place in the spring, summer, and fall. A reference library of flying squirrel calls provides known calls of Northern and Southern Flying Squirrels (Gilley 2013). Radio-telemetry studies have provided additional insight into habitat use, in particular the Northern Flying Squirrel's use of conifers (Ford et al. 2014). A predictive model of

Carolina Northern Flying Squirrel habitat has been developed for GIS analysis and can be used by researchers as a first approximation of species distribution (Ford et al 2015). Management recommendations for the Carolina Northern Flying Squirrel include the need to restore high-elevation forest habitat (Ford et al. 2014).

3.7.6 Threats and Problems

Chapter 5 describes 11 categories of threats the Mammal Taxa Team considered during evaluation and ranking process to identify SGCN. Evaluation results for Metric 9 about the expected scope and severity of these threats are available in Appendix 3 and indicate the most likely threats to have significant impacts on mammal populations in North Carolina over the next 10 years include the following:

- Climate change and severe weather
- Human intrusions and disturbance
- Invasives, problematic species and genes

The high-elevation forests inhabited by Carolina Northern Flying Squirrel are threatened by climate change and mortality of Fraser Fir and Eastern Hemlock. The Southern Flying Squirrel has crept upslope, threatening to infect populations of the Carolina Northern Flying Squirrel because it is a vector of the *Strongyloides robustus* nematode (Weigl 2007). There is the threat of hybridization between Northern and Southern Flying Squirrel where they overlap (Garroway et al. 2010). Open corridors through forests, such as roads with a width that exceeds the gliding ability of a flying squirrel, can inhibit dispersal (Kelly et al. 2013). In some areas, Carolina Northern Flying Squirrels are threatened by residential development.

Habitat loss and fragmentation are two of the most pervasive threats to North Carolina's wildlife. Land-use change, especially from undeveloped land into developed uses, is a critical threat to SGCN mammals. Fire suppression negatively impacts species associated with Longleaf Pines, such as Eastern Fox Squirrels and Southeastern Bat. Many small mammal populations are threatened by loss of early successional habitat across the state due to clean agriculture and timber practices. Loss of suitable roosts for bats is another important concern due to a decrease in snags in forested areas.

The impacts from disease also ranked high in the threat category for the Eastern Spotted Skunk, Allegheny and Southern Appalachian Woodrats, and several bat species, including Indiana Bat, Little Brown Bat, Northern Long-eared Bat, and Tricolored Bat. White-nose syndrome has emerged as a significant threat to bat populations in the state. Continued monitoring of bat populations in the Piedmont for WNS, especially in the Uwharrie region, is important to understanding the spread of the disease. Bats are also impacted by wind turbines. It is foreseeable that increased wind farm development in North Carolina will have adverse impacts on local and migratory bat populations.

Residential and commercial development ranked high as a research priority for many species, especially for the Allegheny Woodrat Southern Appalachian Woodrat, Buxton Woods White-footed Deermouse, Rock Shrew, Southern Bog Lemming, and the Southeastern Bat.

3.7.7 Additional Information

The USFWS Red Wolf Recovery Program continues to manage the state's wild population. . There are currently two known Red Wolf family groups, one resides on Alligator River National Wildlife Refuge (ARNWR) and the other resides on and adjacent to Pocosin Lakes National Wildlife Refuge (PLNWR) (USFWS 2024). The Service began to release and translocate Red Wolves in 2020 into the wild population in eastern North Carolina. These releases are intended to supplement genetic diversity in the population. In September 2023 the USFWS released the final Revised Recovery Plan for the Red Wolf (USFWS 2023) and the Population Viability Analysis of the Red Wolf (Miller et al. 2023).

Interbreeding with the Coyote (a species not native to North Carolina) has been recognized as the most significant and detrimental threat affecting restoration of Red Wolves (USFWS 2015). Coyotes are found in all 100 counties of the state and pose a predatory threat to pets, livestock and native wildlife. On March 18, 2015, the WRC adopted a permanent rule to list the Red Wolf as a threatened species.

The WRC worked collaboratively with USFWS and other partners to develop a surveillance and response plan for WNS in bats (NCWRC and USFWS 2013). The plan objective is to coordinate the conservation community's strategy for addressing WNS as it relates to disease surveillance and response, population monitoring, and research in North Carolina. Available online https://www.ncwildlife.gov/media/1301/download?attachment.

Bat Conservation International (BCI) is an organization that was developed to conserve bat species and their habitats. It works with local, regional, national, and multinational public and private partners to respond rapidly and effectively to bat conservation crises, to prevent the extinction of threatened bats and the extirpation of globally significant populations of bats. For example, conservation strategies developed by Lacki and Bayless (2014) for Rafinesque's Big-eared Bat and Southeastern Bat are available through BCI's website. Online resources for bat conservation also can be found at www.batcon.org.

Information on the ecology of mammals in the South and habitat management techniques to promote conservation can be found in "The Land Manager's Guide to Mammals of the South," a publication developed through collaboration between US Department of Agriculture and The Nature Conservancy (Trani et al. 2007). Available online https://www.nrs.fs.usda.gov/pubs/jrnl/2007/nrs_2007_trani-lndmgr-full_009.pdf.

3.7.8 Recommendations

Evidence-based knowledge is key for planning successful conservation strategies and for the cost-effective allocation of scarce resources (Littlewood et al. 2020). In general, protection and restoration of natural community composition and function and protection of surrounding natural areas under current conditions are the best ways to ensure that suitable habitats are available for these species. Measures that protect a large and diverse pool of populations are best for ensuring that species are able to survive future stresses and adapt to changing climate conditions.

Implement conservation measures and recommendations in protected species conservation plans.

- State protected species conservation plans are available online https://www.ncwildlife.gov/wildlife-habitat/species-conservation-plans.

- Federal protected species recovery plans are available online https://www.fws.gov/program/recovery/recovery-plans.

Implementation of recommendations for surveys, monitoring, and research should follow best practices and protocols established by recognized authorities (see Chapter 7 for information about standard protocols). The following recommendations should be considered appropriate to implement for mammal species.

3.7.8.1 Surveys

Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Prioritize surveys of bat species most impacted by WNS.		
Eastern Small-Footed Bat	Northern Long-eared Bat	Indiana Bat
Little Brown Bat	Tricolored Bat	
• Prioritize surveys for Southern Appalachian, Allegheny, and Eastern woodrats		
Allegheny Woodrat	Southern Appalachian Woodrat	
Eastern Wood Rat		
• Prioritize surveys for Appalachian Cottontail to determine the current distribution and abundance of the population in NC.		
Appalachian Cottontail		

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Conduct surveys for all SGCN, especially those that have knowledge gaps and are a research priority.		
Northern Yellow Bat	Bog Lemming	Rock Shrew
Dismal Swamp Southern Southern Pygmy Shrew	Buxton Woods White-footed Deermouse	Star-nosed Mole
• Establish new survey sites in areas impacted by extreme weather events (i.e., tornados, hurricanes, flooding) to begin assessing effects on wildlife.		

3.7.8.2 Monitoring

Monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. These efforts will inform species and habitat management decisions. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Continue monitoring bat populations in the mountains with capture, roost, hibernacula, and acoustic surveys. Efforts to bring these monitoring programs to the rest of the state was expanded and all bat monitoring is compliant with North American Bat (NABat) protocols.		
Gray Bat	Little Brown Bat	Silver-haired Bat
Hoary Bat	Northern Long-eared Bat	Tricolored Bat
Indiana Bat	Rafinesque's Big-eared Bat	Virginia Big-eared Bat
• Continue monitoring of Carolina Northern Flying Squirrel populations using a variety of survey techniques (e.g. acoustic, den box, etc.) that provide an accurate assessment of conservation status.		
Carolina Northern Flying Squirrel		

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Monitor Southern Appalachian and Allegheny Woodrats based upon the better understood distributions.

  Allegheny Woodrat   Southern Appalachian Woodrat

- Monitor all bat species affected by WNS.

- Investigate interspecific competition, population genetics, hybridization zones, and management of Appalachian Cottontails in western NC.

  Appalachian Cottontail

- Investigate genomics of the Buxton Woods White-footed Mouse (*Peromyscus leucopus buxtoni*) on the Outer Banks, North Carolina.

  Buxton Woods White-footed Mouse

- Conduct monitoring in areas impacted by extreme weather events (i.e., tornados, hurricanes, flooding) to assess effects on wildlife.

3.7.8.3 Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Examine winter behavior of bats in the Piedmont and Coastal Plain.

- Test for evidence of hybridization between Southern and Carolina Northern Flying Squirrels in North Carolina.

  Carolina Northern Flying Squirrel   Southern Flying Squirrel

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Study competition and disease transmission in areas of overlap between Southern and Carolina Northern Flying Squirrels.

  Carolina Northern Flying Squirrel   Southern Flying Squirrel

- Investigate winter roosting behavior of bats in the Coastal Plain ecoregion.

  Tricolored Bat

3.7.8.34 Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Protect bat roosting sites for all priority bat species, particularly those that are known roost sites for species affected by WNS.

- Restore high-elevation forests for

  Carolina Northern Flying Squirrels.

- Mammal SGCN living at the edge of developed areas may face threats from predation by free roaming cats and dogs, persecution by humans, road traffic, and disturbance. Fencing could be erected in some situations, especially along transportation facilities, to reduce exposure of wild mammals to such threats (Littlewood et al. 2020).

- Maintain existing wildlife corridors or develop and protect new movement corridors to reduce conflicts in developed areas and in transportation corridors. Retention of wildlife corridors, such as undeveloped land, riversides, woodland strips or other habitat through which mammals can pass, may reduce or help mitigate impacts of development and subsequent habitat fragmentation (Littlewood et al. 2020).

- Create uncultivated margins around agricultural or pasture fields to benefit small mammals (i.e., rodents, rabbits, shrews).

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Maintain undisturbed refugia adjacent to land during active harvests (crops or timber), mowing, or when conducting prescribed burns. This allows mammals to avoid being trapped so they can escape to nearby cover.

3.7.8.5 Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protection measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation serves numerous purposes in the face of anticipated climate change, but most notably, promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Use programs such as the Wildlife Conservation Lands Program to protect, manage, and restore habitat on private lands.
- Implement the state listing process by routinely evaluating conservation status and recommending legislative updates to revise the state species lists.
- Support citizen science and volunteer efforts to monitor species and habitat.
- Utilize partnerships and research collaborations with local universities and education programs to implement conservation, research, and management actions.
- Develop education, outreach, and technical guidance programs for the public.
- Provide outreach and public education for human-wildlife interactions and conflicts in areas where problems occur or are likely to occur.

Black Bear	Elk	Raccoon
Coyote	Feral Hog	White-tailed Deer
	Fox	

References are located at the end of this document.

3.8 Reptiles

3.8.1 Introduction

Taxonomic Class Reptilia represents crocodiles, lizards, snakes, and turtles. The North Carolina Biodiversity Project reports there are 75 species of reptiles in the state; 70 are native and 5 are established non-native species (NCBP 2025). Reptiles and amphibians are collectively known as herpetofauna and are commonly referred to as "herps", for short. Like amphibians, they are often very difficult to find and even the best available survey techniques may have limited success for detecting many species. This makes it essential to conduct survey and monitoring efforts over many years to collect sufficient information to understand the population status of each of the state's native reptile species.

North Carolina is home to numerous imperiled species of reptiles, ranging from the Bog Turtle in the western part of the state to the Eastern Diamondback Rattlesnake, Southern Hognose Snake, Northern Pine Snake, and many others in the Sandhills and Coastal Plain. Some of these species, like the Bog Turtle, rely on small, interspersed, very specific habitats, such as mountain bogs, for survival. Other species, like the Eastern Diamondback Rattlesnake and Northern Pine Snake, require very large tracts of intact, high-quality Longleaf Pine forests managed with fire to maintain an open and diverse understory. There are unique populations of reptiles in North Carolina currently referred to by various subspecies or clades. These may represent distinct species and need further investigation using modern genomic methods (NCBP 2025).

Many species of reptiles remain common in North Carolina and appear to be able to tolerate some levels of urbanization. Examples of urban-tolerant species include the Green Anole and Eastern Rat Snake. Some species, such as Eastern Diamondback Rattlesnake and Southern Hognose Snake, are generally intolerant of urbanization and the conversion of natural habitat to other uses. Still other species of reptiles have been little studied because of their rarity or secretive nature. Some examples of understudied species include Mimic Glass Lizard, Coal Skink, and Eastern Coral Snake. It is important to continue efforts to survey the state for reptiles and conduct research and monitoring to increase our knowledge of the status of reptiles in North Carolina, for both common and uncommon species.

Reptiles are an important component of Cherokee ancestral lands, contributing to ecological balance, cultural knowledge, and landscape diversity. Yet their conservation is often overlooked. Recent global models suggest that extinction risks for reptiles are widely underestimated, particularly for species in regions with complex topography and limited monitoring (Caetano et al. 2022).

Across the southern Appalachians, reptile populations are threatened by development, habitat alteration, direct persecution, climate change, and emerging infectious diseases (Roll et al. 2017). In response, the Eastern Band of Cherokee Indians (EBCI) has developed a conservation strategy that expands beyond state and federally listed species to also include those that are locally rare, culturally significant, at the edge of their range, or endemic to the region. Our approach prioritizes species based on documented threats, ecological rarity, and the opportunity to restore or strengthen relationships between the EBCI community and these native animals.

The following paragraphs provide information about a few of the reptile species identified by the Taxa Team as SGCN and priority species for research or management, and for which work that has been conducted to implement conservation and management recommendations. Conservation recommendations for the habitats associated with amphibian SGCN have been incorporated into the natural community descriptions in Chapter 4.

3.8.1.1 Crocodiles

The American Alligator (or alligator) is a keystone species found in the southeastern US and the only crocodilian species found in North Carolina, occurring throughout much of the Coastal Plain ecoregion. Alligators are federally protected under the ESA as a threatened species due to its similarity of appearance to the American Crocodile (*Crocodylus acutus*) which is also federally protected as a threatened species. In North Carolina, alligators are protected as a threatened species (Woodward and Elsey 2019, NCWRC 2025).

Alligators are large, semi-aquatic armored reptiles related to crocodiles but they lack the salt-secreting glands of crocodiles. Its range extends from the Florida Keys northward to the North Carolina coastal plain and westward to southern Texas and southeastern Oklahoma and Arkansas (NatureServe 2025). They occur in wetlands, lakes, rivers, creeks, marshes, swamps, and ponds in the Coastal Plain ecoregion. They primarily use freshwater but are able to enter waters with higher salinities for short periods of time to forage for food. Climate conditions have a direct effect on growth rates; the cold winters in North Carolina limits their growth, life span, and reproduction. Since sexual maturity is directly related to body size, they are generally around 6 feet long before being able to reproduce. With slower growth rates in North Carolina, males are about 15 years old and females are about 19 years old before sexual maturity.

3.8.1.2 Lizards

Currently there are 11 native and 3 nonnative lizards in North Carolina, with the highest diversity in the Sandhills and Coastal Plain ecoregions. There are two species listed for state protection, one is listed as endangered and one is listed as special concern.

Lizards, in general, have not been the focus of intensive survey, monitoring, or research in North Carolina. Some species appear to be quite common (e.g., Green Anole, Five-lined Skink), while others are very difficult to detect, or occur in apparently low numbers (e.g., Slender Glass Lizard, Mimic Glass Lizard).

3.8.1.3 Snakes

There are 40 species of snakes native to North Carolina. Snakes can be found from the mountains to the coast, but the highest diversity and the most imperiled species occur in the Sandhills and Coastal Plain. There are 10 species list for federal and state protection: two are listed as federal and state endangered, two are listed as federal and state threatened, and six are listed as state special concern.

Most species are quite secretive. Some remain abundant (e.g., Eastern Worm Snake), while others are becoming increasingly rare (e.g., Northern Pine Snake). Six snake species in the state are venomous, including three species of rattlesnakes, the Eastern Cottonmouth, the Copperhead, and the Eastern Coral Snake.

Inventory and monitoring surveys for reptile species are conducted statewide, at both historical and new locations. These survey efforts have yielded new occurrence records for many reptile species, including the Timber Rattlesnake, Corn Snake, Mole Kingsnake, and several others. Several species are the focus of more intense survey, research, and monitoring efforts in addition to passive surveys, including the Eastern Diamondback Rattlesnake, Southern Hognose Snake, and Northern Pine Snake.

3.8.1.4 Turtles

North Carolina is home to 21 species of turtles, ranging from the terrestrial Eastern Box Turtle to numerous aquatic species, five sea turtles, and the estuarine Diamondback Terrapin. There are 12 species listed for federal and state protection: three are federal and state listed as endangered, three are federal and state listed as threatened, and six are state listed as special concern.

Some species, like the Yellow-bellied Slider, are generalists, using a wide variety of wetland habitats and as such, are common throughout the state. Others, such as the Bog Turtle, are highly specialized, relying on very specific habitat types, and are, accordingly, quite rare and difficult to find. The natural history and distribution of some species have been extremely well-studied, while others are in need of increased survey, research, and monitoring work.

- Bog Turtles are the smallest turtle in North America. There are two distinct US population segments: -- one in the Northeast (MD to New England) and one in the Southeast (GA to VA). In North Carolina, Bog Turtles have been found in 22 counties along the western edge of the Piedmont and Mountain ecoregions. Their habitats include scattered small, grassy, herbaceous , spring-fed wetlands with little canopy and soft mucky substrates, and small riparian systems, often associated with pastureland or open fields (Somers et al. 2007). Roughly 75% of all Bog Turtle habitat in the Southeast is located on private lands, making partnerships with private landowners an integral component of conservation efforts for this species (Herman 2013). Project Bog Turtle is a North Carolina Herpetological Society conservation initiative supported by numerous state, federal, and private partners. The initiative supports inventory surveys, population density studies, and habitat conservation and restoration actions (http://projectbogturtle.org/).

- The Eastern Box Turtle is the only terrestrial turtle species native to North Carolina, and was designated the state reptile in 1979. A collaborative of wildlife professionals, scientists, and educators from several state agencies and two universities initiated the Box Turtle Connection: -- a project designed to collect statewide data on Box Turtles. The project was initiated in response to concerns that this once common and widespread species may be experiencing population declines, due to habitat loss and fragmentation, and pressures from other anthropomorphic impacts (Somers and Matthews 2006). The Eastern Box Turtle is listed on the Conference of the Parties to the Convention on International Trade in Endangered Species of Wildlife Fauna and Flora (CITES) Appendix II list of species that are not currently threatened with extinction, but may become threatened unless international trade is closely controlled.

In early 2013, three turtle species that are native to North Carolina were added to the CITES Appendix II list because they are harvested for commercial trade: Diamondback Terrapin, Spotted Turtle, and Common Snapping Turtle.

- The Diamondback Terrapin is found in brackish waters of the Atlantic Coast and is protected in North Carolina as a Species of Special Concern.

- The Spotted Turtle and Common Snapping Turtle are freshwater species commonly found in ponds and lakes.

Only the Common Snapping Turtle can be harvested commercially in North Carolina, although a wildlife collection license must be obtained from NCWRC for this activity, and take is limited to 10 animals per day and 100 animals per year. However, the CITES listing provides an international focus on conservation concerns for these species.

There are five marine turtle species found in North Carolina's coastal region: Loggerhead, Green, Hawksbill, Leatherback, and Kemp's Ridley sea turtles. More information on marine species can be found in Section 3.10 of this chapter. Jurisdiction over sea turtle activity is divided between the USFWS (land) and NOAA Fisheries (marine) because sea turtles are federally protected species that use both land and sea. The WRC has cooperative agreements with both USFWS and NMFS in order to monitor sea turtle activity in the state. All data collected by WRC biologists and permitted volunteers/cooperators are shared with the appropriate federal agency.

The North Carolina Sea Turtle Program coordinates a network of more than 1,000 volunteers and cooperators that work to monitor sea turtle nesting and stranding activities along the state's coastline. Four species of sea turtle nest along North Carolina's beaches: Loggerhead, Green, Leatherback, and Kemp's Ridley. Volunteer and cooperator groups monitor beaches daily from May to August and mark sea turtle nests. They monitor these nests throughout incubation and inventory each nest after it has emerged to determine hatching success. The Sea Turtle Stranding and Salvage Network collects data including species, carapace measurements, location, and probable cause of stranding from all reported sea turtle strandings.

Other turtle survey efforts have taken place in various parts of the state. These included recent trapping efforts in the mountains, where WRC biologists have detected Stripe-necked Musk Turtles, Eastern Spiny Softshells, Cumberland Sliders, and River Cooters in aquatic habitats where they were not previously documented. Surveys of streams in the Uwharrie Mountains, found in the Piedmont region of North Carolina, have recently documented additional and relatively large numbers of Gulf Coast Spiny Softshell Turtles in several drainages. Data collected from a recently developed public reporting tool for softshell turtles will help guide future monitoring and management efforts for these species. Additionally, a citizen science initiative called the Terrapin Tally has been formed to increase our knowledge of Diamondback Terrapins. Designed to help estimate population numbers, the Terrapin Tally is a joint project with the North Carolina Coastal Reserve and National Estuarine Research Reserve and the WRC.

3.8.2 Comparison of 2005 and 2015 Priority Species

The 2025 Reptile Taxa Team evaluated 81 species for conservation concern to identify SGCN, knowledge gaps to identify research priorities, and management concerns to identify management priorities. Some species may be considered a priority in more than one of the evaluation categories.

The following table provides a comparison of changes to the number of SGCN and priority species between the 2015 SWAP, the 2020 Addendum 1, and the 2025 SWAP. These changes do not necessarily indicate a change in the concern status for these species; they are more likely a result of an increase in our knowledge base for the species.

Reptile Priority Species by Evaluation Categories and Comparison between SWAPs

SWAP Date	SGCN	Knowledge Gaps	Management Needs
2025	46	62	26
2020 Addendum 1	42	46	24
2015	42	46	24

The following sections highlight specific conservation issues related to SGCN and their habitats. This is not an exhaustive list of species-specific conservation concerns but rather highlights some of the concerns in the state. Recommendations for priority survey, monitoring, and research studies, conservation actions, and partnerships are outlined in Section 3.8.

3.8.3 Conservation Concerns

Table 3-7 (Appendix 3) provides a list of Reptile SGCN and other priority species. River basin and habitat associations for these species are provided in Table 3-17 (terrestrial species) and Table 3-18 (aquatic species). Habitat descriptions and associated conservation priorities are located in Chapter 4.

The conservation concerns for reptiles are many and are summed up well by Gibbons et al. (2000). This paper notes that although amphibians are often thought of as much more imperiled, reptiles are also experiencing drastic declines worldwide and face numerous threats to their conservation status. Some of the major concerns that may affect the abundance or distribution of reptile species include habitat loss and alteration, poor habitat management (e.g., lack of appropriate fire regimes), environmental pollution, persecution and killing, unsustainable use, emerging diseases, and invasive species.

Most of the reptiles in North Carolina are affected by not one, but many issues related to their habitats. Sea turtles in particular are species that have experienced declines because of a multitude of threats. For example, sea turtles are threatened when they come ashore for beach nesting (i.e., egg predation, salt-water inundation of nests, human intrusion) and once they are in the ocean (i.e., fishing nets, plastics, predation).

Some turtle species have experienced high levels of collection from the wild, an activity that is unsustainable for most species. Climate change may be another issue that affects the status of reptiles, though this has been relatively understudied. Additional threats faced by reptiles include road mortality and the invasion of nonnative plants and animals, such as Fire Ants.

Many species of reptiles have been heavily affected by the loss of habitat throughout North Carolina. Large snakes and those species that are associated with very specific habitat types likely have been most affected by habitat loss and fragmentation. Bog Turtles have been drastically affected by the loss of mountain bogs and by the lack of management in the bogs that remain. Conservation recommendations for the habitats associated with reptiles have been incorporated into the natural community descriptions in Chapter 4.

- Eastern Diamondback Rattlesnakes have been affected by numerous factors, now limiting them to only a small population in the Coastal Plain. Eastern Diamondback Rattlesnakes are listed as State endangered in North Carolina. This species once occurred throughout much of the Coastal Plain, but populations have been drastically reduced. Historically, Eastern Diamondback Rattlesnakes were found in 13 counties, but since 2005, detections have only come from three counties, with all but three specimens found in a single county. Habitat loss and fragmentation due to development and silviculture are some of the biggest reasons for these declines, as well as road mortality and outright killing.

Another significant issue for the Eastern Diamondback Rattlesnake is limited refugia. Refugium sites are limited to tree stumps, as many of the other refugia used by this species in other parts of its range are absent in North Carolina—no Gopher Tortoise, Pocket Gopher, or armadillo burrows (however, see Section 3.7). Stumps that are large enough for use by an Eastern Diamondback Rattlesnake are uncommon across the landscape. Winter temperatures are likely an important factor in limiting the distribution of the Eastern Diamondback Rattlesnake. Thus, any limits on potential refugia may have an even bigger impact on the species. Recent work on stump-dependent species has shown great promise in the creation of artificial stump holes, and this work will continue.

- Monitoring of Southern Hog-nosed Snakes, a state threatened species, has been ongoing for more than 25 years in the Sandhills and Coastal Plain. These snakes are strongly tied to sandy soils and large tracts of well-managed Longleaf Pine forests. They are extremely secretive during most of the year but can be monitored by finding them crossing roads when they become more active in the fall. A recent publication suggests that no discernable trend in the captures of Southern Hognose Snakes was found over a long-term study in the Sandhills (Beane et al. 2014). However, outside the Sandhills, this species is extremely rare and infrequently encountered. Many coastal counties with historical records of the Southern Hognose Snake have no records within the last 20 years, despite considerable effort to detect the species.

- The Eastern Hog-nosed Snake is a species rarely encountered within EBCI lands but is known historically in surrounding habitats. Despite being non-venomous, the species suffers from misidentification and persecution, and its populations are declining across much of its range.

- Species located at the edge of their natural range are also emphasized in EBCI's work due to their increased sensitivity to habitat change and shifting climate regimes. Rare sightings of the Northern Pinesnake, colloquially known as bull snakes, have been found very near the EBCI lands and may represent one such edge-of-range species with potential presence in suitable upland areas.

- The Slender Glass Lizard is another locally rare species, is known from only a few historical specimens in western North Carolina (Palmer and Braswell 1995). Due to its cryptic appearance and use of grassland and open woodland habitats, it is easily overlooked in standard surveys and remains a high priority for targeted detection. It is one of several species currently being evaluated for presence and habitat association within EBCI-managed areas.

- The Southeastern Five-lined Skink occurs at the northern limits of its distribution in western North Carolina and may face range retraction due to habitat fragmentation and warming temperatures. These species highlight the importance of conducting surveys across not only an elevational and geographic gradient but across jurisdictional boundaries to assess current distributions.

- There are reptiles found just outside of the southern Appalachian region that may have rare populations in the mountains and also warrant special consideration. The Mole Kingsnake is not federally listed but is found exclusively in the southeastern United States and relies on well-connected forest and edge habitats. Its restricted range and vulnerability to road mortality and urban encroachment elevate its conservation importance.

3.8.4 Knowledge Gaps

The current status of many reptile species is poorly known in North Carolina. Inventories using appropriate survey techniques are important for understanding the distribution of species, status of populations, effects of stressors on populations, and the effects of harvest. For instance, biologists lack information about locations and statuses of populations of Rainbow Snake and Mimic Glass Lizard. Some species are more difficult to survey than others, and novel techniques should be developed to make surveys more effective. There are significant knowledge gaps about Bog Turtles, including how they use the landscape outside of bogs (i.e., rivers, forests) as they move across the landscape between wetlands.

Species for which the Reptile Taxa Team determined there are research priorities because of knowledge gaps are included in Table 3-6 (Appendix 3). In general, most of the species noted as knowledge-gap priorities are listed because we lack information regarding statewide distribution and abundance, we have few programs in place to monitor the species, or there are questions regarding what factors affect the population size and distribution of these species.

There have been scientific advances in direct DNA sequencing methods that enabled tests of previous hypotheses of phylogenetic relationships that may result in recommendations for taxonomic revisions. However, newly published taxonomy should not be interpreted as a formal, mandatory change; it is simply an alternative that should be evaluated alongside other such proposals.

- The Bog Turtle is federally listed as threatened and represents one of the rarest and most imperiled reptiles in the United States. While not yet confirmed within EBCI lands, the species' occurrence in nearby headwater wetlands led the Tribe to initiate environmental DNA (eDNA) sampling in 2022, focusing on spring-fed wetland habitats likely to support viable populations.

- Several reptiles hold cultural and historical significance for the EBCI community. The Eastern Musk Turtle (Sternotherus odoratus) was historically recorded in western North Carolina, and though recent records are lacking, its known association with low-gradient aquatic systems suggests a possible lost connection with traditional Cherokee territory.

- In 2016, the EBCI began a long-term capture-mark-recapture program for the Eastern Box Turtle, a culturally important species for Cherokee people. The goal of the project is to better understand spatial distribution and longevity of individuals while promoting cultural reconnection through field-based conservation activities.

3.8.5 Management Needs

Management needs for reptile species vary widely depending on each species' habitat use and natural history traits. In general, terrestrial reptiles often require specific habitat types, often in very large tracts of high-quality, well-managed habitat. Reptiles that rely on fire-maintained pine habitat are drastically affected by the lack of sound management, including prescribed fire. Management of these types of habitats needs to take place on a large scale to preserve reptile diversity.

Lack of fire, fire suppression, and the conversion of open pine habitat to industrial forests have led to the decline of many habitat specialists such as Northern Pine Snakes, Southern Hognose Snakes, and Chicken Turtles. Information on habitat management for herp species can be found in the PARC technical publication on habitat management for amphibians and reptiles in the Southeast (Bailey et al. 2006).

Diverse reptile populations continue to persist in large, soundly managed tracts of Longleaf Pine forests in the Sandhills region. Working with land managers to emphasize the need for management to maintain diverse forests using prescribed fire is extremely important for maintaining diverse reptile populations.

Bog Turtle conservation efforts are another example of implementing management to maintain or increase populations of reptiles. This species is now restricted to very small mountain bogs that are easily shaded out by thick vegetation if active management is not undertaken (Somers et al. 2000). Though sometimes difficult to implement, current efforts to maintain bogs in an open-canopied state are contributing to the conservation of this rare species. The Bog Turtle Conservation Plan was finalized in 2023 and will be utilized to implement conservation actions based upon bog specific threats and associated management needs [https://www.ncwildlife.gov/bog-turtle-conservation-plan-final-07132023pdf/open].

Sea turtles represent a group of species where intensive management is now necessary to maintain or increase populations . Turtle nests must be marked to allow natural incubation, with some receiving predator exclusion material to minimize mammalian predators , and nests are monitored to determine incubation success. Anthropogenic threats to sea turtles in coastal waters including bycatch in fisheries, hopper dredges, and other activities require collaborative relationships with various stakeholders to minimize lethal interactions.

- Many reptile species are also prioritized due to their vulnerability to modern stressors. Although Timber Rattlesnake populations on EBCI lands appear stable, the species is frequently persecuted and therefore remains at risk. Since 2022, EBCI has conducted a mark-recapture study to track individuals, reduce human-wildlife conflict, and promote public awareness of the species' ecological role.

3.8.6 Threats and Problems

Chapter 5 describes 11 categories of threats the Taxa Teams considered during the evaluation and ranking process to identify SGCN; information about the expected scope and severity of the impacts from these threats is available in Appendix 3. Evaluation results for Metric 9 about the expected scope and severity of these threats are available in Appendix 3. The results indicate that the threats most likely to create significant impacts to reptile populations in North Carolina over the next 10 years include the following:

- Climate change and severe weather
- Illegal Collection
- Natural systems modifications (e.g., fire suppression, land management activities)
- Residential and commercial development
- Transportation and service corridors

Research related to these threats and their impacts on certain reptile species was ranked as a high priority. Habitat loss, modification, and mismanagement should be a focus of efforts to reduce threats to many species of reptiles.

Snake Fungal Disease (*Ophidiomyces ophiodiicola*) is an emerging pathogen confirmed in neighboring Tennessee. It poses a significant risk to native snake populations. EBCI biologists regularly examine individual snakes captured during fieldwork to inspect for external signs of infection, including facial swelling, skin nodules, and lesions. There is an opportunity for collaboration between EBCI and NCWRC to expand disease surveillance and better understand the prevalence of this emerging threat.

Three introduced species have been documented in the state, including Texas Horned Lizard, Mediterranean Gecko, and Brown Anole, but none of the populations of these species appear to be widespread. Breeding populations exist for both Texas Horned Lizard and Mediterranean Gecko, but no breeding activity has yet been detected for Brown Anoles in the wild. Of the three nonnatives, the Brown Anole represents the highest threat to native species, because its ability to outcompete the Green Anole has been documented in Florida and elsewhere.

Poaching or illegal collection is a serious threat, primarily for snake and turtle species, because it removes many individuals from populations, thereby hindering gene flow and reducing the capacity for small populations to persist. Native snakes are particularly subject to persecution due to fear or lack of understanding for their importance to biodiversity (NCBP 2025). North Carolina regulates wildlife possession to prevent ecological disruptions and protect native species.

- 15A NCAC 10H.1301 Sale of Native Turtles. This law covers buying or selling any native turtle species except for snapping turtles larger than 13 inches long. [http://reports.oah.state.nc.us/ncac/title%2015a%20-%20environmental%20quality/chapter%2010%20-%20wildlife%20resources%20and%20water%20safety/subchapter%20h/15a%20ncac%2010h%20.1301.pdf].

- 15A NCAC 10H.1302 Possession of Reptiles and Amphibians. This law requires permits for the possession, importation, transportation, purchase, and sale of any native amphibian or reptile species. [http://reports.oah.state.nc.us/ncac/title%2015a%20-%20environmental%20quality/chapter%2010%20-%20wildlife%20resources%20and%20water%20safety/subchapter%20h/15a%20ncac%2010h%20.1302.pdf].

3.8.7 Additional Information

Habitat management information for 246 herps from the southeastern US can be found in a Partners in Amphibian and Reptile Conservation (PARC) technical publication for amphibians and reptiles and is available online at http://separc.files.wordpress.com/2013/04/se-hmg.pdf. The recommendations included in this document have been derived from the body of published information on amphibians and reptiles of the southeastern US, as well as on the extensive experiences of concerned biologists and scientists (Bailey et al. 2006).

Programs and information from the North Carolina Herpetological Society (NCHS), the USGS ARMI, and NCPARC are important resources for conservation of North Carolina's native reptile species.

- NCPARC [https://ncparc.org] is the state chapter of the national organization Partners in Amphibian and Reptile Conservation (PARC). It operates as a conservation network that includes individuals, organizations, and agencies that focuses on conserving habitats and all herp species.

- Project Bog Turtle (NCHS) is a multistate conservation initiative for monitoring historic and potential bog turtle sites, site management and restoration, leasing sites, and pit tagging. [online https://projectbogturtle.org]

- Project Simus (NCHS) was created to gather and maintain information on the natural history, status, and distribution of the southern hognose snake in North Carolina.

- HerpMapper [https://www.herpmapper.org] is a citizen science portal that helps gather and share information about reptile and amphibian observations worldwide.

- The USGS ARMI Ecosystems Mission Area Species Management Research Program [https://armi.usgs.gov] provides essential scientific information to managers to help arrest or reverse amphibian population declines.

- Another online database for tracking reptiles is the Carolina Herp Atlas [www.carolinaherpatlas.org] developed by Davidson College Herpetology Laboratory. This program tracks county-level distribution information for native species in North and South Carolina .

- NCPARC maintains an online identification and information guide, Amphibians and Reptiles of North Carolina [www.herpsofnc.org]. This website aims to foster an appreciation of amphibians and reptiles and to provide information regarding their biology and conservation, focusing on those species occurring in North Carolina.

- The EBCI conducts reptile surveys across the Qualla Boundary using a suite of techniques suited to the terrain and behavior of target species. Standard methods include cover board arrays, drift fence and funnel trapping, turtle trapping, road cruising, and walking transects. In addition, opportunistic observations such as roadkill documentation, community reports, and camera trapping contribute valuable information to species inventory. Since beginning these efforts, EBCI biologists have documented three turtle species, four lizard species, and thirteen snake species within EBCI landscape. Continued monitoring, outreach, and habitat assessment will guide future conservation actions.

Taxonomic classification and agreement on naming conventions for some species are likely to be unsettled until scientific evidence supporting any recommended changes becomes widely accepted. Resources for information about changes in classification include the Center for North American Herpetology (CNAH), an organization that serves as a data bank for information about North American amphibians, turtles, reptiles, and crocodilians. Published research literature documenting taxonomic changes is available online at www.cnah.org. The CNAH web page also provides a link to peer-reviewed articles published in the *Journal of North American Herpetology* and access to articles in the *Contemporary Herpetology* journal archives.

The International Union for Conservation of Nature's (IUCN) Red List of Threatened Species is the most comprehensive assessment of the extinction risk of species worldwide. Reptiles remain the only tetrapod group without comprehensive IUCN assessment because the majority of species found world-wide are data deficient (Caetano et al. 2022).

3.8.8 Recommendations

In general, protection and restoration of natural community composition and function, and protection of surrounding natural areas under current conditions are the best ways to ensure suitable habitats are available for these species. Measures that protect a large and diverse group of populations are the best way to ensure that species are able to survive future stresses and adapt to changing climate conditions. Implement conservation measures and recommendations in protected species conservation plans.

- State protected species conservation plans are available online https://www.ncwildlife.gov/wildlife-habitat/species-conservation-plans.
- Federal protected species recovery plans are available online https://www.fws.gov/program/recovery/recovery-plans.

Implementation of recommendations for surveys, monitoring, and research should follow best practices and protocols established by recognized authorities (see Chapter 6 for a list of protocols). The following recommendations should be considered appropriate to implement for reptile species.

3.8.8.1 Surveys

Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Conduct distributional surveys of Longleaf Pine habitat snake specialists. Some of these include:		
Eastern Coachwhip Eastern Coral Snake	Eastern Diamondback Rattlesnake Northern Pine Snake	Southern Hognose Snake
• Conduct surveys for aquatic or semi-aquatic species of snakes		
Black Swamp Snake	Glossy Crayfish Snake	Rainbow Snake
• Continue to conduct surveys for aquatic turtle species in the mountains, where relatively little is known about turtle assemblages compared to other parts of the state.		
• Survey habitat for Timber Rattlesnakes in the mountains and Piedmont to determine gestation and overwintering locations to protect and monitor these sites.		
• Conduct surveys for turtles in the Coastal Plain to determine where healthy populations still occur and implement conservation efforts accordingly.		
Chicken Turtle	Diamondback Terrapin	Spotted Turtle
• Focus survey efforts on learning more about the distribution and population status of glass lizards, both in the Coastal Plain and in the Piedmont.		

Priority Conservation Action, Examples of Focal Species or Focal Habitats

Eastern Glass Lizard Eastern Slender Glass Lizard Mimic Glass Lizard

- Implement survey recommendations in protected species conservation plans.
    - State protected species conservation plans are available online https://www.ncwildlife.gov/wildlife-habitat/species-conservation-plans.
    - Federal protected species recovery plans are available online https://www.fws.gov/program/recovery/recovery-plans.

3.8.8.2 Monitoring.

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. These efforts will inform species and habitat management decisions. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Monitor priority reptile species that are perceived as declining or rare, especially upland snake species, including the following.

  Eastern Diamondback Rattlesnakes Southern Hognose Snakes Northern Pine Snakes Timber Rattlesnakes

- Continue to monitor Bog Turtle populations annually using mark-recapture and intensive habitat surveys.

  Bog Turtle

- Continue to monitor sea turtles and Diamondback Terrapins using appropriate techniques.

  Sea Turtles Diamondback Terrapin

- Monitor snake populations for signs of emerging diseases that could be detrimental to populations.

  Snake Lungworm Snake Fungal Disease

- Monitor sea turtle nesting sites for fungi and pathogens that can impact hatch success (Sarmiento-Ramirez et al. 2014).

Priority Conservation Action, Examples of Focal Species or Focal Habitats
Fusarium falciforme (fungi) *Fusarium keratoplasticum* (fungi)
• Continue the statewide Box Turtle Connection program, forming a long-term database of the status of the Eastern Box Turtle throughout the state. Eastern Box Turtle
• Continue monitoring of American Alligators and implement recommendations from the 2018 NC Alligator Management Plan available online https://www.ncwildlife.gov/media/1362/download?attachment
• Collaborate with EBCI to monitor for snakes infected by Snake Fungal Disease in western North Carolina. Timber Rattlesnake Hog-nosed Snake

3.8.8.3 Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Continue mark-recapture program to determine status, life history, and population sizes of Bog Turtles. Telemetry work should also aid in understanding population dynamics. Bog Turtle
• Analyze 10-year mark-recapture study data collected on upland snakes throughout the Sandhills Game Land.
• Conduct research on the movements and habitat use of upland snake species to guide land use and protection. If possible, radio telemetry on certain species would be useful in elucidating habitat associations and limiting factors for these species.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
Timber Rattlesnake
• Conduct mark-recapture surveys on Eastern Box Turtles throughout the state to track population trends and determine differences in populations in relation to land use. Eastern Box Turtle
• Continue research on aspects of sea turtle biology, ecology, and recovery along the coast.
• Determine the effects of harvest on the conservation status of aquatic and semi-aquatic turtles. Chicken Turtle, Common Snapping Turtle, Cumberland Slider, Diamondback Terrapin, Eastern Mud Turtle, Eastern Musk Turtle, Eastern Spiny Softshell, Northern Map Turtle, Northern Red-bellied Cooter, Stripe-necked Musk Turtle
• Conduct genetic research on Southern Hognose Snake and Timber Rattlesnake to determine the genetic health of these species in the state to inform management and conservation actions. Southern Hognose Snake, Timber Rattlesnake
• Continue research of American Alligator fecundity, nest and egg survival, recruitment rates, growth rates, size at maturity of adults, and other information vital to understanding population dynamics. American Alligator

3.8.8.4 Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats. We will

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Promote appropriate prescribed fire regimes to maintain open, diverse habitat that supports abundant upland snake populations.
• Restore lands where lack of fire, or fire suppression, has altered pine-dominated forests.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
Longleaf Pine forests
• Continue to manage mountain bogs using appropriate techniques and promote habitat restoration and maintenance on mountain bogs as guided by the Bog Turtle Conservation Plan.
Bog Turtle
• Determine "hot spots" for road mortality and assess ways of alleviating issues, including underpasses or other techniques.
• Restore degraded ephemeral wetland habitat and maintain existing habitat through application of prescribed fire during appropriate seasons and at required intervals to support abundant aquatic turtle populations (i.e., Chicken Turtle).
Eastern Chicken Turtle; Eastern Musk Turtle; Stripe-necked Musk Turtle

3.8.8.5 Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Continue to support programs that limit collection of priority species, including permit requirements, law enforcement oversight, and legislative action that protects species.
• Implement the state listing process by routinely evaluating conservation status and recommending legislative updates to revise the state species lists.
• Consider repatriation of confiscated animals where appropriate.
• Support land trusts and conservation easements as a means to protect reptile habitat.
• Utilize programs such as the Wildlife Conservation Lands Program and others to protect, manage, and restore habitat on private lands.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Support citizen science and volunteer efforts to monitor species and habitats.
• Utilize partnerships and research collaborations with local universities and education programs to implement conservation, research, and management actions.
• Develop education, outreach, and technical guidance programs for the public.
• Work with private landowners to promote habitat that supports a high diversity of reptiles.

References are located at the end of this document.

3.9 Snails

3.9.1 Introduction

Snails and slugs are members of the phylum Mollusca and are in the taxonomic class Gastropoda (commonly gastropods). There are about 40,000 snail species identified worldwide, making this the largest group of living mollusks. According to the NatureServe Explorer database there are 225 terrestrial snail species and 58 freshwater snail species occurring in North Carolina (NatureServe 2025). Gastropods are protected under state law in North Carolina and the NC Natural Heritage Program collects data on rare gastropod species.

Gastropods have a muscular foot used for movement, and in some species it is modified for swimming or burrowing. Snails respire using a lung (group Pulmonata) or gills (several taxonomic groups) (Brusca and Brusca 1990; Hickman et al. 2000). They occupy both wetland and dry landscapes as well as fresh, brackish, and marine waters; however, only freshwater and terrestrial gastropods are addressed in this version of the SWAP.

Most snails have a single spirally coiled shell, whereas slugs lack a shell. Snails also have a mantle that covers internal organs and extends outward to attach to the shell, a well-developed head with eyes and either one or two pairs of tentacles, and a concentration of nervous tissue and cerebral ganglia that forms a primitive brain. Shells may have an operculum, a horny plate that seals the opening when the snail withdraws its body into the shell.

Most snails use a radula (a horny, ribbonlike structure found in the mouth) in some aspect of their feeding behavior, which includes grazing, browsing, or feeding on plankton. They may also be scavengers or detritivores. Snails found in North Carolina include carnivores that prey on other snails and slugs, such as the Gray-foot Lancetooth and the Rosy Wolfsnail, and herbivores or detritivores, such as the Flamed Tigersnail and Mountain Disc.

All land snails and slugs are hermaphrodites, producing both spermatozoa and ova so all individuals have the potential to lay eggs. Some freshwater snails (e.g., Apple Snail) and marine species (e.g., Periwinkles) have separate sexes.

3.9.1.1 Freshwater Snails

In the USA, freshwater gastropods are an especially diverse group of invertebrates, and their highest diversity is in the Southeast (Lydeard and Mayden 1995, Brown et al. 1998, Lysne et al. 2008). An assessment by the American Fisheries Society (AFS) (Johnson et al. 2013) estimates there are 703 native aquatic gastropods from North America (Canada, United States) with the greatest species richness being associated with flowing (lotic) waters (Johnson 2009). The southeastern United States is recognized as having a high diversity of freshwater gastropods (Lydeard and Mayden 1995; Brown et al. 1998; Lysne et al. 2008). Many are endemics with very small geographic ranges, often isolated to a single location, watershed, or geographically restricted drainage (Johnson et al. 2013).

According to the AFS, 74% of all freshwater snails in the United States and Canada are currently imperiled (Johnson et al. 2013).

The taxonomy of gastropods was revised by Bouchet and Rocroi (2005) using the concept of clades (a grouping that includes a common ancestor) to naturally group-related species based on molecular phylogenetics in comparison with other schemes that rely on morphological features. Under this system native freshwater snails in the United States belong to three main clades: *Neritimorpha, Caenogastropoda*, and *Heterobranchia* (Bouchet and Rocroi 2005; Johnson et al. 2013). Snails in the *Neritimorpha* clade are restricted to coastal river environments (Johnson et al. 2013).

Most freshwater snails have an operculum, use gills to breathe, mature slowly, and are long-lived dioecious species with internal fertilization. Operculate snails comprise about two-thirds of all North American freshwater snails. Freshwater snails with an operculum are descended from marine ancestors and extract oxygen from the water with a single gill. They have separate sexes and a short reproductive season, are slow-growing and long-lived, and very sensitive to environmental changes (Johnson 2009). Eggs are attached to firm substrates between late spring and early summer.

Aquatic snails can dominate benthic stream communities in numbers (Hawkins and Furnish 1987; Johnson and Brown 1997; Johnson et al. 2013) and can comprise more than 90% of the macroinvertebrate species in wetland habitats (Suski et al. 2012); can significantly influence algal primary productivity (Brown and Lydeard 2010; Johnson et al. 2013); and play a pivotal role in aquatic food webs and nutrient cycles (Covich et al. 1999; Johnson et al. 2013). Most freshwater species graze on algae and biofilms and some are suspension or deposit feeders. None are predatory (Burch 1989; Brown and Lydeard 2010; Johnson et al. 2013).

Snails are prey for numerous fishes from the families Acipenseridae, Cyprinidae, Catostomidae, Ictaluridae, Centrarchidae, and Percidae (Boschung and Mayden 2004; Johnson et al. 2013), as well as other aquatic and terrestrial species (e.g., Map Turtles, Snail Kites, and Muskrats) (Cagle 1952; Vogt 1981; Neves and Odum 1989; Bourne 1993; Johnson et al. 2013).

A list of freshwater snail SGCN is provided in Table 3-8 and the Taxa Team evaluation results can be downloaded from https://www.ncwildlife.gov/wildlife-habitat/wildlife-action-plan. Natural community descriptions and priority conservation recommendations for aquatic and habitats are provided in Chapter 4.

3.9.1.2 Land Snails

Research by Nekola (2014) estimates there are 1,200 species of terrestrial snails in North America. Not all land (terrestrial) snails are completely terrestrial. Some move between land and freshwater or saltwater habitats. A majority of land snails have a lung for respiration and are pulmonates, but there are some that live in moist habitats that have a gill and use an operculum to seal the shell.

Due to extremely limited data and a scarcity of biologists who work on the taxa, little is known about the 200+ species of native terrestrial gastropods known to exist in the state or the 30+ introduced species of land snails or slugs.

Conservation recommendations for the associated habitats have been incorporated into the natural community descriptions in Chapter 4. Additional recommendations can be found in the river basin descriptions (Section 4.5). The following paragraphs provide information about species identified by the Taxa Team as SGCN or a priority species for research or management, and for which work has been conducted to implement conservation and management recommendations.

Numerous land snails were identified as SGCN and knowledge gap priorities and are listed in Table 3-9. Taxa Team evaluation results can downloaded from https://www.ncwildlife.gov/wildlife-habitat/wildlife-action-plan. Conservation recommendations for the habitats associated have been incorporated into the natural community descriptions in Chapter 4.

3.9.2 Comparison of 2005 and 2015 Priority Species

The 2025 Snail Taxa Team evaluated 46 species of aquatic snails and 217 species of land snails species for conservation concern to identify SGCN, knowledge gaps to identify research priorities, and management concerns to identify management priorities. Some species may be considered a priority in more than one of the evaluation categories.

The following table provides a comparison of changes to the number of SGCN and priority species between the 2015 SWAP, the 2020 Addendum 1, and the 2025 SWAP. These changes do not necessarily indicate a change in the concern status for these species; they are more likely a result of an increase in our knowledge base for the species.

Snail Priority Species by Evaluation Categories and Comparison between SWAPs

SWAP Date	SGCN	Knowledge Gaps	Management Needs
AQUATIC SNAILS			
2025	12	46	29
2020 Addendum 1	8	1	2
2015	6	1	2
LAND SNAILS			
2025	53	190	56
2020 Addendum 1	47	20	14
2015	47	20	14

The following sections highlight specific conservation issues related to SGCN and their habitats. This is not an exhaustive list of species-specific conservation concerns but rather highlights some of the concerns in the state. Recommendations for priority survey, monitoring, and research studies, conservation actions, and partnerships are outlined in Section 3.9.8.

3.9.3 Conservation Concerns

There are two species of snails listed for federal ESA protection in North Carolina: the Noonday Globe is a federal threatened land snail and the Magnificent Ramshorn is a federal endangered aquatic snail. There are also several aquatic and land snails listed for state protection as endangered, threatened, or special concern. Tables 3-8 (aquatic snails) and 3-9 (land snails) in Appendix 3 provides a list of these species.

The National Strategy for the Conservation of Native Freshwater Mollusks (FMCS 2016) outlines 10 priority conservation issues for freshwater mussels and snails. The first priority is to increase knowledge of the distribution and taxonomy of mollusks at multiple scales, over time (FMCS 2016) Lysne et al. (2008) states the primary causes of imperilment for listed snail species are loss or alteration of habitat. Other threats, including water pollution and invasive species, combine with habitat loss or alteration to result in declines of snails worldwide (Lydeard et al. 2004 Lysne et al. 2008).

While efforts to protect healthy aquatic habitats benefits all aquatic species, including aquatic snails, efforts directed specifically to conserve freshwater gastropods have lagged behind efforts to conserve other freshwater species (Lysne et al. 2008). Very little research has addressed gastropods found in large river systems but snails in these systems are subject to the same threats in regulated waters as protected fish and mussel species (Brown et al. 1998; Haynes et al. 1999; Brown 2000, 2001; Greenwood and Thorp 2001). In the Coastal Plain ecoregion, saltwater intrusion is emerging as a significant threat to species in freshwater coastal systems.

Published research on freshwater gastropods in North America has focused on their effects on algae in small-order streams or have focused on pulmonate snails (snails that have a lung and are hermaphroditic) which are rare in large river systems (Greenwood and Thorp 2001). Because prosobranch species do not disperse over land, habitat fragmentation, such as the presence of dams, can isolate populations and increase the risk for local extirpation or extinction (Greenwood and Thorp 2001).

3.9.4 Knowledge Gaps

The first step in a successful gastropod conservation program is to gain an understanding of the diversity of taxa that exist (Perez and Minton 2008; Lysne et al. 2008). We have many knowledge gaps for snails in the state. Most of what is known about land snails in North Carolina as well as in the southeast is based on the work of Leslie Hubricht (Gerber 2010). Recently a new species of micro-sized land snail was discovered in leaf litter near the Broad River; taxonomic details for *Paravitrea nunnehi* have been published in *The Nautilus* (Slapcinsky et al. 2023).

The survey collections of Amy and Wayne Van Devender were donated to the Mollusk Collection at the NC Museum of Natural Sciences and is in process of being cataloged. This collection represents more than 11,000 specimens from over a decade of survey work conducted statewide. Once cataloged, the data will contribute significantly to knowledge about the distribution of land snails in North Carolina.

Overall, there is little survey, monitoring, or research being conducted nor data published for North Carolina, making it difficult to assess conservation status and needs of most species. The need for adequate inventories of extant taxa and an understanding of distributional trends of those taxa is urgent (Lydeard et al. 2004; Wilson 2005; Lysne et al. 2008). Dispersal abilities, life histories, and habitat requirements are not well understood for most species in North Carolina. Limitations include having enough biologists with expertise and resource agency staff devoted to this taxon.

There is a great deal of taxonomic uncertainty as well. Many of the land snails in the family Zonitidae (glass snails) have not been described and very little has been published about their ecology, reproductive biology, or egg laying behavior. As new data are gathered and new species are described taxonomic knowledge databases need to be updated. Molecular/DNA studies can aid in taxonomic clarification and species detection. Simultaneously providing a description of community composition will provide ecological context that will benefit conservation planning (Lysne et al. 2008). There is uncertainty regarding the effects of pollutants on populations of freshwater snails, which continuing research help to clarify.

The species for which the Snail Taxa Team determined there are research priorities because of knowledge gaps are included in Tables 3-8 (Aquatic Snails) and 3-9 (Land Snails) in Appendix 3.

3.9.5 Management Needs

Captive propagation and reintroduction of imperiled snails continues to be explored as a conservation measure. Techniques include rearing snails in captivity for subsequent release into known historic range or other refugia. Other techniques may include relocation or translocation of eggs, juveniles, or adults from viable populations to augment extant populations or establish new populations in suitable habitats. WRC has successfully propagated Magnificent Ramshorn, a federal listed endangered aquatic snail, and released captive bred adults to freshwater pond habitat within its home range in the Coastal Plain ecoregion.

None of these approaches is without risks, such as reduction of genetic material and inbreeding, introduction of disease from individuals released into the wild, and loss of species held captive from human error or equipment failure (Snyder et al. 1996; USFWS 2000; Lysne et al. 2008), but these must be balanced against the extremity of threat to both the species in question and the taxon as a whole.

3.9.6 Threats and Problems

Chapter 5 describes 11 categories of threats the Snail Taxa Team considered during the evaluation and ranking process to identify SGCN; information about the expected scope and severity of the impacts from these threats is available in Reference 3-1 in Appendix 3. Since there is a significant lack of information about aquatic and land snails in the state, the evaluation results for Metric 9 are largely qualitative and do not adequately assess anticipated impacts from threats for nearly all species considered by the Taxa Team.

The evaluation results indicate the threats most likely to create significant impacts on populations of Magnificent Ramshorn and Greenfield Ramshorn in North Carolina over the next 10 years include:

- residential and commercial development
- agriculture and aquaculture
- transportation and service corridors
- natural system modifications
- pollution
- climate change and severe weather

Acid deposition from air pollution can affect soil calcium levels, which in turn may affect snails. An association has been made between snail abundance and diversity and availability of calcium (from soil cations, detritus, plants) for regulation of bodily processes, reproduction, and shell building (Burch 1962; Fournie et al. 1984; Nekola 1999; Nekola and Smith 1999; Kalisz and Powell 2003; Hickman et al. 2003; Dourson 2013). Snails play a critical role in concentrating calcium (in shells) which then becomes available to species in higher trophic levels, especially birds that need calcium for egg shells (Skeldon et al. 2007). Some research suggests that snail abundance and diversity can serve as an indicator for the effects of acid deposition (Hamburg et al. 2003; Skeldon et al. 2007).

Contamination of freshwater habitats by chemicals, sediments, heavy metals and other substances has been recognized as a serious ecological impact to all wildlife. Chemicals that affect survival and persistence (e.g., EDCs) in vertebrates and other mollusks can also affect freshwater snails (Fox 2005; Iguchi and Katsu 2008). There is also growing concern for salinization of freshwater systems from man-made sources such as road deicing, wastewater and mining effluents, oil and gas extraction methods, agricultural practices (Suski et al. 2012), and upstream encroachment of salt water (salt wedge) facilitated by increased navigational dredging and sea level rise.

Species invasions have a demonstrated detrimental effect on the biodiversity of all mollusks, including snails (Lydeard et al. 2004; Lysne et al. 2008), directly through competition for resources, such as food and space, and indirectly through changes in ecosystem function (Hall et al. 2003; Richards 2004; Kerans et al. 2005; Lysne et al. 2008).

Many species of terrestrial gastropod, including those found throughout North Carolina, are known to be a vector for common parasites. For instance, the Flamed Tigersnail is known to be an intermediary host for *Parelaphostrongylus tenuis*, a common meningeal nematode parasite of White-tailed Deer and other ungulate species (Lankester and Anderson 1968; Anderson and Prestwood 1981; Garvon and Bird 2005).

Invasive and nonnative snails impact native species both directly and indirectly (Brown et al. 2008). For example, direct impacts include competition for food and space and indirect impacts can occur when invasives or nonnatives create changes in ecosystem function (Brown et al. 2008). Other impacts may be the introduction of a new parasite or pathogen that reduces health or causes mortality or the introduction of predators that consume adults and/or juveniles.

North Carolina is home to the only known population of the state-listed endangered Greenfield Ramshorn, a large planorbid snail historically found only in Greenfield Lake and Orton Pond. Likewise, the Magnificent Ramshorn was historically known from two freshwater ponds in Brunswick County. When populations are so small, confined to specific landscapes, or associated with unique habitats, they are at extreme risk of extinction from any threat but moreso from transportation, utility, and development (Mallin 2010).

3.9.7 Additional Information

In 2013, the AFS Endangered Species Committee on freshwater gastropods developed a list of snails in Canada and the United States found in freshwater habitats (Johnson et al. 2013). The Committee's assessment indicates that about 64% of freshwater snails are in some level of imperilment, including 53 species found in North Carolina, and another 10% are considered extinct. More information is available on the USGS website: http://fl.biology.usgs.gov/afs_snail/index.html.

Collections of land snails can be found at a number of museums around the country. Review of those collections will be critical to better verify species identifications and distributions for records pertaining to North Carolina. Collections are available at:

- NC Museum of Natural Sciences, Raleigh, NC. The Invertebrates Collection is worldwide in scope, with emphasis on localities in the Eastern United States. The core of the holdings are collections acquired from state agencies (e.g. NCWRC), the Institutes of Marine Sciences (IMS), a private collection from Herbert D. Athearn, Tennessee which contained over 23,000 lots of freshwater mollusks, and recently a collection from Amy and Wayne Van Devender with over 11,000 specimens of land snaiils. Online catalog http://www.naturalsciences.org/research/invertebrates-collection.

- Field Museum of Natural History, Chicago, IL. The collections of Hubricht are available on the web. https://www.fieldmuseum.org/department/invertebrates.

- Academy of Natural Sciences, Philadelphia, PA. The collections of Henry A. Pilsbry are housed here, which form the basis for the monograph of land snails of North America (see key references).Online https://ansp.org/research/systematics-evolution/malacology.

- Florida Museum of Natural History, Gainesville, FL. John Slapcinsky is conducting work on the family Zonitidae of western North Carolina; computerized collections. Online https://www.floridamuseum.ufl.edu/iz/collection.

- Carnegie Museum of Natural History, Pittsburgh, PA. Tim Pearce has a very large land snail collection which should be reviewed for North Carolina records. Online https://carnegiemnh.org/research/mollusks-malacology.

- Ohio State Museum of Zoology. Tom Watters has a computerized collection of land snails that may contain information on western North Carolina species. Online https://mbd.osu.edu/collections/invertebrates.

The Freshwater Mollusk Conservation Society (http://molluskconservation.org) is dedicated to the conservation of and advocacy for freshwater mollusks, North America's most imperiled taxon. The organization publishes *Walkerana: The Journal of the Freshwater Mollusk Conservation Society*, newsletters, and reports.

A recent publication by Dan Dourson (2013) provides an inventory of the land snails found in the Great Smoky Mountains National Park and Southern Appalachians. Other published resources include older materials such as:

- Bayard Burch J. 1962. *How to know the eastern land snails. Picture-keys for determining the land snails of the United States occurring east of the Rocky Mountain Divide*. Dubuque (IA): William C. Brown Co..

- Bayard Burch J, Shrader Van Devender A. 1980. *Identification of eastern North American land snails. The Prosobranchia, Opisthobranchia and Pulmonata (Actophila)*. Ann Arbor (MI): University of Michigan.

- Bayard Burch J. 1982. *Freshwater snails (Mollusca: Gastropoda) of North America*. EPA-600/3-82-026. Cincinnati (OH): US Environmental Protection Agency, Environmental Monitoring and Support Laboratory.

- Hubricht L. 1985. *The distributions of the native land mollusks of the eastern United States*. *FieldianaZoology*, new ser. no. 24. Available online http://www.biodiversitylibrary.org/bibliography/3329#/summary.

3.9.8 Recommendations

In general, protection and restoration of natural community composition and function and protection of surrounding natural areas are the best ways to ensure suitable habitats are available for this taxon. Measures that protect a large and diverse pool of populations are the best way to ensure that species are able to survive future stresses and adapt to changing climate conditions.

3.9.8.1 Surveys

Distributional and status surveys are needed for every snail species, not just those believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats	
• Conduct a thorough statewide survey to confirm species distributions beyond river basin and county inventories.	
Christy's Elimia	Lapped Elimia
• Continue species distribution surveys for SGCN and knowledge-gap priority species.	
• Continue to explore additional habitats that may be appropriate for reintroduction of federal and state listed species.	
Magnificent Ramshorn	Greenfield Ramshorn

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Conduct surveys for species suspected to be extirpated from the state.

  Carib Fossaria Buffalo Pebblesnail

- Identify uniform data collection and reporting standards that will support periodic status assessments. Use survey methods that provide data needed for trend analyses.

3.9.8.2 Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. These efforts will inform species and habitat management decisions. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with existing monitoring programs where feasible and data sharing is encouraged.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Conduct long-term monitoring to identify population trends.

- Monitor reintroduced population(s) such as Magnificent Ramshorn for continued survival and reproductive success.

  Magnificent Ramshorn

- Monitor known populations that are potentially endemic to the state or otherwise have limited distribution to specific habitats or localities (e.g., high elevations, rock outcrops, isolated wetlands).

Noonday Globe	Big-tooth Covert	Engraved Covert
Tree Thorn	Clingman Covert	Talus Covert
Spiral Coil	Mirey Ridge Supercoil	Smoky Mountain Covert
Roan Covert	Appalachian Gloss	Wandering Globe
Smallmouth Vertigo		

3.9.8.3 Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, impacts of climate change and invasive species, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

  Pilsbryna clingmani *Glyphyalinia solida*

- Review existing collections to verify NC species records. This should include species for which there is uncertainty whether they are native or nonnative to the state.

  Carrot Glass Rosy Wolfsnail
  Corncob Snail Spike Awlsnail

- Continue to refine knowledge of systematics, taxonomy, and genetic structure of all species; conduct much-needed taxonomic review on all snails but especially aquatic species.

  Zonitidae species *Pleuroceriae* species
  Hydrobiidae species

- Focus research on life history of SGCN and knowledge gap priority species, including habitat use/preference, fecundity, population dynamics, feeding, competition, and vulnerability to predation

- Continue to refine captive-propagation and reintroduction techniques for rare snail species (e.g., Magnificent Ramshorn) (Lysne et al 2008).

- Investigate SGCN and knowledge gap priority species considered a host or vector for pathogens or parasites, their prevalence, and pathways for infection of White-tailed Deer and other ungulate species. Studies may include collection and testing of ungulate fecal samples, brain tissue, or vertebral canal tissue (Slomke et al. 1995).

- Conduct population genomics study for SGCN and knowledge gap priority species.

  Waccamaw Ambersnail

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Conduct research to facilitate appropriate conservation actions. Research should focus on life history studies of SGCN and knowledge gap priority species.
• Investigate thermal tolerance for freshwater snails. This will be critical data as climate related temperature increases result in warmer water temperatures.

3.9.8.4 Management Practices

Management practices that reduce habitat impacts and work synergistically with other conservation actions are needed to enhance the resilience of this taxon. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Update and expand hatchery facilities in order to support successful propagation of declining and federal or state protected species.
• Protect and restore native, forested riparian buffers on all waterways. Shading reduces water temperatures and provides detritus that is critical to food webs and cover.
• Track locations of nonnative species populations and document abundance. Chinese Mystery Snail; Apple Snail; Slender Walker Japanese Mystery Snail; Black Velvet Leatherleaf Slug
• Develop an early detection and response plan for nonnative species and disease.

3.9.8.5 Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it increases ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Work with partners to encourage and implement riparian buffer protection and restoration.
• Work with partners to pursue reductions of contaminants and sediment into waterways, as well as implementation of impervious surface and stormwater reduction.
• Raise awareness of invasive species and proactively prevent new introductions through education on decontamination and transport prevention, as well as enforcement of existing regulations.
• Identify and prioritize suitable habitats for protection through acquisition, easements, or buffers.
• Support Scientific Council evaluations used to inform the state listing process. Identify species that likely need to be listed. Rotund Mystery Snail Ridged Lioplax
• Work with the NC Department of Agriculture to identify and develop programs to address nonnative species in the pet trade that could become an invasive species problem if released to the wild (aquarium releases). Red-rim Melania

References are located at the end of this document.

3.10 Insects

3.10.1 Introduction

Insects and other arthropods are the most diverse group of any organisms, plant or animal. The NC General Statutes define insects, for the most part belonging to the taxonomic class Insecta, as any of the numerous small invertebrate animals generally having the body more or less obviously segmented, comprising six-legged, usually winged forms as adults (e.g., beetles, bugs, bees, flies), and other allied classes of arthropods whose members are wingless and usually have more than six legs (e.g., spiders, mites, ticks, centipedes, and sowbugs) (NCGS 106-65.24(12)]. For this section of the SWAP only these groups are considered: Bees, Butterflies and Moths, Dragonflies and Damselflies, Macrobenthic EPTs, and Spiders are discussed,

The ecological significance of insects is great. They play a key role in ecological processes such as primary consumption, decomposition, and pollination. The majority of North Carolina's plant species that are on the state or federal endangered and threatened lists are dependent on insects for pollination. In some cases, specific s insect pollinators may do most of the work and their loss may contribute to the endangerment of the plant. The Rough-leaf Loosestrife (federal and state endangered) may be one such example in North Carolina (Franklin 2001). The current low levels of seed set may indicate that a major, specialized pollinator has been lost.

Insects are a primary food source for many vertebrate species. Endangered species that rely primarily on insects include the Red-cockaded Woodpecker, Virginia Big-eared Bat, Gray Bat, and Indiana Bat. Game species that are largely or partly dependent on insects for food include Wild Turkey, Northern Bobwhite, Ruffed Grouse, and even Black Bear (Landers et al. 1979).

The US has the greatest diversity of freshwater insects in the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), which are commonly referred to as EPTs (Abell et al.2000; Silk and Ciruna 2006). A review of occurrence data recorded in the NHP database indicates there are well over 2,000 species of Lepidoptera (butterflies, moths) known to occur in the state (LeGrand et al. 2014). This group is the best-studied order of insects in North Carolina Equally large, if not larger, numbers can be expected for several other insect orders. Beetles (order Coleoptera) in particular are believed to outnumber all other taxonomic groups in terms of the number of species.

Federally listed insect species are protected under the provisions of the Endangered Species Act, and in North Carolina the USFWS is the lead agency for conservation of these species. Two state agencies are actively involved in long-term insect surveys and monitoring.

- The NC Division of Water Resources (DWR, formerly Division of Water Quality), Biological Assessment Branch conducts aquatic invertebrate sampling as part of widespread monitoring of biological integrity in NC waters. The Biological Assessment Branch uses stream insects (EPTs, beetles) for monitoring water quality and conducts stream surveys across the state on a regular basis. However, DWR biologists do not attempt to determine the conservation concern for any of these species, nor does staff seek protection for insects per se. A benefit of this work is that some stream reaches identified as High-Quality Waters or Outstanding Resource Waters through this process receive a significant amount of protection.

- The Natural Heritage Program (NHP) is the only state agency involved in directly determining the conservation status of individual insect species and other invertebrates and using this information to help guide ecosystem conservation. NHP biologists conduct surveys for a few selected groups including moths, butterflies, grasshoppers, and dragonflies (the results of several of these surveys are available as NHP reports). NHP biologists also collaborate with the DWR Biological Assessment Branch in using survey data to identify rare species of aquatic insects. NHP staff works in partnership with USFWS to conduct status surveys on several species of rare insects such as surveys on the St. Francis' Satyr that led to its being listed as an endangered species.

The NC Department of Agriculture and Consumer Services (DACS) has authority and jurisdiction over those insect species deemed to be pests for plant and forest trees. Otherwise, insects and other non-crustacean arthropods are not protected by state law, nor are other groups of invertebrates except for mollusks and crustaceans. Yet several insect species are among the most endangered of NC species, primarily due to wide use of pesticides, herbicides, and other biological control agents or from the loss of particular types of habitats.

The WRC does not have jurisdiction over species discussed in this section. Most biologists focused on insects are associated with universities or private businesses (i.e., home pest companies, agrichemical and pesticide manufacturers). Knowledge levels and data availability for insects as a group and terrestrial snails are among the lowest of any animal group in the state. However, these taxa are an integral part of the ecosystems they share with other invertebrate and vertebrate species, as well as being vital for agriculture.

Recognizing that insects fall outside the bounds of the WRC's prioritization process used by the Taxa Teams (and described in the White Paper, Appendix 3), we have used recommendations from species experts from federal and state agencies, conservation partners, and universities, and have reviewed NHP occurrence data to identify conservation priorities for insects. We have incorporated species and habitat priorities and conservation recommendations for these groups into the SWAP where possible.

Table 3-10 lists SGCN priority insect species that occur in North Carolina. This list was developed through recommendations from species experts.

3.10.1.1 Aquatic Insects

Inland freshwater covers a very small percentage of the Earth's surface but they provide habitat to almost 100,000 insect species from at least 12 orders that have one or more life stages in freshwater. Aquatic insects spend one or more stages of their life cycles in the water, with the majority living in water as eggs and larvae before maturing into adults and moving to terrestrial habitats. Nearly half of all aquatic insects considered to be true flies (order *Diptera*) are almost exclusively restricted to freshwater by an aquatic larval stage, as are Mayflies, Stoneflies, Caddisflies, Dragonflies, and Dobson flies (order *Megaloptera*) (Suter and Cormier 2014). Often the aquatic larval stage lasts significantly longer than the terrestrial adult life stage (e.g., mayflies)..

Their ecological roles as primary consumers, detritivores, predators, and pollinators have an important influence on both terrestrial and aquatic communities and they can serve as bioindicators of natural community health (Suter and Cormier 2014). Aquatic insects are a primary food resource for many fish and crayfish species. As they emerge from aquatic larvae to adult insects and disperse to surrounding areas they become an important prey resource for terrestrial wildlife (i.e., birds, bats) that forage in riparian areas.

3.10.1.2 Terrestrial Insects

The largest number of insects worldwide are wholly terrestrial species (Deutsch et al. 2008) that have defined life cycle phases and specific foraging requirements for each stage. For instance, insect herbivores and pollinators are likely to have life cycles synchronized to plant phenology. For pollinators such as butterflies and moths this can be crucial (e.g., monarch caterpillars and availability of milkweed) as development outside the period of optimal conditions can have severe fitness consequences for both the insect (missed food resource) and plants (missed pollination, lack of seed set) (VanAsch & Visser 2007, Cornelissen 2011). An estimated 80% of wild plants depend on terrestrial insects for pollination (Ollerton et al. 2011), while 60% of birds rely on terrestrial insects as a food source (Morse 1971, Hallmann et al. 2017).

Most insects are ectotherms, meaning they rely on external sources for temperature regulation. Given that thermoregulation is important for activity and survival for ectotherms (Heinrich 1996, Deutsch et al. 2008), temperature is likely an important mechanism influencing terrestrial arthropod communities at multiple scales (i.e., climatic, altitudinal, latitudinal) and social structures (i.e., colonial species) (Abram et al. 2016, Wong et al. 2019). North Carolina's climate is typically humid and temperate and insects are likely to benefit from warming trends and the increase in number of excessive heat days.

3.10.2 Conservation Concerns

Decline of insects has been increasingly reported worldwide over the last few decades (Dirzo et al. 2014; Hallmann et al. 2017, Homburg et al. 2019, Orr et al. 2023). Invertebrates often have highly specific habitat requirements, much more than is typical for vertebrates. Many insects, for example, have larvae that feed only on a particular host plant. Habitat requirements for these species include host plants as well as habitats for the adult insects. In addition to those considered critically imperiled, many species identified for conservation concern are known from only a single population in the state; are associated with rare plants or unique natural communities; are endemic or known only to occur in North Carolina. Some have highly disjunct populations separated from the rest of their range or the best known populations occur in the state.

In North Carolina, there are two federally listed insect species protected under the ESA: St. Francis' Satyr butterfly (endangered) and Spruce–fir Moss Spider (endangered). The Monarch butterfly has been found to warrant listing for federal protection as a threatened species; the status is pending USFWS regulatory processes. Several at-risk species are under review by USFWS for potential federal protection listing: Southern Plains Bumblebee, American Bumble Bee, Variable Cuckoo Bumble Bee, Frosted Elfin Butterfly, Regal Fritillary, Appalachian Grizzled Skipper, Cherokee Clubtail, Septima's Clubtail, Margarita River Skimmer, Edmund's Snaketail, Smokies Needlefly, and Blueridge Springfly (USFWS 2025d). These at-risk species represent pollinators and species with an aquatic life phase dependent on freshwater systems.

- Data from the website www.DiscoverLife.org (Ascher et al. 2009) indicate that there are more than 3,500 bee species in six taxonomic families in the US. NatureServe Explorer (2025) shows there are 519 bee species with a distribution that includes North Carolina. There are numerous species that are of high conservation concern because they have experienced alarming population declines, especially within the past 20 years. In some cases, local extirpations may explain their absence from parts of their native range. For example, if the long-term declining trend for relative abundance of the Southern Plains Bumble Bee continues, this species could potentially go extinct before the end of this century (Hatfield et al. 2012).

- In 2013, a petition was submitted to request that the Rusty-patched Bumble Bee be listed as an Endangered Species under the ESA. Another species, the Variable Cuckoo Bumble Bee is considered to be critically endangered because the population has declined by more than 80% overall based on historic records, while more current survey data show declines in relative abundance of more than 99% during the past decade (Hatfield et al. 2014). Declines are at least in part due to pathogen infection, habitat alterations and conversion, declines in habitat quality, and exposure to certain types of insecticides and other environmental chemicals.

- The St. Francis' Satyr butterfly is only known from Cumberland and Hoke counties in the Sandhills ecoregion. The larval host of the St. Francis' Satyr Butterfly is sedges (Carex spp.) (Murdock 1996). This butterfly is known to inhabit wide, wet meadows dominated by sedges and other wetland graminoid species. These wetlands are often acidic and ephemeral boggy areas that are relicts of beaver activity. These sites must be continually maintained to prevent woody vegetation from becoming established.

- Spruce–fir Moss Spider occurs in well-drained moss and liverwort mats growing on rocks in well-shaded areas of spruce–fir forests in the Appalachian mountains of North Carolina and Tennessee. As published in the Federal Register (USFWS 2001) the USFWS designated primary elements found in the Pisgah National Forest in North Carolina and portions of the Cherokee National Forest in North Carolina and Tennessee as critical habitat for this species. Within these areas the primary elements considered as critical habitat include the Fraser Fir or fir-dominated spruce–fir forests at and above 5,400 feet elevations. It also includes moderately thick and sheltered mats of humid (not wet) moss and liverwort growing on rocks that have a thin layer of soil or humus between the moss and the rock found under the spruce and fir trees.

- Status surveys conducted on three species resulted in NHP recommendations that Eastern Arogos Skipper be listed as threatened (Hall et al.1999) and that an undescribed species of dusted skipper (*Atrytonopsis* sp. 1) be listed as endangered after its taxonomic status has been resolved (Hall 2003). Results from a status survey for the Venus Flytrap Cutworm Moth indicate that this species be recommended for listing as endangered (Hall and Sullivan 2000, 2004).

- At least three other species are believed to have been extirpated from the state: Regal Fritillary, Eastern Arogos Skipper, and Southern Dusted Skipper. Repeated surveys for these species have failed to detect their presence at sites where they were formerly known to occur. Several other insect species are also known only from historic records but no real surveys have been made.

A complete list of all species tracked by the NHP, including insects, is published in the report "List of the Rare Animal Species of North Carolina" (Ratcliffe et al. 2024). Tracked species include those listed as endangered, threatened, special concern, and significantly rare. The arachnid list is selective of cave and other montane species and is not intended to be a complete list of the rare arachnids in the state. Checklists for arachnids, bees, beetles, butterflies and moths, dragonflies, hoppers and orthoptera are available from the NC Biodiversity Project website https://nc-biodiversity.com/taxonomic-groups.

3.10.3 Knowledge Gaps

Conservation of insects in North Carolina requires more surveys, research, and monitoring of species, as well as management, restoration, and protection of habitat. Our understanding of this group of species is far lower than almost any other animal group in the state because there are few biologists focused on the type of surveys, research, and monitoring activities needed to understand them. They are an integral part of the ecosystems they share with other species and it is important to take advantage of any opportunities to expand our knowledge and understanding when possible.

There are a large number of species that are still too poorly known to estimate their conservation significance. The NHP has undertaken a series of insect inventories in the Coastal Plain ecoregion of North Carolina to bring understanding of the distribution, abundance, and habitat affinities for at least a few important groups of invertebrates. Surveys in the Appalachian Mountains of western North Carolina have discovered new genera of *Apameini* moth (*Cherokeea attakullakulla*) that are highly restricted to their k presumed host plant (Hill Cane, *Arundinaria appalachiana*) that is found in the foothills and lower mountain elevations (Quinter & Sullivan 2014). Insect surveys of longleaf pine preserves have reported five new or yet to be described moth species (*Doryodes bistrialis, Morrisonia triangula, Abablemma* spp.*,* and *Zale* spp). One or more undescribed species are part of species complexes, including the *Crambidia pallida* complex and *Elaphria festivoides* complex (Hall & Schweitzer 1993).

The USFWS listed the Rusty patched Bumble Bee for federal protection as an endangered species in 2017 and North Carolina is within its range. Occurrence records for many bees in the state are from historical records or observation records have not been updated for decades. With the potential for additional federal listings of bumble bee species, WRC collaborated with the Xerces Society in 2021 to address data gaps for bee species. The aim is to collect occurrence data statewide for bumble bees as a means of filling in knowledge gaps. The Southeast Bumble Bee Atlas, a citizen science portal for collecting regional observation data for all Bombus species, was developed and is available online https://www.bumblebeeatlas.org/pages/southeast.

3.10.4 Management Needs

If ecosystem-level conservation planning is to succeed, managers must include invertebrates in site management considerations (Hall 1999a). Wherever possible, management activities should be restricted to only a portion of a given habitat type so that refugia in adjacent areas is provided for all terrestrial wildlife to escape. This is especially true of species associated with ecosystems maintained by frequent disturbances, such as fire, storms, or floods. While vertebrates (and many plants) often have escape mechanisms for coping with unpredictable ecological disruptions, invertebrates typically do not. The only way many insects species survive in habitats maintained by frequent fire, for instance, is through recolonization of recently burned areas from unburned patches of habitat (Hall and Schweitzer 1993). The NHP has developed a set of guidelines for conducting burns in ways that minimize impacts to rare insect populations (Hall and Schwietzer 1993; Hall 1999a).

Management actions that significantly alter some aspect of an ecosystem are likely to have major effects on insects and other invertebrates. The responses of these species to the management actions may be very different than those of plants or vertebrates, the usual intended beneficiaries of the action. In the worst case, a large number of the unknown but important "cogs and wheels" of the ecosystem may be lost as a result of the action. Keeping this in mind, additional rules of thumb will be described below that can help reduce the likelihood of a dire outcome.

Insect populations often undergo extreme fluctuations in numbers, resulting from vagaries in weather or cyclical changes in abundance of their predators or parasites. They are much more prone to local extirpation than either vertebrates or plants. As discussed below, they often survive only where there are enough well-dispersed habitat patches to support metapopulations.

Conservation biologists are just beginning to realize how important metapopulations are for animals in general (Chowdhury et al. 2023). Due to the greater fluctuations their subpopulations experience within a given year or season, invertebrates are often dependent on metapopulation structures. Several insects are believed to have become critically endangered through loss of metapopulation structure, even though habitats within portions of the range of the metapopulations still appear to be high in quality. Examples in the Coastal Plain include the Arogos Skipper, St. Francis' Satyr, and Venus Flytrap Cutworm Moth.

- A metapopulation is composed of a number of subpopulations, each of which may be relatively unstable, some increasing in a given year, others declining to the point of extirpation. As long as movement is possible between the sub-populations, declining populations can be "rescued" by immigration from increasing populations elsewhere within the metapopulation.

- A metapopulation can therefore be much more stable than its parts, at least as long as not all subpopulations are affected by the same set of events.

- Metapopulations are most stable when they are spread over a significant area of the landscape.

Preserves can be regarded as islands of habitat to some degree. They are often chosen for conservation as something special in areas where the rest of the landscape has been significantly altered. All too frequently, preserves contain the only remnants of native ecosystems for miles around. While these preserves are intended to remain "natural," active management is often needed to accomplish this goal, although management, almost by definition, involves some form of artificial disturbance. This disturbance may replace a natural form, such as wildfires, or it may be entirely new, such as spraying an entire preserve with a pesticide to control an exotic pest such as the gypsy moth (Hall 1999a, b).

In cases where a management action affects an entire preserve, as in treatment for gypsy moths, decisions about the scope, intensity, and alternative treatments should be based according to the proximity of refuge areas beyond the boundary of the preserve. Where other, untreated blocks of habitat are located close by, a wider range of management options can be considered. Even in the worst case, where species are extirpated from the preserve, recolonization from outside can still be expected. Where external refuges are located far away, however, management decisions should be based on the worst possible case: irrecoverable losses of species from the preserve.

3.10.5 Threats and Problems

Conservation efforts aimed at protecting native ecosystems offer the best hope for the majority of endangered insect species. Even on lands that have been protected to maintain their natural features, management practices need to take the specific requirements of insects into account.

Long-term threats to insects have commonly been related to habitat loss. However, climate change impacts are rapidly becoming the most significant threats from recurring flood events, especially catastrophic events associated with hurricanes and tropical storms, are significant short-term threats that can result in long term impacts. Flooding events will wash away or destroy eggs, larvae, and pupae of all insect species.

Population growth and subsequent development, especially habitat degradation, fragmentation and destruction, result in impacts to terrestrial and aquatic systems that can affect all insect species. In addition, nontarget impacts of pesticides (insecticides and herbicides) are harming invertebrate (macro and soil dwelling) and vertebrate populations (Larson et al. 2013; Hopwood et al. 2013; Pleasants and Oberhauser 2013; Gibbons et al. 2015).

Introduced pathogens from the commercial bumble bee industry are suspected as potential contributors to significant bumble bee declines throughout North America (Cameron et al. 2011; Colla et al. 2006; Otterstatter and Thomson 2008; Murray et al. 2013). Declines in bumble bee species may be associated with the introduction of pathogens imported on a species of bumble bee reared in Europe and reintroduced for pollination of crops in the United States (primarily for blueberry, cranberry, and greenhouse tomato production) (Cameron et al. 2011).

Some species — particularly butterflies — are sought after by collectors, and overcollection can be a threat in some situations. A giant skipper species, *Megathymus cofaqui*, may have been extirpated from the state due to overcollection. Insect collecting is not regulated under state law, although permits are required in some cases for collecting on public lands (e.g., state parks, game lands, national forests).

Insects themselves can be the source of the threat and nonnatives can present considerable pest management challenges, especially introduced exotics such as the Gypsy Moth and Hemlock Woolly Adelgid (Hanula et al. 1995). Fire ants are a threat to many amphibian and reptile species, especially juveniles as they emerge from their natal habitats (e.g., froglets transitioning from tadpoles). There are numerous insects that pose a threat to agricultural crops while simultaneously providing a food resource for wildlife, especially birds. New nonnative insects, predominantly pest species, frequently enter the state on imported landscape plants or through transportation corridors (i.e., roads, rail, ships).

3.10.6 Additional Information

Given the strategic (not operational) nature of this document, we have not identified population objectives for each and every species mentioned herein. However, conservation and management objectives may have been developed through cooperative efforts of specific conservation partnerships.

Relevant conservation information for federal listed species is available online:

- St. Francis' Satyr https://www.fws.gov/species/saint-francis-satyr-butterfly-neonympha-mitchellii-francisci.
- Spruce–fir Moss Spider https://ecos.fws.gov/ecp/species/4801
- Butterflies of North America (Lotts and Thomas 2014). Northern Prairie Wildlife Research Center webpage http://www.butterfliesandmoths.org. This site provides state-by-state accounts of butterfly species, including information on habitat, range, conservation, management need, global rank, and references.
- Conserving Bumble Bees. Guidelines for Creating and Managing Habitat for America's Declining Pollinators (Hatfield et al.2012). Available from the Xerces Society webpage http://www.xerces.org/wp-content/uploads/2012/06/conserving_bb.pdf.

3.10.7 Recommendations

In general, protection and restoration of natural community composition and function and protection of surrounding natural areas under current conditions are the best ways to ensure suitable habitats are available for amphibian species. Measures that protect a large and diverse pool of populations are the best way to ensure that species are able to survive future stresses and adapt to changing climate conditions.

3.10.8.1 Surveys

Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities. Surveys are needed for all "insect" species.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Establish long-term survey plots on WRC managed public lands for annual survey activities for insect SGCN, especially native bumble bees. Bumble Bees

3.10.8.2 Monitoring

There are few monitoring programs in place for beneficial insects (i.e., pollinators). Long-term monitoring is critical to assessing species and ecosystem health and gauging the resilience of organisms to a changing climate. New monitoring efforts are needed to document insects as the efforts are a crucial first step toward broadly tracking trends in insect abundance and diversity. Using established insect monitoring methods and sharing data will maximize benefits from the information (Montgomery et al. 2021). A successful long-term national monitoring program will generate broadly accessible, continuous, and reliable authoritative data sets that span multiple time periods, sites, and species, and can be used to explore and answer a broad range of questions (Woodard et al. 2020).

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Develop a statewide monitoring program for insect SGCN using consistent methods and making data accessible to conservation partners.		
• Reduce population impacts by using non-lethal methods for collecting data and identifying species (to the extent possible).		
• Focus monitoring programs on SGCN priority species, host plants, and habitats.		
Native bee species	Endemic host plants	Longleaf Pine Savanna
• Participate in national strategies and networks, adopt standardized survey and monitoring protocols, and utilize existing data sets in trend analysis.		
USDA National Native Bee Monitoring Network	SE Bumble Bee Atlas	

3.10.8.3 Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Support research to develop native bee identification capacity and improve capability for taxonomy and systematics.
- Identify optimal survey methods and priority taxa (Woodard et al. 2020).

3.10.8.4 Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Avoid using systemic pesticides such as neonicotinoids, this includes seeds coated with neonicotinoids since can kill wildlife that ingest the seeds and the chemical can contaminate the soil (Hatfield et al. 2012).
- When possible, encourage use of species-specific insecticides to minimize nontarget impacts. Nontarget impacts, particularly to rare species, also need to be carefully assessed any time pesticides (or biological control agents) are applied to natural areas.
- Key natural areas must be protected during large-scale applications of insecticides with broad nontarget impacts. This is especially important in areas where native habitats are restricted in distribution (e.g., maritime and longleaf pine forests) (Hall et al. 1999a).
- Moths and other night-flying insects are particularly impacted by outdoor lighting and where possible, low-voltage, shielded fixtures should be used. Lighting of any kind should be avoided around habitats likely to support rare nocturnal insects (Hall 1999a).
- Native plants serve as habitat and host plants for insects, including many rare species. Use native plants because they are beneficial to pollinators by providing nectar and pollen sources. Perennial plants with purple, blue, or yellow flowers may be preferred by many native bees (Hatfield et al. 2012).

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- When applying management treatments (fire, mowing, herbicides) to habitats, leave one or more adjacent large patches untreated to serve as refugia. When burning areas with bumble bee nests, consider burning no more than one-third of the land area each year and burning specific areas once every three to six years (Hatfield et al. 2012).

  Prescribed Fire

- Do not purchase commercial bumble bees for use outside of the native range of the species. Only use commercial bumble bees in greenhouses. Do not use them for open-field crops. (Hatfield et al. 2012).

- Consider letting fields remain fallow for two to three years as it may allow goldenrod, tickseed, partridge pea, and milkweed to emerge. These native perennials are beneficial for many SGCN and when dormant during winter they provide cover and winter habitat for many beneficial insects.

- Employ Integrated Pest Management (IPM) practices to minimize environmental and non-target impacts from pest management.

3.10.8.5 Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Support the NC Pollinator Conservation Alliance efforts to identify and implement research opportunities that benefit pollinators.

- Coordinate and promote citizen science efforts for pollinator conservation. An example is the Southeast Bumble Bee Atlas project developed in partnership with the Xerces Society.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
SE Bumble Bee Atlas
• Work with the Plant Conservation Program and Natural Heritage Program staff to identify important pollinator habitat, to conduct surveys for rare and declining populations of insects (not just pollinators), and to develop and implement conservation actions to protect the habitat and insect SGCN populations.
• Develop best management practices to enhance habitat and pollinator diversity; make the information available online.
• Support pollinator conservation by providing workshops focused on pollinator topics, technical guidance for best practice recommendations, and sources for native seeds and plants.
• Compile a database detailing pollinator life cycles, any relationships with plants, and best practice habitat management actions that are beneficial for insects.

References are located at the end of this document.

3.11 Pelagic Seabirds

3.11.1 Introduction

Pelagic seabirds spend long periods away from land and obtain all or most of their food from the sea while flying, swimming, or diving (Nettleship 1977, 1991) and come to land only to breed. In general, these species are seen primarily away from the sight of land and thus are typically seen only from boats and ships when in North Carolina offshore waters. Since 1991, the Black-capped, Herald, and Fea's petrels have been recorded annually and photographed on numerous occasions off North Carolina's coast (Brinkley 2012).

The Gulf Stream, a warmwater current that runs roughly parallel to the NC coast, is a critical region for pelagic birds using North Carolina's coastal waters between the months of May and October. The segment offshore from Oregon Inlet to south of Cape Hatteras is especially important due to the interplay with the southbound Labrador Current, which creates an upwelling of nutrient-rich waters.

- Key pelagic species within the Gulf Stream off North Carolina's coast include the Black-capped Petrel and other tubenoses (family Procellariidae). Cold inshore waters are a critical zone during winter. Key pelagic species associated with this region include Northern Gannet and alcids (family Alcidae).

- Bermuda Petrels are endemic to Bermuda and nest on four small islets that provide less than 3.5 acres breeding habitat in the western North Atlantic Ocean. These nesting sites are highly erodible limestone and prone to being overwashed during storms. While they nest in Bermuda they are seen off the NC coast.

- Several other pelagic species have been reported to occur off the NC coast primarily as they travel between breeding grounds and wintering habitats. They are not considered to be "resident" in our waters during either the warmer months or during the winter. Transient species include most jaegers and the Roseate Tern.

- Several pelagic species have been identified as species of concern by the Northwestern Atlantic Marine Bird Conservation Cooperative and ranked by level of concern based on regional, continental, and responsibility concerns (as of 2014, online https://atlanticmarinebirds.org/resources/priority-species-list). Responsibility was based on the proportion of population occurring in the Northwestern Atlantic region (Maine to Florida). Two species, Roseate Tern and Black-capped Petrel, are both federally listed for protection under the ESA as endangered.

The South Atlantic Migratory Bird Initiative (SAMBI) Pelagic Bird Conservation Plan (SAMBI 2008) and the Southeastern Waterbird Conservation Plan (Hunter et al. 2006) are key resources that identify conservation and management actions for pelagic bird species in the southeastern

United States. These plans identify information on ecology and status, priority species, species suites, and habitat requirements, population issues, habitat issues, implementation recommendations and opportunities, conservation strategies, inventory and monitoring needs, research needs, education and outreach needs, and potential partners. Key information taken from those reports is summarized below.

The following sections highlight specific conservation issues related to SGCN and their habitats. This is not an exhaustive list of species-specific conservation concerns but rather highlights some of the concerns in the state. Recommendations for priority survey, monitoring, and research studies, conservation actions, and partnerships are outlined in Section 3.8.

3.11.2 Conservation Concerns

Table 3-20 (Appendix 3) provides a list of SGCN pelagic seabirds based on USFWS, NOAA, and Atlantic Coast Joint Venture priorities. Three seabird species are federally protected by the ESA: Roseate Tern (two distinct populations), Black-capped Petrel, and Bermuda Petrel. Two SGCN species are listed by the International Union for Conservation of Nature (IUCN) as endangered (Bermuda Petrel, Black-capped Petrel). A taxon is listed by IUCN as endangered when the best available evidence indicates that it meets any of the evaluation criteria and is therefore considered to be facing a very high risk of extinction in the wild. IUCN evaluation criteria can be found online at http://www.iucnredlist.org/technical-documents/red-list-documents.

The 2025 State of the Birds (NABCI 2025) report notes American seabird populations are in steep decline. Seabird colonies in low-lying islands are at risk from rising sea levels. Marine heatwaves are disrupting food sources, mortality from bycatch, habitat loss, infectious diseases (i.e., highly pathogenic avian influenza), and microplastic pollutions are contributing to the population declines. Band-rumped Storm Petrel, Bermuda Petrel, and Black-capped Petrel are red-alert tipping point species with extremely low populations and steep declining trends (NABCI 2025).

The South Atlantic Migratory Bird Initiative (SAMBI 2008) is a conservation planning process to implement the Atlantic Coast Joint Venture (ACJV) and a partnership of federal, state, non-governmental, and private organizations and individuals. The SAMBI Pelagic Bird Conservation Plan (2004) and the Southeast United States regional waterbird conservation plan (Hunter et al. 2006) are key resources that identify conservation and management actions for pelagic bird species in the southeastern United States. These plans identify information on ecology and status, priority species, species suites, and habitat requirements, population issues, habitat issues, implementation recommendations and opportunities, conservation strategies, inventory and monitoring needs, research needs, education and outreach needs, and potential partners. Key information taken from those reports is summarized below. The PIF bird conservation plan for the South Atlantic Coastal Plain (Hunter et al. 2001) also presents similar information.

Where appropriate, the recommendations put forth in the SAMBI Plan should be incorporated into pelagic bird conservation efforts in North Carolina by all partner agencies and organizations. Key needs are detailed for Black-capped and Bermuda Petrels, most of which are in the Caribbean (Bermuda, Hispaniola, Lesser Antilles). It should be noted that some of the SAMBI Plan recommendations are not necessarily attainable in North Carolina, but are included below to highlight the need for cooperation and coordination among states and countries to effect change.

The impact that conservation efforts in North Carolina can have on pelagic seabirds is less direct, especially since most of the species do not breed in the state (except the occasional Sooty Tern). Key breeding areas for pelagic species include the Arctic region, the north Atlantic, the West Indies/Caribbean, and other portions of the south Atlantic. Still, all efforts to promote activities that aid in research, management, and conservation of pelagic seabird species should be pursued whenever possible in North Carolina.

3.11.3 Knowledge Gaps

There is strong evidence that seabird bycatch rates vary by fishing fleet and by area (Yeh et al. 2013). In a summary of studies done in the Atlantic Ocean from 1987 to 2006, reported bycatch rates varied from 0.07 birds per thousand hooks in Canadian fisheries in 2001 to 4.7 per thousand hooks for the fisheries of Uruguay in 1993/1994 (Tuck et al. 2011). A lack of observer data from most member countries constrained the International Commission for the Conservation of Atlantic Tunas (ICCAT) Subcommittee on Ecosystems estimate of the annual seabird bycatch for the entire ICCAT area (e.g., Atlantic Ocean) (ICCAT 2010a; Yeh et al. 2013). The United States is a member of ICCAT and actively participates and supports the protocols and research recommendations developed by the organization.

The ICCAT Standing Committee on Research and Statistics (SCRS) reviewed ecological risk assessments of the impact of ICCAT fisheries on sea turtles and seabird bycatch mitigation measures and recently developed a list of research needs. The recommendations for research topics include a need to review whether ICCAT mitigation measures reflect best practices; to develop indicators that can be used to evaluate the efficiency of mitigation measures; and to review the estimation methodologies and compile indirect bycatch mortality estimates for sea turtles (ICCAT 2014).

3.11.4 Management Concerns

address concerns about negative interactions with marine fisheries, the NOAA Fisheries Unit (hereafter NOAA Fisheries) works with the USFWS, regional fisheries management councils and coastal states through the Interagency Seabird Working Group. As a part of this Working Group's effort, in 2001 NOAA Fisheries (also National Marine Fisheries Service, NMFS) began implementing the National Plan of Action for Reducing the Incidental Catch of Seabirds in Longline Fisheries (NMFS 2001). In that same year, an Executive Order established that every federal agency whose actions are likely to impact migratory bird populations negatively must enter into a Memorandum of Understanding with the USFWS (Murphy 2004).

Two specific issues relevant to North Carolina include bird bycatch in gillnets (especially for Red-throated Loon, Common Loon, and Northern Gannet) (Hunter 2004b) and pelagic longline bycatch (especially for Black-capped Petrel, Bermuda Petrel, and Audubon's Shearwater) (Hunter 2004a).

3.11.5 Threats and Problems

Chapter 5 describes 11 categories of threats the Taxa Teams considered during the evaluation and ranking process to identify SGCN; information about the expected scope and severity of the impacts from these threats is available in Appendix 3. Evaluation results for Metric 9 about the expected scope and severity of these threats are available in Appendix 3. The results indicate that the threats most likely to create significant impacts to reptile populations in North Carolina over the next 10 years include the following:

The major issues facing pelagic seabirds in offshore and nearshore waters are conflicts with fisheries, oil and hazardous materials, and debris ingestion and entanglement. Major habitat issues for all species include loss and degradation of habitat and impacts from global climate change. The Southeastern Waterbird Conservation Plan (Hunter et al. 2006) notes pelagic species are vulnerable to conflicts with off-shore fishing gear, colliding with lights on boats and structures during inclement weather, and possibly high mercury contamination in forage (especially fish). Information about threats that require management action is provided in the following paragraphs and in Chapter 5 (Threats).

Fishing Gear. Marine fisheries exact a significant toll on ocean-feeding birds through bycatch – the incidental catching and killing of seabirds. The distribution of many pelagic seabirds overlaps with marine fishing operations making seabird bycatch from longline, demersal longline, trawl, and other pelagic fisheries an important threat (Baker et al. 2007; Watkins et al. 2008; Anderson et al. 2011; Yeh et al 2013). The distribution of many seabird species overlaps with pelagic longline fisheries for tuna, tuna-like species, and sharks (Yeh et al. 2013). The ICCAT reports that fleets from at least 36 countries operating in the Atlantic Ocean were responsible for deploying an average 315 million hooks annually from 2004 to 2008 (ICCAT 2010a; Yeh et al. 2013). ICCAT identified 41 seabird populations of 28 species as being at serious risk from ICCAT longline fisheries (ICCAT 2008). These included one critically endangered, seven endangered, and nine vulnerable species as listed by the IUCN (see IUCN Red List, http://www.redlist.org).

Longlines, gillnets, and other fishing gear can prove fatal (Forsell 1999). In North Carolina, the Red-throated Loon may be the most heavily impacted by gillnets. Excessive bycatch of forage fish as well as fisheries using the same prey used by waterbirds can reduce the birds' food supplies. Trawls that affect the sea bottom alter the habitat on which the prey of seabirds and coastal waterbirds depend.

Seabirds ingest materials and debris as a natural consequence of foraging. Ingesting plastics and other artificial flotsam can be detrimental. Additionally, seabirds are caught in discarded and/or abandoned fishing line, nets, and other waste.

Oil and Wind Energy. Oil is a major environmental threat to pelagic species, especially along major shipping transportation corridors. Oil may be released during platform construction, offshore drilling, and shipping and spillage. Waterbirds are commonly injured by oil spills, chronic oil discharge in bilge water, and release of hazardous materials. Additionally, lights on drilling structures may disorient, attract, or confuse some pelagic birds, resulting in injury or death.

Energy exploration and development off the coast of North Carolina, either for oil extraction or wind, is an emerging hazard that potentially threatens numerous marine and pelagic species, including seabirds. The federal Bureau of Ocean Energy Management (BOEM) is responsible for an offshore wind energy program and has mapped final wind energy areas for lease (see Figure 3-# in Appendix 3).

Habitat Loss. Conflicts with fisheries, oil and hazardous material issues, and offshore pollution contribute to the degradation of foraging habitat for many pelagic species, particularly in shipping channels and areas heavily used by the marine fisheries industry. Mass harvest of Sargassum would affect forage prey base for pelagic species. Harvest or overharvest of Atlantic Menhaden, Atlantic Herring, and other managed prey populations may affect the forage prey base for pelagic seabirds. Seabirds congregate throughout the year, and in non-nesting seasons they congregate at roosts and loafing areas. These sites require both protection and management to maintain their value to seabirds.

3.11.6 Additional Information

In 1999, the United Nations Food and Agriculture Organization (FAO) developed the International Plan of Action for reducing seabird bycatch in longline fisheries (FAO 1999) that called on longline nations to assess their impact and implement mitigation regulations where necessary. Since the development of that plan, best-practice guidelines have been developed to facilitate creation of national plans of action by individual countries and to provide a framework from which to implement those plans at the level of regional fisheries management organizations (FAO 2008; Yeh et al. 2013).

The Agreement on the Conservation of Albatrosses and Petrels (ACAP) was established in 2001 to achieve and maintain favorable conservation status for albatrosses and petrels through research, monitoring, reduction of incidental mortality in fisheries, eradication of nonnative species at breeding sites, reduction of disturbance and habitat loss, and reduction of pollution (Species assessments 2015). Thirteen countries (known as Parties to the Agreement) have joined the ACAP. The United States is not currently a party to the agreement. Recommendations on bycatch mitigation, conservation guidelines, management plans, and data resources may provide information that can be applied to species of regional concern.
Birds Caribbean is an international network that helps partners achieve shared conservation goals, publishes a peer-review journal, and provides a platform for sharing best practices. The

Journal of Caribbean Ornithology is an open source journal published biannually; issues are available online at https://jco.birdscaribbean.org/index.php/jco/issue/archive.

3.11.7 Recommendations

In general, protection and restoration of natural community composition and function, and protection of surrounding natural areas under current conditions are the best ways to ensure suitable habitats are available for these species. Measures that protect a large and diverse group of populations are the best way to ensure that species are able to survive future stresses and adapt to changing climate conditions. Implement conservation measures and recommendations in protected species conservation plans.

3.11.7.1 Surveys

General surveys are needed to complete primary distributional status for all priority species (see Table 3-20, Appendix 3).

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Conduct pelagic bird surveys in areas outside of the Oregon Inlet to Hatteras Inlet region, both in the cold water zone north of Oregon Inlet and the warm waters (including the Gulf Stream) south of Hatteras Inlet.
• Review ultra-high resolution digital imagery collected for offshore wind energy projects using the Remote Marine and Onshore Technology (ReMOTe) data management system to address knowledge gaps about pelagic species.

3.11.7.2 Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to continued impacts to waters of the state. Studies include identification of population trends, as well as assessment of impacts from conservation or development activities. These efforts will inform species and habitat management decisions. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Initiate species-specific monitoring for White-tailed Tropicbird, Audubon's Shearwater, and Roseate Tern.

  Audubon's Shearwater Roseate Tern

- Increase monitoring of seabird bycatch to inform related policy needs; monitor mortality and morbidity of seabirds wherever it occurs.

- Identify and monitor important foraging, migrating, and wintering seabird areas.

- Obtain seasonal population estimates, distribution, and abundance information for seabirds in the southeastern US Continental Shelf.

- Increase monitoring and reporting of stranded seabirds.

  Bird islands Dredge spoil islands

- Obtain seasonal population estimates, distribution, and abundance information for seabirds in the southeastern US Continental Shelf.

3.11.7.3 Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of the histories and status help determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Along South Atlantic coast beaches, research the rates of and reasons for wintering Common Loon mortality. This should help evaluate the risks to seabird populations in this area.

  Common Loon

Priority Conservation Action, Examples of Focal Species or Focal Habitats	
• Establish whether foraging Black-capped Petrels within the Gulf Stream (especially off of Cape Hatteras) are the same as birds concurrently breeding in Haiti (Hunter 2004b).	
Black-capped Petrel	
• Examine the role of commercial fisheries in seabird mortality and review the estimation methodologies and compile indirect bycatch mortality estimates for sea birds (ICCAT 2014).	
• Determine population level effects of oil and hazardous materials on seabirds.	
• Review whether ICCAT mitigation measures reflect best practices (ICCAT 2014).	
• Develop indicators that can be used to evaluate the efficiency of mitigation measures (ICCAT 2014).	
• Examine value of Sargassum to seabirds and the effects of Sargassum harvest to seabird habitat and populations.	
• Assess mercury loads in seabirds	
• Identify key marine habitats.	
• Investigate the value of using offshore metocean data collected for offshore wind energy lease projects. Metocean buoy/TRBM devices use numerous sensors that continuously collect data from tagged animals: nanotag antennas; bird and bat Mic-SM4-Acoustic sensors; Marine Mammal Hydrophone-Loggerhead LS1-Acoustic sensors and Chelonia F-POD; and VEMCO fish tag receivers are examples. https://remote.normandeau.com/uswind_home.php and https://remote.normandeau.com/buoy_overview.php.	
Red Knot Piping Plover Roseate Tern	Spring and Fall migrant passerines

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Along South Atlantic coast beaches, research into the rates of and reasons for wintering Common Loon mortality should help evaluate the risks to seabird populations in this area.

  Common Loon

- Investigate whether foraging Black-capped Petrels within the Gulf Stream (especially off of Cape Hatteras, North Carolina) are the same as birds concurrently breeding in Haiti.

  Black-capped Petrel

- Develop indicators that can be used to evaluate the efficiency of mitigation measures.

3.11.7.4 Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats. In addition, education about and regulation and prevention of the introduction and spread of exotic or invasive species are vital.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Strictly enforce the prohibition of debris, line, and net dumping, especially gillnets and longlines. Methods should be improved for tracing lost or abandoned fishing gear back to owners.

- The policy for elimination of waterbird bycatch in fisheries should be embraced by all fisheries management entities in North Carolina.

NCWRC	NOAA Fisheries	ASMFC
NCDMF	USFWS	

- Protect seabirds from contaminants from ships and off-shore exploration drilling. Minimize oil effects on seabirds through increased enforcement of shipping activities, safe operational procedures, spill clean-up, and rehabilitation of oiled birds.

3.11.7.5 Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Habitat conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Follow the recommendations for education and outreach measures put forth in the North American Waterbird Conservation Plan (Kushlan et al. 2002).

- Follow through on all South Atlantic–Caribbean seabird connections as outlined in the Atlas of Breeding Seabirds of the West Indies to set regional priorities.

- Develop partnerships between seabird conservation efforts and fishery industries and sport anglers.

- Address impacts to seabirds from offshore and inshore fisheries in all future fishery plans.

- Consider specifying forage fish allocations of species used by seabirds as prey, within appropriate Fisheries Management Plans (FMPs).

- Develop cooperative relationships with partners and organizations collecting scientific data and implementing conservation actions focused on pelagic species.

Avian Research and Conservation Institute (ARCI)	Movebank (NCMNS partner)

References are located at the end of this document.

3.12 Marine Species

3.12.1 Introduction

Marine and pelagic species were not directly prioritized during the Taxa Team evaluation process primarily for reasons of jurisdictional limitations and lack of information. However, marine species and habitats are a critical resource for North Carolina, and the management and conservation of those resources are high priorities. The information provided in this section was developed by reviewing existing information sources on marine and pelagic species and habitats and through review and input by partner organizations that are directly responsible for managing these resources. Pelagic bird species are addressed as a separate topic in Section 3.11.

Note that sea turtle species were evaluated by the Reptile Taxa Team because they use terrestrial habitats (beaches) for nesting; therefore, sea turtles are also included in the reptile SGCN list (see Section 3.8 and Table 3-7 in Appendix 3) .

3.12.2 Regulations

The management and protection of migratory, pelagic, or other marine species fall under a host of jurisdictions in North Carolina depending on the location of the species at a given point in time. Similarly, there is inter-jurisdictional responsibility for management of coastal, estuarine and marine habitats that are critical to marine species survival. This presents a constant challenge to resource managers because coordinated efforts among multiple agencies are necessary to manage the fish and wildlife resources of the state effectively.

Four agencies have jurisdiction and authority over particular estuarine and marine (aquatic) species in the state; two are federal agencies and two are state agencies:

- National Oceanic and Atmospheric Administration (NOAA) Fisheries
- US Fish and Wildlife Service (USFWS)
- NC Division of Marine Fisheries (NCDMF)
- NC Wildlife Resources Commission (NCWRC), when the species are in inland or joint waters.

3.12.2.1 Federal Regulations

Under the Marine Mammal Protection Act (MMPA), all marine mammals are protected from take in US waters and by US citizens on the high seas, and marine mammals and marine mammal products are prohibited from importation into the US.

The NOAA Fisheries is responsible for the management, conservation, and protection of living marine resources within the US Exclusive Economic Zone (three to 200 miles offshore), including sea turtles, marine and anadromous fish, plants and invertebrates, cetaceans, and pinnipeds. The NOAA Fisheries jurisdiction also extends into state waters for protected marine species. Central to that mission are the objectives to protect ocean, coast, and Great Lakes resources, to recover protected species, and to rebuild and maintain sustainable fisheries.

The NOAA Fisheries Office of Protected Resources (OPR) is charged with the implementation of the Endangered Species Act (ESA) of 1973 for marine and anadromous species. The OPR develops, implements, and administers programs for the protection, conservation, and recovery of species protected under the ESA. This office also develops and implements policies, procedures, and regulations for permits to take (harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect) listed species according to the ESA. The NOAA Fisheries has developed and is responsible for implementation of recovery plans for threatened and endangered marine species.

- Recovery plans are available for several species from this webpage: http://www.nmfs.noaa.gov/pr/conservation/ https://www.fisheries.noaa.gov/resources/all-publications.

- In addition to these plans, marine mammal stock assessment reports for all Atlantic species are available from the following webpage: https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-stock-assessment-reports.

NOAA Fisheries, Highly Migratory Species Division manages Atlantic highly migratory species (HMS), including tunas, sharks, swordfish, and billfish, and implements the Fishery Management Plans (FMPs) for Atlantic tunas, swordfish, and sharks. Management of HMS requires international cooperation, and rebuilding programs must reflect traditional participation in the fisheries by US fishermen, relative to foreign fleets.

Along with the Magnuson–Stevens Act, US fisheries management must be consistent with the requirements of other laws, including the Atlantic Tunas Convention Act, Marine Mammal Protection Act, the Endangered Species Act, the Migratory Bird Treaty Act, and several other federal laws.

3.12.2.2 State Regulations

North Carolina is a member of the Atlantic States Marine Fisheries Commission (ASMFC). The ASMFC represents the 15 Atlantic coast states as a deliberative body, coordinating the conservation and management of shared nearshore (within state waters) fishery resources (marine, shell, and anadromous species) for sustainable use. The ASMFC promotes interstate fisheries management, law enforcement, research and statistics, fisheries, science, and habitat conservation.

The NCDMF is responsible for the stewardship of the state's marine and estuarine fisheries resources and the agency's jurisdiction encompasses all coastal waters and extends to three miles offshore. The agency actively participates in federal and regional management of migratory species by providing technical guidance, assisting with coastwide or regional fishery management issues, and working cooperatively with other state and federal agencies.

3.12.3 Conservation Concerns

Table 3-21 provides a list of marine SGCN based on USFWS and NOAA priorities. Some federally protected species, such as sea turtles, receive significant attention when nesting on our beaches, but the majority of their lives are spent at sea. The USFWS is responsible for sea turtles when they are on land, including nesting females, their incubating eggs and emergent hatchlings. The NOAA Fisheries Office of Protected Resources (OPR) establishes cooperative agreements with states regarding listed marine species management and protection and identifies endangered species research needs to collect appropriate information for management decisions. For example, NOAA Fisheries has a cooperative agreement with NCWRC regarding sea turtle strandings in North Carolina coastal waters.

NOAA Fisheries grants at-risk marine mammal species a variety of protection levels under the ESA and the MMPA. Among these are endangered status, threatened status, and depleted status. Under the MMPA, a species is designated as depleted when it falls below its optimum sustainable population. Once a species has been designated as depleted, a conservation plan is developed to guide research and management actions to restore the health of the species. Similar levels of federal and state listings such as MMPA Depleted or the state Significantly Rare (SR) designation indicate conservation concern for marine species (NHP).

Musick et al. (2000) identified marine, estuarine, and diadromous fish stocks at risk of extinction in North America. While the North Carolina coast is not identified as a "hotspot" for species at risk, our coastal waters fall within the potential range of 17 species listed in the publication - seven of which do not carry any protection status.

The IUCN has listed several marine species on their Redlist (IUCN 2025) as Critically Endangered, Endangered, Near Threatened, or Vulnerable for species whose current or historical range includes North Carolina coastal or offshore waters. The list of species includes several sharks, skates, and paddlefish as well as other groups.

Some of the species discussed above may also be found in estuarine or inland waters (e.g., Diamondback Terrapin, West Indian Manatee, anadromous fish) or on North Carolina beaches (e.g., sea turtles). Others not directly mentioned may also use marine or estuarine environments (e.g., beach-nesting birds). For those typically marine species that are also associated with coastal estuaries and beaches or that travel into inland waters, we have addressed appropriate conservation needs within those particular habitat types (see Chapter 4 Habitats).

3.12.4 Knowledge Gaps

There is great need to continue cooperative efforts among regulatory and management agencies to expand our understanding of and protection for those species. Surveys, monitoring, and research of estuarine and marine species is difficult, making the collection of data, the synthesis of information, and the protection of those species that much more challenging.

The results of a peer-review journal database search indicates there have been few recent publications of systematic status surveys or accounts of species rarity or distribution for marine or estuarine fish species in the state. The work by Trindade-Santos et al. (2022) uses rarity metrics to assess rarity of bony and cartilaginous marine fish species in general, considering the extent to which species exhibit rare combinations of traits and being geographically restricted (Trindade-Santos et al. 2022). The IUCN Redlist (IUCN 2025) includes several data deficient marine animals, primarily cephalopods and pipefish species.

3.12.5 Management Needs

The FMPs developed by regional Fishery Management Councils (FMCs) for species commercially and recreationally harvested are implemented by NOAA Fisheries Regional Offices. North Carolina is a member of two fishery management councils: the Mid-Atlantic Fishery Management Council (MAFMC) and the South Atlantic Fishery Management Council (SAFMC).

- The MAFMC is responsible for management of fisheries in federal waters that occur predominantly off the mid-Atlantic coast from North Carolina to New York. The FMPs for NC marine resources can be found online at the MAFMC website http://www.mafmc.org.

- The SAFMC is responsible for the conservation and management of fish stocks within the federal 200-mile limit of the Atlantic, off the coasts of North Carolina, South Carolina, Georgia, and Florida (east coast only to Key West). The SAFMC resource library provides FMPs for species managed by the Councils, including coastal migratory pelagics (mackerels), bluefish, flounder, and shrimp, as well as marine habitats. http://safmc.net.

North Carolina's DMF is also responsible for preparing interstate FMPs for adoption by the state Marine Fisheries Commission (MFC) for all commercially and recreationally significant species or fisheries that comprise state marine or estuarine resources. The goal of these plans is to ensure long-term viability of these fisheries. The NCDMF has reviewed the FMP (NCDMF 2023) which updated FMPs for managed species.

The NCDMF Habitat Protection Section is responsible for the development of the Coastal Habitat Protection Plan (CHPP) (NCDEQ 2021) to conserve and protect important marine fisheries habitat (see Chapter 4 for more information on estuarine habitats).

3.12.6 Threats and Problems

The successful conservation of marine species will require the mitigation of threats both within North Carolina's borders and beyond. Thus, interstate and international partnerships and cooperation are critical components of marine species conservation. Descriptions of the threats listed below were taken from various marine species recovery plans and peer-reviewed journal publications.

Fishing pressure and climate change are known threats to fish functional diversity and rarity that have synergistic impacts (Trindade-Santos et al. 2022). Climate change is causing marine heatwaves, periods of abnormally high ocean surface temperatures, with the frequency of heatwave events increased over 20 times historical rates (Laufkötter et al. 2020). Assessments highlight the predominantly negative impacts of climate change on marine ecosystems and fisheries such as range shifts, reproductive failure, and increased mortalities (Cheung et al. 2022). Cheung et al. (2022) notes the combination of heatwave events and decadal-scale climate change can lead to long-term changes in fish stocks and fisheries that will be difficult to recover. Negative impacts include both short- and long-term reductions in phytoplankton biomass, decreases in forage fish species, declines of piscivorous marine bird species, and negative trends in marine mammal populations (Suryan et al. 2021, Tittensor et al. 2021).

3.12.6.1 Nesting Threats (Terrestrial Habitats)

These onshore threats primarily impact beach-nesting sea turtles and birds.

- *Artificial lighting* – Nighttime lighting associated with beachfront development (residences, street lights, vehicles) can severely impact emerging hatchlings by causing misorientation, which drastically increases fatalities. Artificial lighting can attract nesting females and hatchlings, causing them to move in the opposite direction of the water, which then exposes them to predators, entrapment in vegetation, and/or vehicle strikes. Adult nesting sea turtles may abort nesting attempts at greater frequencies near lighted areas.

- *Beach cleaning* – Mechanical raking (using heavy machinery) can compact or destroy incubating eggs and/or emergent hatchlings. Disposal of debris near the dune line can cover incubating clutches, entrap emergent hatchlings, and/or alter nest temperatures.

- *Beach erosion* – Erosion can result in partial or total loss of suitable nesting habitat. Coastal development and associated activities have accelerated erosion rates and interruption of natural shoreline migration.

- *Beach nourishment/renourishment* – If nourishment occurs during nesting season, direct impacts can include burial of nests and nest disturbance. Dissimilar sand sources can impact site selection, digging behavior, incubation, and hatchling success. Beach nourishment can also result in significant compaction or concretion of the beach.

- *Exotic dune and beach vegetation* – Nonnative vegetation can out-compete native vegetation such as sea oats and dune grass. Often less stabilizing, nonnative vegetation can lead to erosion and degradation of nesting habitat.

- *Increased human presence* – Disturbance to nesting sea turtles and emerged hatchlings is the most critical threat caused by human presence on beaches. Night-time human activity can cause female turtles to abort nesting attempts, and can misorient hatchlings with personal artificial lights.

- *Military exercises* – Training activities on coastal shorelines have the potential to disrupt nesting behavior and increase non-nesting emergences of nesting females, run over nesting females and emerging hatchlings, and destroy nests.

- *Nest depredation* – Predation by ghost crabs, raccoons, foxes, or fire ants (among others) is a significant threat to eggs and hatchlings (both sea turtle and shorebirds). *M*isorientation of emergent hatchlings by artificial lighting increases their chances of being depredated by one of these animals.

- *Poaching* – Illegal harvest of eggs (primarily sea turtle) from nests is unlikely but does occur.

- *Recreational beach equipment (especially onshore vehicular driving)* – Beach chairs, tents, and other recreational equipment can directly impact nests (covering or disturbing incubating nests) or indirectly cause disturbance such that female turtles abort nesting attempts. Vehicle use on beaches has similar effects to heavy machinery used in beach-cleaning efforts (compact or destroy nests, entrap hatchlings); vehicle lighting can disorient hatchlings and adults alike. Sea turtle mortality in North Carolina has resulted from being run over by vehicles driving on the beach.

- *Shoreline modifications* – Fortifications put in place as a result of shoreline development (including sand fences, sea walls, rip rap, groins, jetties, hay bales) can accelerate beach erosion rates and reduce available nesting habitat; improperly placed drift fences can impede nesting attempts and/or trap hatchlings or nesting female sea turtles.

3.10.6.2 Marine Threats (Essential Fish Habitats)

These threats are water related and may impact sea turtles, fish species, and marine mammals.

- *Dredging* – Dredging can result in direct destruction or degradation of habitat and/or incidental take of marine species. Channelization of inshore and nearshore habitats can result in the disposal of dredge material on beaches and shallow habitats, impacting nesting success or foraging grounds.

- *Entanglement* – Marine species can become entangled in a variety of materials other than active fishing gear, including steel or monofilament line, synthetic or natural rope, or discarded plastic material, often resulting in injuries which can lead to weakened individuals who are more susceptible to death by other factors, or to direct mortalities.

- *Fisheries* – Bycatch of marine organisms occurs in a number of different fisheries, including trawl, purse seine, hook and line, gill net, pound net, long-line, and trap fisheries. When managed properly these gears can have low mortality or injury rates. Without directed management of fishing gear, these interactions may lead to serious injury or death.

- *Ingestion of marine debris* – Marine species may ingest a variety of potentially harmful debris materials, including plastic bags, balloons, styrofoam, and tar balls. Effects of debris ingestion can include obstructions of the gut, absorption of toxic byproducts, and reduced absorption of nutrients. Microplastic ingestion has been documented in nearly all marine speices that have been investigated, although the impacts of this exposure remains poorly understood.

- *Noise* – The impacts of noise from shipping, industrial, construction activities, or military activities on the communication, behavior, and distribution of whales and other marine species remains unknown, but is suspected to be significant.

- *Oil and gas exploration* – Oil spills have been shown to impact respiration, blood chemistry, and salt-gland function in sea turtles, not only from exposure to oil but also to dispersants commonly used in response to oil spills. Spills in the vicinity of nesting beaches can place nesting adults, eggs, and hatchlings at significant risk. Oil deposits on the ocean floor can reduce food sources for all marine species and result in ingestion of tar balls. In addition to suffering effects from spills, sea turtles and other marine species can be negatively impacted by seismic surveys, operational discharge containing heavy metals, explosive platform removal (mentioned below), platform lighting, and noise from drill ships and production activities.

- *Poaching* – Illegal harvest of marine species has declined considerably since the development and enforcement of protection regulation; however, arrests are still made for illegal capture and possession of marine species.

- *Pollution* – Pesticides, polychlorinated biphenyls (PCBs), and heavy metals have been detected in marine species, though levels that result in adverse effects are difficult to quantify.

- *Power plant entrainment* – Saltwater cooling intake systems at coastal power plants have been reported to entrap marine species, including sea turtle.

- *Underwater explosions* – Use of underwater explosives to remove abandoned oil platforms, for military activities, or for oil exploration can result in injury or death to marine species in the vicinity of the explosion.

- *Vessel interactions (including collisions)* – Propeller and collision injuries are a significant threat, especially to marine mammals and sea turtles. These types of injuries are reported at higher frequencies in areas that have heavy boat and vessel traffic.

3.12.7 Additional Information

Recovery plans are available for the following federally listed species that can be found in North Carolina coastal or offshore waters (NOAA 2025). Recovery plans for federal listed marine species can be accessed at https://www.fisheries.noaa.gov/national/endangered-species-conservation/recovery-species-under-endangered-species-act.

- Green Sea Turtle
- Leatherback Sea Turtle
- Loggerhead Sea Turtle
- Kemp's Ridley Sea Turtle
- Hawksbill Sea Turtle
- Shortnose Sturgeon
- Right Whale
- Humpback Whale
- Fin/Sei Whale
- Sperm Whale

Take reduction teams (TRTs) have been formed and convened with the purpose of developing take reduction plans to assist in the recovery or to prevent the depletion of strategic marine mammal stocks that interact with various commercial fisheries. A strategic stock is one which is listed as endangered or threatened under the ESA, is declining and likely to be listed as threatened under the ESA, is listed as depleted under the MMPA, or has direct human-caused mortality exceeding the stock's Potential Biological Removal level (see Glossary). These TRTs consist of a balance of representatives from the fishing industry, fishery management councils, state and federal resource management agencies, the scientific community, and conservation organizations. To date, several TRTs have been established and represent Atlantic coast resources.

More information on the TRTs and the take reduction plans developed for marine mammal stocks can be found online at the NOAA Fisheries webpage https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-take-reduction-plans-and-teams.

Several managed species FMPs are available for Atlantic highly migratory species and can be found on the NOAA Fisheries webpage https://www.fisheries.noaa.gov/topic/atlantic-highly-migratory-species.

The International Union for Conservation of Nature (IUCN) is a worldwide network whose members represent both government and civilian society organizations that are global authorities on the status of the natural world (IUCN 2025). The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) resulted from an IUCN resolution that is an international agreement between governments. Its aim is to ensure that international trade in specimens of wild animals and plants does not threaten the survival of the species (UNEP-WCMC 2025). Species listed on CITES Appendix I, II, or III are afforded different levels or types of protection for over-exploitation.

- Appendix I lists species that are the most endangered among CITES-listed animals and plants. They are threatened with extinction and CITES prohibits international trade in specimens of these species except when the purpose of the import is not commercial (e.g., scientific research).

- Appendix II lists species that are not necessarily now threatened with extinction but that may become so unless trade is closely controlled. It also includes species that look like species listed for conservation reasons (i.e., in trade they look similar).

- Appendix III is a list of species included at the request of a CITES member that already regulates trade in the species and that needs the cooperation of other countries to prevent unsustainable or illegal exploitation. International trade in specimens of species listed in Appendix III is allowed only on presentation of the appropriate permits or certificates.

3.12.8 Recommendations

In general, protection and restoration of natural community composition and function and protection of surrounding natural areas under current conditions are the best ways to ensure suitable habitats are available for marine species. Measures that protect a large and diverse pool of populations are the best ways to ensure that species are able to survive future stresses and adapt to changing climate conditions.

The following recommendations apply broadly to all efforts toward marine species conservation.

3.12.8.1 Surveys

Distribution and status surveys should focus on SGCN and other priority species believed to be declining or dependent on at-risk or sensitive communities. Specifically, efforts to develop more precise population estimates for all marine taxa are needed.

3.12.8.2 Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to continued impacts to waters of the state. Studies include identification of population trends, as well as assessment of conservation or development activities. These efforts will inform species and habitat management decisions. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

3.12.8.3 Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of the life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration for priority species. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Conduct genetics research to further understand stock structure and breeding population contributions in North Carolina and beyond, especially for Bottlenose Dolphin, Pilot Whale, and Loggerhead and Green sea turtles.

Loggerhead Sea Turtle	Bottlenose Dolphin
Green Sea Turtle	Pilot Whale

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Examine pollution effects on coastal and estuarine species.		
• Continue to incorporate climate and ecosystem considerations into Essential Fish Habitat (EFH) and Habitat Areas of Particular Concern designations, National Environmental Policy Act Reviews, restoration planning, and other management actions and products (Quinlan et al. 2023).		
• Continue and expand incorporation of climate-related information and uncertainty into protected species reference points and related ESA actions (i.e. incidental take recommendations, biological opinions, listing, recovery, critical habitat designation) in a consistent manner across the Southeast region (Quinlan et al. 2023).		
• Develop maps showing the expected future head of tide in priority watersheds, the expected distribution of Essential Fish Habitat and projections for hydrographs for rivers in which NOAA Fisheries trust resources are affected or NOAA needs to do an EFH or ESA consultation (e.g., Catawba River shad and blueback herring populations, Atlantic and Shortnose sturgeon; Roanoke ad Chowan Rivers shad and striped bass) (Quinlan et al. 2023).		
Shad	Atlantic Sturgeon	Catawba River
Blueback Herring	Shortnose Sturgeon	Chowan River
Striped Bass		Roanoke River
• Compile data on temperature (evapotranspiration), precipitation, and river discharge for use in evaluating impacts on EFH and protected species (Quinlan et al. 2023).		
Estuarine Habitats	Coastal Waters	
• Study the impacts of climate change on changes in freshwater (rainfall, river flows, water use conflicts) as it affects marine mammals, sea turtles, sturgeon, and sawfish. Changes in salinity may impact marine mammals and sea turtle health and habitat suitability (Quinlan et al. 2023).		
Sea Turtles	Sturgeon	Sawfish
• Assess impacts of increasing temperatures on sea turtle sex ratios (Quinlan et al. 2023).		
Sea Turtles		

- Study the impacts of a changing climate (increasing ocean temperature and acidification, shifts in trophic structure, increasing frequency and severity of tropical storms) and their effect on sea turtle nesting and sturgeon populations (Quinlan et al. 2023).

  Sea Turtles Sturgeon

- Conduct post-disaster (hurricanes, freshwater intrusion events, harmful algal blooms) assessments to include research on disaster impacts and identify key areas of vulnerability for fisheries and protected resources (Quinlan et al. 2023).

- Develop models to predict changes in managed fish populations due to climate change including changes to species' distribution, movement, and reproductive patterns.

3.12.8.4 Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats. In addition, education about and regulation and prevention of the introduction and spread of exotic or invasive species are vital.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Support the implementation of FMPs to manage and protect marine species.
• Implement public education and other efforts to reduce discarded "ghost" fishing gear to reduce marine species entanglement; provide a fishing line recycling program.
• Improve communications and coordination with other NOAA offices, state and federal marine resource agencies, and universities to combat common threats and develop efficient and effective conservation strategies for all marine species and their habitats.

3.12.8.5 Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. This improves chances of achieving conservation goals, improves efficiency, and prevents duplication of effort.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Continue and expand cooperation between NOAA Fisheries and the appropriate state agencies to facilitate marine species management, protection, and research, especially for listed species.

- Support and assist in the attainment of the goals, objectives, strategies, and performance measures set forth in all NOAA Fisheries Strategic Plans (SPs).

  National Seabird Program SP | SE Fisheries Science Center SP (Peterson and Walter 2023) | Marine Aquaculture SP

- Support the recommendations in the CHPP (NCDEQ 2021) to promote fisheries habitat protection in North Carolina and to facilitate the necessary policy decisions.

- Coordinate between NOAA Fisheries and NCDMF to evaluate interactions between marine mammals, sea turtles, and fishing gear and develop gear modifications where needed.

  Marine Mammals | Sea Turtles

- Continue cooperation with fisheries resource managers, commercial fishermen, and regulatory agencies to reduce bycatch and unintentional take of protected marine resources (e.g., explore Diamondback Terrapin bycatch in crab pots).

  Diamondback Terrapin

References are located at the end of this document.

This page intentionally blank for double-sided printing

3.13 Plants

The term "habitat" is used in this SWAP to describe the natural communities and their components that sustain individual plants and animals, discrete populations, or taxonomic groups. Habitats are considered the sum of all the resources a species needs to survive and persist (Hall et al. 1997) and are made up of many biotic and abiotic components that are too numerous and diverse to describe in this document.

Many, if not most, of the terrestrial natural communities in North Carolina are composed primarily of plants and, depending on the natural community type, composition will include a range of woody trees, shrubs, herbs and forbs, grasses, non-vascular plants, and composite organisms. Further, plants are fundamental elements of wildlife habitat, providing food, shelter, sites for reproduction, structures for resting and hunting, and often much more, depending on the species or taxonomic group. For example, many wildlife species, such as insect pollinators, butterflies, and moths, are adapted to rely on specific host plants to complete their life cycle.

Since plants are rooted within their landscape position, they are at greater risk to direct impacts from threats when compared to wildlife that are better able to move across the landscape to other areas. Considering this, it is important to support conservation of North Carolina's native plants considered to be Species of Greatest Conservation Need (SGCN) to preserve genetic diversity and seed sources, especially those limited to small, isolated, or fragmented populations.

3.13.1 Introduction

The North Carolina Natural Heritage Program (NCNHP) maintains a statewide inventory of native plant species that are rare, in decline, believed to have been extirpated, or presumed extinct. The inventory is maintained with current data and an updated *Rare Plant List* is published every two years, making it easy to compare the level of current knowledge about a species' conservation status over a relatively short time frame. The most recent version of the *Rare Plant List* (NCNHP 2024) lists over 4,900 native plant species for the state. The majority of these are vascular plants, with the remainder including non-vascular and composite organisms that are lichens, mosses, liverworts, and hornworts. Approximately 18% of the native plant species occurring in NC are tracked by the Natural Heritage Program as state listed endangered, threatened, special concern, or significantly rare, indicating the need for high conservation concern for these rare and at-risk plant species.

In most cases, common names are used throughout this document to identify a species. Exceptions include pest species and species for which there is taxonomic uncertainty or when common practice is to use a form of the scientific name as the common name; in those instances, the scientific name may be used to identify the species. Scientific names for all plant SGCN are provided in Table 3-13 in Appendix 3.

3.13.1.1 Federal Regulations

One of the most important protective measures for conservation is the Endangered Species Act (ESA) of 1973, designed to protect and recover endangered and threatened species of fish, wildlife, and plants within the United States and its territories. Currently, there are 27 plant species known to occur in North Carolina that are listed by the US Fish and Wildlife Service (USFWS) for federal protection under the ESA (USFWS 2025).

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is an agreement between international governments to protect wild plants and animals from becoming threatened or endangered from international trade (CITES 1975). The United States is a participating member nation. Protection is afforded through listing of a species in one of three lists, or appendices (CITES 2021).

- Appendix I provides the highest protection, limiting any trade of a species on the list only to exceptional circumstances because they are threatened with extinction.
- Appendix II controls trade of species that are at higher risk when trade could be incompatible with their survival.
- Species included in Appendix III are protected in at least one country that is party to the convention and CITES has been asked for assistance in controlling trade of the species.

There are 15 plants identified as SGCN that are included in CITES Appendix II; four are in the Order *Nepenthales* and 11 are in the Order *Orchidales*. There are no other plants from North Carolina listed in other CITES appendixes.

3.13.1.2 State Regulations

The N.C. Nature Preserves Act enacted in 1985 (NCAC 1985: a.2 c.143B §49-§135.273) allows the State to obtain and dedicate land as permanently protected nature preserves. North Carolina's Department of Agriculture and Consumer Services, Plant Conservation Program (PCP) was authorized by the Plant Protection and Conservation Act (NCAC 1979: a.19B c.106 §202.12-§.202.22) to manage plant conservation in the State including adopting a state list of protected plant species, adopting and enforcing regulations that protect, conserve, and enhance those listed species, and developing conservation programs for the benefit of listed species.

The PCP is responsible for managing more than 14,500 acres of conservation preserve properties across the state (Friends of Plant Conservation 2021). These preserves provide critical conservation for about 18% of the listed plant species in North Carolina. Additional plant protection is provided by legislation that protects land from criminal trespass (NCAC 2014: a.22 c.14 §126-§159.4) and prohibits taking of certain wild plants from private or public land without a permit issued by the owner.

3.13.2 Evaluation and Identification of Plant SGCN

As noted in earlier sections of this chapter, conservation priorities need to consider the greatest variety of biological diversity possible to ensure species survival and viable ecosystem services. Similar to methods used by the taxonomic Scientific Councils convened by the NCWRC's Nongame Wildlife Advisory Committee, the PCP convenes a Scientific Committee to evaluate, identify, and recommend plant species that need protection through state listing. The evaluation process considers the rarity, threats, and short-term trends of every species tracked by the NCNHP. The methodology involves broad participation by species experts and provides opportunities for public input through a 60-day comment period. The species evaluation process and a list of participants involved in developing and implementing the evaluation process are described in a white paper provided in Appendix 3 as Reference 3-3. Habitat associations for plant SGCN are provided in Appendix 3 Table 3-22.

3.13.3 Conservation Concerns

Most at-risk plants in North Carolina are endemic species and species with small, isolated populations limited to narrow distributions in insular and highly fragmented habitats (Cartwright 2019). As part of the PCP Scientific Committee's evaluations, a threats analysis is performed for plant species which considers each population as a discrete unit. In this way the viability of each population is considered by the Committee and the overall species' viability is assessed by reviewing the status of the populations within the state. It is understood that some imperiled or rare species in North Carolina might be more common elsewhere; however, each species' viability within the state is considered at face-value in the interest of maintaining our state's biodiversity.

For species with very small populations, the long-term viability is highly questionable. Small populations tend to suffer from genetic loss which can lower the overall fitness at the population and even species level within a region. By tracking population viability, the NCNHP's database of rare plant populations helps conservationists to prioritize species and populations within species' ranges which are at elevated risk of loss unless population sizes increase. Conservation efforts that support population increases often requires mitigation of more than one threat.

Historical populations of rare species continue to be tracked by NCNHP for two primary reasons. First, historical populations can help us understand the full range and distribution of species as they undergo losses or range changes. Second, it is possible that historical populations can be rediscovered at or near known records during future surveys when environmental conditions are suitable. Most often these rediscoveries occur after appropriate land management is conducted to rehabilitate the habitat at a site, but sometimes a resurvey simply turns up previously undetectable individuals for unknown reasons.

3.13.4 Knowledge Gaps

Beginning in 1982, the NCNHP's county inventory biologists systematically studied the ecology of each county, conducting biological inventories of natural areas and maintaining a database of high-quality natural communities and rare species occurrences. Since the first county inventory was complete (Dare mainland), 97 of North Carolina's 100 counties have been comprehensively inventoried by NCNHP biologists (only Clay, Swain, and Wilkes have not been completed as of 2021). After completion of the initial county inventories, biologists in the NCNHP and partners including Wildlife Resources Commission, Division of Parks and Recreation, and Plant Conservation Program and many others, update the state's natural heritage inventory regularly as new lands are acquired for conservation and through partnership monitoring efforts.

However, even with the collaborative efforts of field biologists working across North Carolina, many species and habitats remain under surveyed due to lack of staff resources or difficulty of access. For this reason, some species are considered "data deficient" and were not included in the SGCN priority list. An ongoing need exists for additional surveys and monitoring of species included in the SGCN list to keep the dataset current and complete, as circumstances change due to natural processes and human impacts to the landscape.

Populations that have not been inventoried in more than 30 years (on average) are considered "historical". Where species occur in rapidly developing urban areas, species may be considered "historical" if they have not been observed in greater than 20 years. This difference is due to the likelihood of local extirpation caused by habitat conversion.

The NCNHP and partners obtain permission from landowners before conducting any biological inventories on private land. In many areas, staff biologists recognize the high likelihood of rare species or natural community occurrences on private land where they are unable to obtain survey permission, these areas represent knowledge gaps in the dataset (data deficiencies).

3.13.5 Management Needs

Management needs for rare species are directly linked to the threats faced by those species. In order to address an overarching threat like habitat loss, protection from development (both direct land conversion and indirect encroachment) is key. Habitat degradation is often followed by habitat destruction. Therefore, many of North Carolina's most important plant habitats need protection from land conversion or development. Management activities need to include mitigation of both on-and off-site threats and restoration of previous damages. Thus, it is possible for several rare species living in similar habitats to have similar management needs, while some other species have varying management needs in different parts of their range. In other words, a management prescription depends on the threats and damages being addressed.

Despite habitats varying across North Carolina, land managers will likely find themselves addressing one or more of the following management needs, regardless of their location.

- Fire suppression is one of the largest threats to North Carolina’s plant species and thus, prescribed fire is recommended to mitigate woody encroachment and other impacts of fire suppression. Careful planning is needed not only for safety, but also to obtain the best outcomes from each fire. For instance, to reduce competing vegetation, the timing of prescribed burns (season and interval) is important.

- Although prescribed burning is a supported and growing practice in our state, the need for prescribed fires is greater than what can be met with existing resources. Understanding what other management practices can be used as fire surrogates will be increasingly important as these and other constraints limit the use of fire as the primary management tool in areas where fire is needed.

    - Climate change is lengthening the natural wildfire season in our region and elsewhere in the country. The direct and indirect impacts of this longer season result in personnel and resources needed for prescribed burning being deployed to containment and suppression efforts, effectively shortening the prescribed fire window of opportunity due to lack of available resources.

    - Climate change is also leading to more extreme weather which is further reducing the number of “good burning days” available to fire practitioners.

    - Lastly, increasing development, as discussed earlier, is greatly increasing the wildland-urban interface which adds additional safety and sensitivity concerns to prescribed fire planning in these areas, further limiting the opportunities to conduct effective burns for habitat management.

Invasive species control is needed in nearly every disturbed site. The various forms of habitat degradation mentioned before each cause inroads for invasive species to colonize, especially in areas where the natural community matrix has been disturbed. Managing invasive species should be equal parts avoidance, control, and eradication of existing infestations.

Hydrological alterations are also very common forms of habitat degradation but may be the most challenging and least straight-forward threats to address, especially alterations related to climate change such as seal level rise and saltwater intrusion. Understanding the hydrological needs of a species or community is critical to managing for such conditions. In areas with alterations, consider options that restore historic stream flow and capacity for maintaining surface and groundwater levels.

- Right-of-way maintenance is unique compared to natural areas and brings with it a specialized set of management considerations. For one, these areas can simultaneously be highly altered and provide important habitat, especially for sun-loving plant species easily out-competed by surrounding vegetation. Appropriately timed mowing regimes can be highly effective at managing a wide variety of plant habitats in rights-of-way. However, increasingly, rights-of-way are being maintained with herbicide instead of mowing for generalized maintenance focused on human uses (e.g., maintaining visibility in road shoulders and avoiding hazards in powerlines).

3.13.6 Threats and Problems

The threat assessment tool used to develop the plant SGCN list helps to assess the conservation needs of an individual species and also identifies the greatest threats across all the reviewed species. The PCP has identified the following as the top threats to rare plants in North Carolina: natural system modifications (i.e., incompatible land management and hydrological alterations), residential and commercial development (i.e., habitat loss), invasive and other problematic species and genes, and stochasticity. Apart from stochasticity, these threats are defined in Salafsky et al. (2008).

The most important threats relate to habitat loss and habitat degradation. This is not surprising considering the stationary nature of plants, especially relative to most other taxonomic groups. Not surprisingly, these threats are particularly impactful in North Carolina given the state's long history with agriculture and other land-use intensive industries, as well as its recent and ongoing rapid development and growth. By fragmenting landscapes and damaging natural communities and natural processes, natural areas that are not directly disturbed can face secondary or indirect impacts from nearby habitat losses. Further, habitat fragmentation can disrupt or diminish the connectivity between remaining habitats which can cause populations to be isolated, leading to genetic diversity losses.

Additional noteworthy threats identified for plants in our state include trampling and disturbance caused by recreation activities. Related to this threat are over-collection and exploitation which is an uncommon but a very impactful threat where it occurs. Another concern is climate change and related extreme weather events (e.g., drought, wind damage, flooding, excessive heat, and seasonal norm variations).

According to the NC Risk Assessment and Resilience Plan (NCDEQ 2020) some habitats considered most at risk, and therefore most in need of monitoring, include:

- Low-lying areas along the coast are vulnerable to sea-level rise impacts including coastal erosion, saltwater intrusion, and storm surge. These habitats include Freshwater Tidal Wetlands, Maritime Wetland Forests, Blackwater Floodplains, and Large River Systems.

- High elevation natural communities are vulnerable to climate change. Even though many of these sites are already in conservation ownership, changes in seasons, extreme heat, drought, and heat waves all affect plants and animals that were adapted to live in conditions unique to the high elevation mountaintops. These changes are most likely to affect High Elevation Cliffs and Rock Outcrops.

- Wetland habitats dependent upon frequent fire are vulnerable to any changes in land use or landscape context that result in fire suppression or changes in hydrology. These threats affect Wet Pine Savannas in the Sandhills and Coastal Plain.

- Freshwater aquatic systems – already impacted by pollution, sedimentation, and obstructions due to dams and culverts – are also vulnerable to climate changes such as changes in water temperature and precipitation amounts as well as flows brought about by heat waves and extreme heat. These threats affect aquatic communities across the state.

- Rare plant and animal species occurring in all the habitats listed above should be routinely surveyed to facilitate early detection of declines due to habitat changes. Management intervention, if feasible, should be considered where needed to avoid local extirpation.

Importantly, the worst threats that plants are facing are not easily mitigated by rules or regulations. Instead, habitat conservation, habitat restoration, and population level management are the most important strategies for mitigating threats to plants.

3.13.7 Additional Information

There has been a longstanding disconnect between the documented conservation needs for plant species and the disproportionately low funding and support for the recovery of rare, at-risk, and imperiled species. In a review of species listed under the Endangered Species Act, plants vastly exceed all other taxonomic groups in number of species listed but represent the lowest investment per species compared to all other taxonomic groups (Negron-Ortiz 2014). Making additional resources available for conserving these unique and foundational components of our natural world should be a higher priority. With the increase in North Carolina's human population and the rapid pace of land use change over the past 20 years often resulting in habitat destruction and degradation, the need for plant and wildlife habitat conservation and management is more urgent than ever. The need for funding, staff, and public support cannot be overstated.

North Carolina benefits from a robust conservation community and network of organizations involved in plant conservation. Some partners include North Carolina's Plant Conservation Program and Friends of Plant Conservation, Natural Heritage Program, Botanical Garden, Division of Parks and Recreation, Forest Service, and Wildlife Resources Commission, as well as federal partners such as the US Forest Service, National Park Service, and Coastal Reserve Program. Universities also collaborate for research and education, especially the University of North Carolina system (Chapel Hill, Asheville, Appalachian State, NC State, Western Carolina, Wilmington), Duke University, and Catawba College.

In addition, many land trusts and local governments monitor preserves for rare species and incorporate prescribed fire and wetland restoration into their practices. Groups such as the Plant Conservation Alliance and the Rare Flora Discussion Group play a role in fostering communication and collaboration among these many partners.

3.13.8 Recommendations

In general, protection and restoration of natural community composition and function and protection of surrounding natural areas under undisturbed conditions are the best ways sustain ecosystems and ecosystem services. Measures that protect a large and diverse pool of community components are the best way to ensure that species are able to survive future stressors and adapt to changing climate conditions.

The following recommendations should be considered appropriate to implement for all plant SGCN. Other conservation recommendations for the habitats associated with these species have been incorporated into the natural community descriptions provided in Chapter 4.

3.13.8.1 Surveys

Distributional and status surveys need to focus on plant species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Conduct statewide assessment (status, distribution, and description) of significantly rare natural communities. Efforts should include creating GIS mapping, assessment of threat scope and severity, and documenting element occurrences of plant SGCN.		
• Conduct surveys for nonvascular bryophyte species. Little is known about their distribution, habitat requirements, and abundance statewide.		
Mosses	Liverworts	Hornworts
• Assess the conservation status of graminoid species, especially those associated with rare or special natural communities (e.g., bogs, wetlands, early successional).		

Priority Conservation Action, Examples of Focal Species or Focal Habitats	
• Conduct surveys for historically rare species to update NHP element occurrence data.	
Special Concern-Historic	Significantly Rare-Historic
• Assess the conservation status of isolated wetlands, including upland pools and depressions, nonalluvial mineral wetlands, and upland seepages.	
• Assess the conservation status of freshwater wetlands subject to tidal influences. These systems will be at risk of salt water intrusion from sea level rise and stormwater surge.	
• Identify rare plant populations at risk or threatened by invasive or exotic species and develop a response to eliminate or moderate threats.	
• Routinely survey rare plant communities to facilitate early detection of declines due to habitat changes.	

3.13.8.2 Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. Studies should identify population trends, as well as assess impacts from conservation or development activities. These efforts will inform species and habitat management decisions. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Long-term monitoring sites need to be identified and monitoring protocols developed for all priority plant species.
• At the site or population level, monitoring activities should include annual (or regular) observations of area of occupancy with an emphasis on changes in this area (both contractions and expansions), relative vigor (often recorded as the reproductive proportion of the population), and notable concerns such as disease or other impacts.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• At the species level, monitoring activities should help describe or calculate short-term trends for several populations. This level of monitoring often involves demographic data collection and can be very time and resource intensive.

3.13.8.3 Research

Research topics that facilitate appropriate conservation actions include natural community preferences, fecundity, population dynamics and genetics, propagation and transplant methods for the most imperiled species, and food web dynamics. All studies should provide recommendations for mitigation and restoration.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Increased understanding of life histories and population statuses helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation.
• Evaluate the impacts of climate change on biodiversity of important natural communities.

3.13.8.4 Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, maintaining and restoring natural processes such as fire and natural flood regimes, and improving degraded habitats. There is a need for more understanding of how management practices conducted at varying scales impact plant populations.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Some practices should be employed in very controlled and isolated applications (i.e., herbicide treatments), whereas other practices are more effective if applied across a larger landscape (i.e., prescribed burns).

Priority Conservation Action, Examples of Focal Species or Focal Habitats	
• Factoring in the feasibility of employing the best management practices at the most appropriate scale is a critical component in management planning, especially for rare plant species and sensitive habitats.	
• Develop protocols and procedures for safeguarding rare plants.	
• Close sensitive sites to stop direct (trampling, loss of habitat to recreation developments such as trails) and indirect (disturbance, plant poaching) human impacts.	
• Restore mountain bog habitats.	
Bogs	Wetlands
• Develop and implement a management plan to address invasive species.	
• Promote and support new and ongoing conservation and restoration projects within tribal communities and incorporate climate resiliency to the extent possible.	
• Work with state agencies responsible for managing public lands to identify plants and community components that need specific management activities and assist with developing appropriate management schedules.	

3.13.8.5 Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Promote use of native species. Consider propagation of rare or declining species for use in restoration or augmentation projects.		
• Provide incentives to private landowners to conserve imperiled plants and habitats on lands they own.		
• Continue to build and expand the North Carolina Plant Conservation Alliance network.		
• Acquire acreage of rare or significant natural community types through purchase, conservation easement, or other perpetual management agreements.		
Spruce-Fir habitats	Prairie grasslands	Plot Balsams
Bogs and other wetlands	Coastal marshes	Black/Craggy Mountains
Carolina Bays		
• Protect corridors that serve as landscape connections to other conservation sites.		
Floodplains		
• Work with the USFWS to develop Candidate Conservation Agreements (CCAs) for lands where propagated listed plants can be planted as restoration.		
• Work with private landowners owning significant botanical sites, provide technical support and assist with management to sustains rare communities and plants.		

Chapter 4
Habitats

4

Chapter 4. Habitats

Required Element 2: Descriptions of locations and relative condition of key habitats and community types essential to conservation of species identified as conservation priorities.

4.1 Introduction

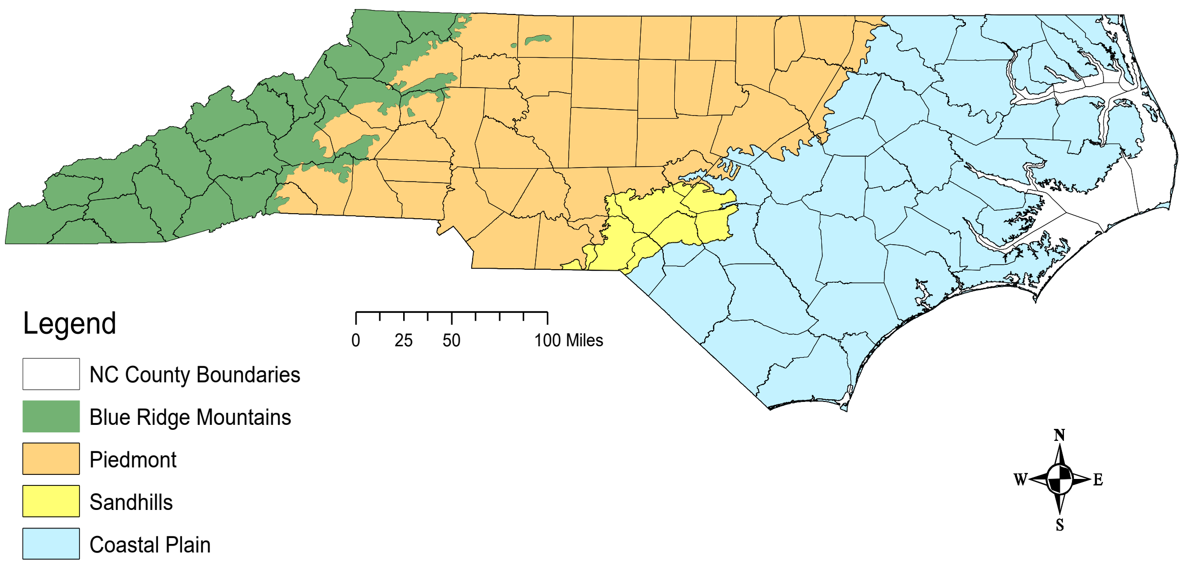
There are many factors that influence where a species occurs in the landscape, its distribution and abundance, and its rate of reproductive success and survival (Hall et al. 1997; Winger 1981; Turner 1989). A landscape composed of multiple natural community types is more likely to contain the necessary resources to provide habitat for a species (Stewart et al. 2010; Morrison et al. 2012). Landscape composition varies across the state with elevation, moisture and temperature gradients, and soil textures having a significant influence on natural community structure. The concept of habitat is based on the availability of the appropriate combination of food, cover, and water resources, climatic conditions, and other environmental conditions (e.g., competitors, predators, connectivity) that supports the ability of a species to survive and reproduce (Hall et al. 1997; Morrison et al. 2012).

An important concept in wildlife–habitat relationships is that they are specific to the organism, are temporally and spatially scale-dependent, and are influenced by each organism in the system (Hall et al. 1997; Wiens 1989). Some habitats that can form when vegetation is dormant and rainfall is high, such as ephemeral pools and wetlands, are distributed seasonally due to climatic and environmental conditions. In other cases, a habitat may be distributed based on periodic natural disturbances, such as wildfire or flooding. Given the complexities of natural communities and the variability of the organisms associated with them, we use local and regional landscape-scale approaches more often than species-specific approaches to accomplish conservation. Therefore, habitats are considered to be the sum of all the resources a species needs to survive and persist (Hall et al. 1997).

Whether they are aquatic or terrestrial systems, natural communities and the habitats they provide are highly interconnected and influence one another. As an aid to understanding this complexity and to provide a landscape framework for conservation planning, it is helpful to represent broadly the distribution of important natural communities by using widely accepted ecoregional units. Ecoregions are often defined based on landscape settings and patterns that are influenced by climate, soils, land surface form, and potential natural vegetation (Omernik 1987), and can be useful for organizing, interpreting, and reporting information about land-use dynamics (Gallant et al. 2004).

Though North Carolina generally is considered to consist of three physiographic provinces - Mountains, Piedmont, and Coastal Plain - we have used four ecoregion boundaries described by Bailey (1995, 1998, 2009) and Omernik and Griffith (2008) as a framework for the wetland and terrestrial community descriptions found in this document. Figure 4-1 provides a map of the four ecoregions used in this Plan to organize information.

Figure 4-1. North Carolina Ecoregions (Bailey 2009).



- **Southern Blue Ridge Mountains (Mountains)**. The Mountain ecoregion includes all portions of the Southern Appalachian mountain physiographic province that are west of the Blue Ridge Escarpment. As shown in Figure 4.1, there are several foothill ranges (the Brushy, Sauratown,and South mountains) located within the Piedmont province that are part of the Mountain ecoregion. North Carolina has the highest elevations of any state east of the Mississippi River, with Mount Mitchell being the highest peak at 6,684 feet (above mean sea level or amsl) (SCO 2014). This ecoregion covers about 17% of the state and is predominantly forested with small patches of agricultural and developed lands found mainly in the broad valleys.

- **Piedmont**. The Piedmont ecoregion includes areas east of the foot of the Blue Ridge Escarpment and west of the fall line, excluding the Brushy, Sauratown, and South mountain ranges. The fall line is a major break in geologic structure between the Piedmont and the Coastal Plain which results in differences in ecosystem patterns and the variety of relief and roughness (Bailey 2009). This ecoregion covers about 40% of the state, is centrally located between the Mountains and Coastal Plain, and generally contains the most urban areas with the highest population densities. A variety of underlying hard rock formations influence the landform, with gently rolling hills to the rather steep hills of the Uwharrie Mountain Range (Montgomery, Randolph, and Stanly counties) and the Kings Mountain Range (Cleveland and Gaston counties) (SCO 2014). Elevations range from about 1,500 feet (amsl) in the foothills to about 200 feet (amsl) at the fall line (SCO 2014). Because water resources are often seasonally limited, several reservoirs have been built to provide drinking water to rapidly developing urban and suburban centers that are replacing agriculture and forest lands (Gallant et al. 2004).

- **Sandhills**. The North Carolina Sandhills are the southwestern portion of the Coastal Plain physiographic province. The Sandhills ecoregion is distinguished because of its distinctive geomorphology and vegetation and covers about 3% of the state. It is generally located between the south-central and southeastern part of the state, encompassing portions of Anson, Cumberland, Harnett, Hoke, Lee, Moore, Richmond, Scotland, and Montgomery counties. The name derives from the predominantly sandy soils formed of Cretaceous-age marine sands and, in some places, clays that are capped by Tertiary-age sands deposited over Piedmont metamorphic rocks. The landscape has rolling hills and nutrient poor soils. The Sandhills represents a former coastline and is well known for having many rare plants (Omernik and Griffith 2008).

- **Mid-Atlantic Coastal Plain (Coastal Plain).** This ecoregion includes areas east of the fall line (excluding the Sandhills) and the tidal coast (ocean, sounds, barrier islands, and mainland brackish and salt marshes). The Coastal Plain covers about 40% of the state (Land et al. 2004). It may be divided roughly into two sections: the tidewater area (lower Coastal Plain), which is largely flat and swampy, and the interior portion (upper Coastal Plain), which is made up of gently sloping elevations and is better drained than other regions. The average elevation is from about 200 feet (amsl) at the fall line (or western boundary separation from the Piedmont), sloping to an elevation of generally 50 feet (amsl) or less over most of the mainland landscape, with barrier islands being close to sea level (SCO 2014).

4.1.1 Natural Community Descriptions

This chapter provides descriptions for important aquatic, wetland, and terrestrial natural communities found in North Carolina. The community descriptions incorporate a subset of the climate change vulnerability assessments conducted by the NC Natural Heritage Program (NCNHP) with other resource agencies in 2010 and updates drafted in 2025. As noted in previous chapters, common names are used throughout this document for all species except those for which there is taxonomic uncertainty; in those few instances the scientific name is used to identify the species. Appendix 3 provides common and scientific species names for invasive and nonnative species as well as for SGCN and priority species.

Appendix 3 contains crosswalks between the natural communities described in Chapter 4 and the SGCN species associated with those habtats.

- Table 3-17 (wildlife) provides a crosswalk between the terrestrial SGCN and priority species introduced in Chapter 3 and wetland and terrestrial upland natural communities.
- Table 3-18 (wildlife) provides a crosswalk between aquatic SGCN and aquatic habitats and river basins that are associated with those habitats.
- Table 3-19 (plants) is a crosswalk between plant SGCN associated with the natural habitats described in this chapter.

Section 4.2 provides descriptions for 3 water temperature regimes and 9 aquatic community types. Their characteristics have been incorporated into the descriptions of the 17 river basins described by the NC Department of Environment and Natural Resources, Division of Water Resources (https://www.deq.nc.gov/about/divisions/water-resources/water-planning/basin-planning-branch).

Table 4-1 provides a list of the aquatic community descriptions provided in this chapter and the ecoregions where they occur. The stream and river system classifications are based on a framework developed by the Southeast Aquatic Resources Partnership(SARP) (Sheldon and Anderson 2013) and system descriptions are delineated based on size of the drainage area (DA).

Table 4-1 Aquatic communities and ecoregion associations

	Mountains	**Piedmont**	**Sandhills**	**Coastal Plain**
TEMPERATURE REGIMES				
Coldwater Systems (<20°C or <68°F)	**X**	**X**		
Coolwater Systems (20 –25°C or 68 –77▫F)	**X**	**X**		
Warmwater Systems (>25°C or >77°F)	**X**	**X**	**X**	**X**

Table 4-1 Aquatic communities and ecoregion associations

	Mountains	Piedmont	Sandhills	Coastal Plain
COMMUNITY DESCRIPTIONS				
Groundwater, Springs, Subterranean Water	X	X	X	X
Headwaters/Small Creek Communities (<40 sq.mi. or <104 sq.km. DA)	X	X	X	X
Large Creeks/Small River Communities (40–200 sq.mi. or 104–518 sq.km. DA)	X	X	X	X
Medium River Communities (200–3,800 sq.mi. or 518–9,842 sq.km. DA)	X	X	X	X
Large River Communities (>3,800 sq.mi. or >9,842 sq.km. DA)				X
Stream Swamp Systems				X
Natural Lakes				X
Reservoirs & Impoundments	X	X	X	X
Estuarine Aquatic Communities				X

Section 4.3 in this chapter provides descriptions for 12 wetland communities. The community types are based on descriptions developed by the NCNHP (Schafale 2012, 2024). Table 4-2 provides a list of the wetland and terrestrial community types (in alphabetical order) described in this chapter and the ecoregions where they occur.

Table 4-2 Wetland and terrestrial upland natural community types and ecoregion associations

COMMUNITY TYPES	Mountains	Piedmont	Sandhills	Coastal Plain
WETLAND COMMUNITIES				
Bogs and Fens	X			
Estuarine Wetland Communities				X
Floodplains – Blackwater Systems			X	X
Floodplains – Brownwater Systems				
Floodplains – Inland Systems	X	X	X	
Freshwater Tidal Wetlands				X
Freshwater Herbaceous Marsh	X	X	X	X

Table 4-2 Wetland and terrestrial upland natural community types and ecoregion associations

COMMUNITY TYPES	Mountains	Piedmont	Sandhills	Coastal Plain
Nonalluvial Mineral Wetlands			X	X
Pocosins			X	X
Upland Pools and Depressions	X	X	X	X
Upland Seepages and Spray Cliffs	X	X	X	X
Wet Pine Savannas			X	X
UPLAND COMMUNITIES				
Caves and Mines	X	X		X
Cove Forests	X			
Dry Longleaf Pine Communities		X	X	X
Grass and Heath Balds	X	X		
High-elevation Cliffs and Rock Outcrops	X			
Low Elevation Flatrocks, Cliffs, and Rock Outcrops	X	X		X
Mafic Glades and Barrens	X			
Maritime Forests				X
Maritime Grasslands				X
Mesic Forests		X	X	X
Montane Oak Forests	X			
Northern Hardwood Forests	X			
Oak and Mixed Hardwood/Pine Forests and Managed Timber		X	X	X
Piedmont and Coastal Plain Oak Forest		X	X	X
Piedmont and Mountain Dry Coniferous Woodlands	X	X	X	X
Sand, Shell, and Wrack Shorelines				X
Spruce–Fir Forests	X			
Successional Communities (Herbaceous, Shrub, and Woody)	X	X	X	X

Section 4.4 provides descriptions for 18 terrestrial (upland) community types based on descriptions developed by the NCNHP (Schafale 2012, 2024), as well as information about conservation concerns and priority actions.

Section 4.5 discusses the 17 river basins as defined in NC Statutes and provides priority conservation recommendations. Table 4-3 provides a list of the 17 river basins and identifies which ecoregions of the state they cross.

Table 4-3 North Carolina river basins and ecoregion associations

River Basin	Mountains	Piedmont	Sandhills	Coastal Plain
Broad	X	X		
Catawba	X	X		
Cape Fear		X	X	X
Chowan				X
French Broad	X			
Hiwassee	X			
Little Tennessee	X			
Lumber			X	X
Neuse		X		X
New	X			
Pasquotank				X
Roanoke	X	X		X
Savannah	X			
Tar-Pamlico		X		X
Watauga	X			
White Oak				X
Yadkin-Pee Dee	X	X	X	

4.1.2 Natural Community Priorities

The North Carolina Wildlife Resource Commission's (NCWRC) land acquisition objectives include consideration for protecting important aquatic and terrestrial habitats. Other objectives include expanding and connecting game lands and land conservation areas; providing the public with opportunities for hunting, fishing, wildlife observation, and other recreation activities; and protecting wildlife migration corridors and providing connectivity between priority habitats. These and other objectives are outlined in the Commission's Phase I Land Acquisition Investigation Form used to evaluate potential land acquisition sites.

The NC Division of Coastal Management (NCDCM) manages the Coastal and Estuarine Land Conservation Program (CELCP), which is a federal funding program that helps protect important coastal and estuarine lands (NCDCM 2007, 2011). In North Carolina, the CELCP Plan identifies coastal and estuarine areas in the 20 coastal counties that have significant conservation, recreation, ecological, historical, or aesthetic values, or that are threatened by conversion from their natural or recreational state to other uses. Priority is given to lands that can be effectively managed and protected and that have significant ecological value. The most recent update of the CELCP Plan (NCDCM 2011) identifies wetlands, coastal forests, working lands (agriculture and forestry), waterfront lands (barrier islands, riparian lands), island ecosystems (including beach and dune systems), floodplains and riparian zones, wildlife preserves and game lands, trails and greenways, cultural and historic sites, and marl outcrops as priority areas for conservation.

Many of the state's natural community types cover large areas and are well represented, while others cover less area and may be more at risk from loss of biodiversity when considering local and regional threats (i.e., land use change, development). Given the richness of their biodiversity, the ecosystem services they support, and the benefits they provide to wildlife (including SGCN and other priority species), certain natural community types are of higher priority for land conservation action because they are more imperiled (NCWRC 2012). These priority habitats are identified in Table 4-4.

Table 4-4 Priority natural community types and their ecoregion associations

Ecoregion	Community Type
Statewide	All wetlands All riparian and floodplain communities All streams and rivers Caves and mines Early successional communities Rock outcrops
Mountains	Bogs and fens High-elevation habitats Spruce–fir forests
Piedmont	Large unfragmented tracts near existing conservation holdings Managed early successional landscapes
Sandhills	Large unfragmented tracts near existing conservation holdings Managed early successional landscapes

Table 4-4 Priority natural community types and their ecoregion associations

Ecoregion	Community Type
Coastal Plain	Coastal peatlands (pocosins) *Estuarine islands *Inlet spits Maritime grasslands and dunes Maritime forests Sand, shell, and wrack shoreline (beaches)
*Community descriptions for estuarine islands and inlet spits are not provided in this document; however, the estuarine islands and inlet spits are found along the state's coast and are created by natural sand deposition and by placement of dredged (spoil) materials (NCWRC 2012). These habitats are important for numerous colonial waterbirds, long-legged wading birds, and beach-nesting shorebird species, including many that are listed as SGCN and priority species.	

4.1.3 Species and Habitat Associations

The habitats presented in this document represent the major habitat types in the state. Each description provides information about the wildlife associated with that habitat and highlights the threats, needs, and conservation priorities of that particular habitat. Appendix 3 contains a list by taxonomic group forSGCN and other priority species associated with each habitat discussed in this chapter. Some habitat associations reflect use as secondary or transitional for a species and are used as corridors or connections when they need to move from their primary habitat to another location.

- Table 3-17 provides habtat associations for terrestrial SGCN wildlife
- Table 3-18 provides habitat associations for aquatic SGCN wildlife
- Table 3-22 provides habitat associations for plant SGCN

The usefulness of the habitat association table will depend on the species. For some, the associations can be loosely defined or opportunistic. For others, the relationship is tight or obligate. The Peregrine Falcon, which usually nests on high-elevation rock outcrops but has been known to nest on top of urban highrise buildings, provides an example of an opportunistic habitat association. Other examples include colonial nesting waterbirds that typically use shell middens or flats between sand dunes for nesting but have also used gravel roof tops of buildings adjacent to the shoreline. Some bats require specific types of maternity roosts (e.g., tree cavities) and hibernacula (e.g., caves), which is a tight habitat association. However, their use of stream and river corridors or open riparian areas for foraging can be considered a loosely defined habitat association because the community structure will vary by location, depending on vegetation, DA, hydrology, and other landscape factors.

4.2 Aquatic Communities

While aquatic systems represent a small percentage of the landscape, they are living systems that represent some of the most endangered ecosystems in the state because they are subject to an increasing number of persistent threats that include resource withdrawals, pollution, invasive species, barriers, the effects of climate variability, and impacts to the surrounding terrestrial communities (MEA 2005; Revenga et al. 2005; Abell et al. 2000, 2008).

The various geology, physiography, and climate attributes of North Carolina contribute to the wide diversity of aquatic resources found across the state's ecoregions (Abell et al. 2000; Smock et al. 2005). North Carolina's natural aquatic communities provide a variety of habitats that are influenced by numerous conditions such as landscape position, gradient, width, depth, temperature, velocity, substrate or bed material, chemistry, and land cover (Winger 1981). The aquatic communities can be thought of as a mosaic of temporal and spatial conditions spread across the continuous reach of the system (Vannote et al. 1980).

There are many subject areas in science and biology where classification systems have been developed and accepted for standard practice, and are commonly used as descriptions and for locating, storing, and exchanging data. While there is not one globally agreed upon classification system applied to describing aquatic communities or hydrologic systems, there are several definitions and classification schemes in wide use. For example, watersheds (also called basins or catchments) (Thorp 2002; Wagener et al. 2007) are commonly described and delineated to include all of the land draining into a particular surface water system such as a stream, river, or lake (Abell et al. 2000).

A watershed can represent an unlimited number of spatial scales such as the area that drains to a single headwater stream or a larger area that encompasses several streams that share a hydrologic connection. The largest watersheds delineated in North Carolina represent all of the land draining into one of the 17 major river systems in the state which are identified in Table 4- 3 and described in Section 4.5 of this chapter.

Inland freshwaters are a type of aquatic natural community generally categorized as being either lotic or lentic systems.

- Lotic systems are running waters such as rivers and streams (Alexander and Fairbridge 1999; Abell et al. 2000; Thorp et al. 2001) and there are various methods used to classify them based on pattern, geomorphological conditions, or by groups using shared characteristics (Rosgen 1994).

- Lentic systems are standing waters such as lakes, reservoirs, ponds, swamps, and marshes. Schindler and Scheuerell (2002) note that lakes are complex ecosystems with distinct habitats that are influenced by physical parameters (e.g., depth, substrates), thermal influences (e.g., air and water temperatures, discharges), and water chemistry (e.g., oxygen, nutrients, pollution) and how these influences are stratified throughout the water body (vertical dimensions). Benthic habitats within standing waters are associated with the physical structure and substrates of the lake bottom (Eschmeyer 1936; Christensen et al. 1996b; Covich et al. 1999; Schindler and Scheuerell 2002). Riparian or littoral habitats occur at the transition between terrestrial communities and the aquatic system (Schindler and Scheuerell 2002).

An early method categorizes streams based on connectivity patterns (e.g., as orders) with other flowing systems, and classifies streams into a dendritic hierarchical order where the smallest unit is a first order stream (Strahler 1957). As first order streams connect to other streams the hierarchy increases to second order, third order, and on so that the largest are rivers that are higher order systems.

Another method organizes streams into hydrologic units representing a defined drainage network comprised of a stream and all of its tributaries (Benke and Cushing 2005; Wagener et al. 2007; Sawicz et al. 2011). These drainage networks are referred to as drainage areas (DAs) and the characteristics of each unit are influenced directly by the landscape attributes within the boundaries that define the basin (Huang et al. 2007; Sawicz et al. 2011).

Estuarine systems are another type of aquatic natural community that is formed at the link between land, freshwaters, and the ocean, and may be referred to as estuarine, brackish, or transitional waters (Levin et al. 2001; Tagliapietra et al. 2009).

- Estuarine systems are semi-enclosed coastal waters that are tidally influenced, have a connection with seawater, and contain brackish waters that result when seawater is measurably diluted with fresh water from land drainage (Cameron and Pritchard 1963; Pritchard 1967; Cowardin et al. 1979; Tagliapietra et al. 2009).

- Brackish waters result from the mingling of freshwaters and marine saltwaters and in most cases will have a low salinity gradient (measured as parts per thousand), but can range from mixohaline (0.5–30 ppt) to euhaline (30–40 ppt) to hyperhaline (>40 ppt) depending on proximity to ocean salt waters and fluvial, tidal, and climatic conditions that drive salt water (i.e., salt wedge) upstream into freshwaters (Cowardin et al. 1979; Emery and Myers 1996; Neuendorf et al. 2005; Tagliapietra et al. 2009).

Water quality is not the only variable that will influence species richness and relative abundance in aquatic communities. The presence of variable habitat types (pools, riffles, and runs in streams); the difference in water velocities, depths, and temperatures; and the types and combinations of substrate coarseness and material (e.g., sand, gravel, aquatic vegetation, woody debris) (Hrodey et al. 2009) have an influence on which species make up the community.

- Moderate to high-quality in-stream habitats will have a substrate of heterogenous substrates with low embeddedness; woody debris such as sticks, leafpacks, snags; undercut banks with root mats; frequent distribution of pools and riffles of varying depths and widths; and stable banks with good tree canopy and a medium to wide riparian zone with few (if any) breaks (NCDWQ 2011c). Species diversity is potentially greatest in large streams and medium-sized rivers, especially in riffle and run habitats.

- Poor in-stream habitats will have primarily sandy, unconsolidated substrates, an absence of riffles; narrow and sparsely vegetated riparian zones with breaks; and deeply entrenched channels with unstable, vertical, and sparsely vegetated banks (NCDWQ 2011c).

4.2.1 Problems Affecting Aquatic Communities

There are numerous threats that can affect a broad range of aquatic natural systems and some of the most common and widely occurring are described in this section. The natural community descriptions provided in this chapter provide information about the problems that affect specific community types. Additional information about threats likely to impact SGCN and habitats is provided in Chapter 5.

Wastewater Discharges. Point source discharges from industrial or municipal effluent can be a source of contamination to aquatic systems. These potential sources of water pollution are subject to the National Pollutant Discharge Elimination System (NPDES) permit requirements designed to address numerous types of pollutants associated with specific industry types and subject to US Environmental Protection Agency (USEPA) regulation. For example, effluents associated with sewage treatment can affect the pH of receiving waters and be a source of suspended solids, biological oxygen demand, ammonia, phosphates, and chlorine. Suspended solids in discharges can increase turbidity that reduces light penetration, absorbs metals and organic materials in the water column, and concentrates them into sediment when they settle on the bottom substrate. High levels of total dissolved solids in the discharges can add salts to receiving waters. Acidic or alkaline wastes can change the pH of receiving waters and affect the solubility of dissolved chemicals and adsorption of certain metals, which can result in toxicity and lethal water conditions for aquatic organisms (McDaniel 1993). Emerging contaminants in wastewater effluent such as pharmaceuticals, endocrine-disrupting compounds (EDCs), cosmetics, and other personal care products have become a source of concern for adverse health impacts to aquatic life (see “Pollution” below).

Thermal Discharges. Discharge waters with temperatures that are a few degrees different from receiving waters can cause changes to the metabolic activity, behavior, and physiological conditions of aquatic species. Growth rates are impacted by increased temperatures, and life history synchrony (reproduction or emergence) might be affected where there are thermal discharges (McDaniel 1993).

Petroleum Spills. Waterborne spills of petroleum products such as oil and grease can impact receiving waters by interfering with gaseous exchange and coating substrates with sludge and smothering organisms. Oil and grease can coat respiratory structures of fish and aquatic invertebrates and oxygen depletion in the water column can change community composition and structure (McDaniel 1993).

Pathogens and Microorganisms. These types of contaminants are primarily a concern to human health through water-based recreation activities and water-supply usage streams. Significant concerns include, but are not limited to, salmonellosis, shigellosis, enteropathogenic *E. coli*, enterovirus, and parasitic protozoa and worms. Many of these organisms are harbored in warm-blooded animals and are shed through animal wastes or fecal contamination of meats during food production processes. Freshwater fish can also harbor organisms that are consumed by humans. Other sources of these contaminants are sewage wastes, stormwater runoff, and concentrated animal operations (McDaniel 1993).

Nutrient Loads. Phosphorus and nitrogen are the nutrients most often associated with enrichment problems in aquatic ecosystems. Nutrient enrichment causes eutrophication that will cause changes to aquatic ecosystem structure and function (Smith et al. 1999, 2006). Eutrophication increases the frequency and intensity of algal blooms, especially cyanobacteria (blue-green algae) in freshwater lakes and harmful phytoplankton (e.g., dinoflagellates) blooms (referred to as red tides) in coastal areas (Anderson 1994; Downing et al. 2001; Huisman et al. 2005; Smith et al. 2006;).

Dams. Impoundments create direct impacts through alteration of flow patterns and loss of in-stream habitats; changes in sediment transport and channel structure; impediments to genetic flow through restriction of fish movement; and thermal stratification and low dissolved oxygen (DO) content. They also can cause thermal or nutrient discharges from storage water (Yeager 1993). Hydropower dams, as a subset, contribute to unnatural flow regimes and hypolimnetic releases that cause a cool or warmwater assemblage to be replaced by a cold or coolwater one. Dams on rivers with anadromous fish block historical spawning grounds that can result in reduced populations due to lack of good spawning habitat and altered fish assemblage in rivers and streams above impoundment.

Withdrawals. Water withdrawals are commonly made for use in industrial processes, irrigation for crops, livestock watering, and drinking water resources. The physical characteristics of streams and rivers are altered when waters are impounded to form reservoirs. Physical changes caused by withdrawals taken from rivers and streams that reduce water levels include changes to the channel dimensions, water velocities, substrate composition, and water temperature. Withdrawals can permanently reduce availability of local water resources when there is no return of any of the withdrawn water to the local hydrologic cycle. Withdrawals can also result in lowered water tables and secondary impacts to nearby riparian wetlands and littoral habitats (Zale et al. 1993).

Land Use Impacts. Converting land use from natural forest to agriculture or silviculture production and residential and commercial development continues to threaten stream integrity because of the loss of riparian buffers and related increases in sediment, bank erosion, and stormwater runoff containing sediment and other potentially toxic materials. Erosion and the resultant sedimentation are the largest sources of nonpoint source pollution in this system. Livestock access to streams contributes heavily to bank erosion, sedimentation, and nutrient input. Timber harvests and poorly constructed and maintained timber roads are additional sources of erosion if proper controls are not used and maintained.

An increase in impervious surfaces due to roads, parking lots, homes, and businesses increases the amount and speed of runoff being delivered into aquatic systems. Decreased groundwater recharge between storms due to impervious surfaces leads to a decrease in stream base flows. Runoff from urban areas often contains higher concentrations of nutrients (such as nitrogen and phosphorus), sediment, metals, hydrocarbons, and microbes.

Nonnative and Invasive Species. Nonnative species invasion is a concern for all habitats and species assemblages. In aquatic habitats the Basket Clam (formerly Asian Clam) and the Rusty and Virile Crayfishes have been collected in both cool and coldwater streams. Basket Clam populations have become established throughout the state and in some instances are extremely abundant. These may have negative effects on native species, such as competition for space and resources. With increases in water temperature, some invasive species may move into habitats that were formerly too cold for their persistence.

Invasive plants in the riparian area (such as Japanese Knotweed) can have negative impacts on stream systems by creating a monoculture with poor nutrient inputs, reducing bank stability, and allowing too much sunlight to infiltrate, resulting in warmer stream temperatures. Other invasive species, such as the exotic pest Hemlock Wooly Adelgid, may be a significant factor in coldwater stream communities because of the important role that hemlock plays in these riparian areas. If hemlocks are removed from the system, nutrient inputs and temperature regimes may be disrupted, which would in turn disrupt aquatic organism life cycles and cues.

Clearing and Snagging. Clearing removes standing trees and riparian vegetation from streambanks and snagging removes woody debris (logjams, snags, mid-channel bars) from within streams. These measures are often taken to lower stream discharge volume and improve drainage, especially in urban areas. Direct effects are the physical alteration of the habitat while indirect effects include changes in fluvial processes (Cobb and Kaufman 1993).
Riparian vegetation is critical to the overall stream and streambank stability and moderation of water temperatures. Lack of riparian vegetation or inadequate forested buffer widths can cause streambank erosion and sedimentation. In addition to stabilizing streambanks, riparian

vegetation serves as nutrient input to the stream community, filters pollutants, and helps regulate stream temperature by providing shade. Lack of sufficient vegetation cover contributes to rising water temperatures, especially where water depths are shallow enough that the entire water column is subject to solar heating.

Climate Variability. Research conducted by Eaton and Sheller (1996) and Mohseni et al. (2003) assessed the effects of climate warming on 57 species of fishes in streams across the United States. Depending on minimum temperature tolerance assumptions, species requiring coolwater habitats could experience a 12–15% decrease in available habitat (DeWan et al. 2010). When the connectivity between streams and rivers within drainage basins provides adequate dispersal corridors, species at the southern extent of their geographical distribution may shift their distributions northward into cooler habitats (Allan et al. 2005). Where adequate dispersal corridors are limited or restricted, access to or availability of cooler water habitats may limit the range of those species subject to narrow temperature tolerance (DeWan et al. 2010).

Increased air temperatures may lead to increased water temperatures and potentially lower DO levels; however, increased air temperature may have varying effects on coolwater systems due to factors such as the degree of groundwater influence, amount of shading by riparian vegetation, and watershed aspect. Hot spells can have the same effect as overall increased air temperatures but on a much more acute scale. Problems such as increased evaporation and therefore, lower amounts of flowing water, will vary depending on factors such as groundwater influence.

Chronically warmer water temperatures and lower DO levels may increase stress on organisms. The increased water temperature alone can cause a decline in DO and if significant, can lead to fish kills, whether as a direct result of increased water temperature or as a secondary effect of algal blooms. Thermal stratification will likely not be an issue when aquatic systems are relatively shallow; however, the large river systems of the Piedmont and Coastal Plain ecoregions and deep water reservoirs could experience stratification, algal blooms, and potential fish kills related to higher than normal water temperatures (DeWan et al. 2010; Band and Salvesen 2009).

Drought. Severe and prolonged droughts may decrease stream flow, decrease groundwater recharge, and increase evaporation. Lower water levels during dry times will increase stress to the system. Connectivity to contributing waters within the system will be restricted or eliminated by low and no-flow conditions. Changes in flow regime will likely result in changes in the overall stream morphology and transport of sediment that leads to altered habitat composition. The balance between surface flow and groundwater recharge may be altered. Decreases in overall summer precipitation may cause reduced water flows, which can further contribute to warmer water temperatures and water quality stressors (DeWan et al. 2010; Karl et al. 2009; Band and Salvesen 2009; US EPA 2010).

Pollution. Decreased stream flows can allow an accumulation of sediment and chemical inputs from stormwater runoff and effluent discharge because there is less frequent flushing in the system. Recent studies have shown that endocrine-disrupting chemicals (EDCs) in treated wastewater can inhibit reproduction and cause feminization of mussels, fish, and some amphibians (Hayes et al. 2006; Elrod et al. 2003a, b; Huang et al. 2003a, b). Although little is known about the effects of EDCs, additional studies are being conducted to document the levels of EDCs in discharges, and measures are being identified to reduce or eliminate EDCs from wastewater prior to discharge, should those discharge studies show increases in EDC levels (Conn et al. 2006; Kim et al. 2007; Kasprzyk-Hordern et al. 2008; Joss et al. 2006; Kolpin et al. 2002; Nowotny et al. 2007).

An emerging concern is the prevalence of microplastics in aquatic systems and the persistent toxicity associated with the pollutants, especially perfluoroalkylated substances (PFAS) (Scott et al. 2021, Cormier 2020). The ecological impacts include more than human consumption of contaminated fish. Research has found keystone aquatic species (Alewife, American Shad, Blueback Herring, Striped Bass, and Sea Lamprey) are exposed at all trophic levels (Melnyk et al. 2024). Other pathways of exposure includes waterfowl and turtles that consume contaminated fish (Melnyk et al. 2024). The implications are not easily understood and research should be a priority.

Phenology Changes. There is a life history link between freshwater mussels and fish, and the mechanisms or effects of phenological disruptions are unknown at this time. Freshwater mussel larvae (glochidia) are dependent on a host fish for transformation into juveniles. Temperature cues play a large role in the release of glochidia from female mussels and also in the movement and migrations of fish. Therefore, predicted changing temperatures could cause phenological disruptions affecting the reproductive capacity of freshwater mussels. As water temperatures increase, freshwater mussels inhabiting cool water systems could experience a shift in their range, moving into previously coldwater systems as their host fish move upstream.

Storms. Increased storm intensity can lead to flooding and therefore increased stormwater runoff and erosion. With increased stormwater runoff, there is an increase in loading of sediments, nutrients, and contaminants into streams and potential negative effects on biota, such as fish kills. With a change in the intensity and variability of rainfall, there are potential changes to stream flow patterns, channel hydrodynamics, and the volume of groundwater (Band and Salvesen 2009; US EPA 2010; Bakke 2008). An increase in the number of tropical events can lead to flash flooding, which causes many of the abovementioned responses. Effects such as increased sediments and contaminants into aquatic systems, in addition to major disruption to channel design and hydrodynamics, potentially upset the physical, chemical, and biological structure of streams (Band and Salvesen 2009).
Heavy rainfall and extreme weather events have impacted the western mountains of the state, resulting in heavy soil erosion, sedimentation, and stream dynamics (DeWan et al. 2010). An increase in the number of tropical events can lead to flash flooding, which causes many of the

abovementioned responses and landslides, which are of particular concern in mountainous, high-elevation areas. Landslides lead to increased sediments and contaminants in aquatic systems, in addition to major disruption to channel design and hydrodynamics, potentially upsetting the physical, chemical, and biological structure of streams (Band and Salvesen 2009).

4.2.2 Statewide Aquatic Community Recommendations

The recommendations provided in this section are appropriate for implementation in all aquatic natural communities. Additionally, the individual aquatic natural community descriptions have recommendations and priorities specific to each habitat. Actions specific to the river basins that contain these types of aquatic communities are provided in Section 4.5 of this chapter.

4.2.2.1 Surveys

Distributional and status surveys are needed for aquatic snails, crayfish, mussels, and fish (in order of general need).

Priority Conservation Action, Examples of Focal Species or Focal Habitats	
• Conduct stream surveys adjacent to areas poised for development (edge of urban expansion) to establish baseline populations and identify problems before development expands.	
• Work cooperatively with partners to collect occurrence and abundance data on macrobenthic species.	
Macrobenthic species	
• Conduct surveys to detect presence and collect life-history and abundance data for freshwater snails and crayfishes, as there is limited information available on these species.	
Crayfishess	Aquatic Snail

4.2.2.2 Monitoring

Monitoring of aquatic taxa is critical to assessing species and ecosystem health and gauging the resilience of organisms to a changing climate. These monitoring efforts will inform future decisions on how to manage aquatic species. Long-term monitoring is needed to identify population trends and to assess performance of conservation actions. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Monitor aquatic taxa to assess species and ecosystem health and to gauge resiliency of organisms to a changing climate.

- Develop long-term monitoring strategies to document population trends, from which conservation strategies can be specifically designed to target those species which are experiencing declines.

- Monitor population trends to determine if species are adapting to changing habitats and apply what is learned to future management decisions (Bakke 2008).

- Monitor aquatic nonnative invasive species, analyze population trends, and assess their effect on native priority species populations.

  Nonnative Species   Invasive Species

- Use survey efforts to develop long-term monitoring strategies that will document population trends and provided a basis to design conservation strategies that target priority species.

- Monitor the effect of base flow impacts on priority species and correlate results with climate conditions.

- Develop climate change monitoring protocols or methods to monitor baseflow where priority species occur outside projects related to regulated water use (Federal Energy Regulatory Commission [FERC] licensing).

- Monitor agriculture and forestry best management practices (BMPs) to determine if they are meeting stormwater runoff control requirements.

- Ensure that bridge and culvert designs allow for stream movement and aquatic organism passage. Design standards may need alteration to accommodate environmental changes and increased floodwaters (Transportation Research Board 2008).

4.2.2.3 Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behaviors, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Research must also be conducted to determine vulnerability of priority species to specific threats and studies and should provide recommendations for mitigation and restoration. Aquatic species propagation is an area of current and ongoing research. Developing techniques for propagation of aquatic species is critical for preserving those species and their genetic stock, particularly those that are rare, at high risk of extinction or extirpation, and difficult to propagate in a laboratory setting.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Expand hatchery facilities and efforts of the Conservation Aquatics Center at NCWRC Marion Hatchery to support research aquatic species propagation.
• Conduct genetic research to resolve taxonomic issues for aquatic species.
• Statewide, assess stream habitats and the effect of perched and undersized pipes and culverts that are a barrier to fish passage.
• Conduct studies to improve our understanding of habitat trends and key habitat associations for priority species.
• Investigate relationships between macrobenthic and aquatic priority species assemblages.
• Utilize environmental DNA (eDNA) and other emerging genetic techniques to better understand aquatic species.
• Use propagation techniques to grow new populations of priority and declining aquatic populations.
• Examine stream temperature and associated microclimatic responses to a range of shading variables from riparian vegetation.
• Work with partners and support development of regulations for control of aquatic nuisance species.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
Nuisance species
• Study the extent and impact of exotic species introductions, as well as effective control measures for the most problematic exotics.
• Gain information regarding the specific microhabitat needs of priority species to develop long term conservation strategies.
• Conduct research to determine the best way to use a habitat guild approach in developing habitat suitability criteria in a stream system. This research will have benefits for studies melding hydrodynamic models to habitat needs for fish assemblages and the best approach to including rare species into habitat guilds (Persinger et al. 2011).
• Assess guild structures and their associated criteria in other rivers and test the transferability of guilds between river systems (Persinger et al. 2011).

4.2.2.4 Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Expand hatchery facilities to increase capacity for propagation of priority and nongame species.
• Ensure that management of riverine habitats promotes the natural evolution and movement of woody and rocky structures and natural processes like bank dynamics, channel meanders, and flood regimes.
• Implement and support use of agriculture and forestry Best Management Practices (BMPs) to control stormwater runoff. Structures such as bioretention cells (i.e., rain gardens), cisterns,

Priority Conservation Action, Examples of Focal Species or Focal Habitats
permeable pavement, runnels, vegetated swales, and filter strips can be used in various ways as stormwater BMPs.
• Support fencing livestock out of streams as a measure to protect riparian vegetation, maintain bank stability, and reduce nutrient inputs to the aquatic system.
• Reduce impervious surfaces as one measure to control runoff and erosion. Research has shown that impervious levels of 8–12% represent a threshold region where small changes in urganization can cause major changes in stream condition (Wang et al. 2001). There are also many BMPs that may be alternatives to reduce runoff. Encourage use of pervious paving materials where feasible.
• Initiate a drought management program that modifies discharge permits when base flow conditions decrease and the 7Q10 is lowered.
• Augment in-stream habitat to enhance its structural complexity to increase fish community abundance, biomass, and diversity (Hrodey and Sutton 2008).
• Preserve or restore riparian vegetation to maintain stable streambanks and dissipate water runoff energy, which allows for sediment deposition.
• In managed rivers, restore stream flows that promote controlled overbank flows and hydrological connectivity between the river and the floodplain.
• Update flood maps as required by changes in flood patterns (frequency and duration) and flooded lands to ensure protection of life and property (Band and Salvesen 2009).
• Protect potential migration corridors and preserve connectivity that allows for species and ecosystem migration.

4.2.2.5 Partnerships and Cooperative Efforts

Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Work with partners and support development of regulations for control of aquatic nuisance species.
• Undertake immediate and continuing efforts to limit water quality deterioration from point sources of pollution as well as nonpoint sources. In general, the most critical conservation actions necessary to sustain populations of riverine habitat species involve protection of water quality and aquatic habitats.
• Protect floodplains and riparian wetlands from development or land uses that interfere with flood control or floodwater attenuation. Changes in flood patterns (frequency and duration) and flooded lands may periodically require updating flood maps to ensure protection of life and property (Band & Salvesen, 2009).
• Preserve forests and open space, farm land, rural landscapes, and park lands. Manage open lands and plant trees and vegetation in urban areas to aid in carbon sequestration.
• Plant riparian areas with vegetation with a broad elevational range within a particular watershed and with broad hydrologic tolerance to promote resiliency from climate change.
• Use easements and value taxation, and fee simple purchase for land conservation or preservation.
• Promote efforts to control stormwater management and point source pollution.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Land use planning and zoning laws are needed to guide development, land clearing activities, and hydrology alterations within floodplains. Planning such as this may for example route highways and other corridors that cross floodplains as closely as possible to existing corridors to avoid fragmenting large forested areas.

The following three sections provide information about temperature regimes of aquatic communities.

- Section 4.2.3 Coldwater Systems
- Section 4.2.4 Coolwater Systems
- Section 4.2.5 Warmwater Systems

Depending on landscape position and contributing waters it is possible that an aquatic community could have more than one temperature regime.

4.2.3 Coldwater Systems

4.2.3.1 Ecosystem Description

Coldwater habitats can be found in different sized streams in the Mountain ecoregion, certain locations within the Piedmont ecoregion, and in springs or groundwater-fed systems found in all ecoregions of the state. Often the streams are headwaters in the Mountains, but the upper portions of some small and medium river systems can have coldwater habitats if they are influenced by cooling water discharges from hydropower facilities or effluent discharges from industrial processes.

The coldwater designation is based upon two general principles: temperature regime and fish community structure. When used to classify coldwater streams, the temperature regimes of summer water temperatures typically do not exceed 20 degrees Celsius (°C) [68 degrees Fahrenheit (°F)]. This is a suggested temperature that will usually support a coldwater fish community structure that includes salmonid species (e.g., trout species) (USACE 2003). For migrating salmonids in the Pacific northwest, the EPA recommends a 7-day average daily maximum water temperature of 20°C (USEPA 2012a). McCullough et al. (2009) suggest 22°C–23°C as a threshold for juvenile salmonid species. A review of research literature seems to indicate the need for availability of a temperature gradient appropriate to support differing size, age, and possibly sex of the species.

Whether the seasonal and daily variation of water temperature is natural or induced, the temperature will influence the distribution of aquatic species in this aquatic system (Caissie 2006). Coldwater streams generally have a fish species composition that includes: Brook, Brown, and Rainbow trout, Mottled Sculpin, Longnose and Blacknose Dace, and Central Stoneroller. This list of species is not inclusive and is provided as general guidance on community structure.

Table 4.2.3-1 lists the type of aquatic natural communities that may provide coldwater habitats and the ecoregion where they likely occur. Descriptions of these natural communities can be found in later sections of this chapter.

Table 4.2.3-1 Aquatic natural communities containing coldwater habitats

Stream Size	Ecoregions
Springs/Groundwater/Cave Waters	Statewide
Headwaters/Small Creeks (< 40 sq.mi. DA)	Mountain, Piedmont
Large Creeks/Small Rivers (40–200 sq.mi. DA)	Mountain, Piedmont
Medium Rivers (200–3,800 sq.mi. DA)	Mountain, Piedmont
Reservoirs & Impoundments	Mountain

4.2.3.2 Location of Habitat

Coldwater aquatic communities can be found in the Broad, Catawba, French Broad, Hiwassee, Little Tennessee, New, Savannah, Watauga, and upper Yadkin river basins. A review of US Geological Survey (USGS) real-time stream gauge data for water temperatures shows that Cataloochee Creek (near Cataloochee, NC), Mills River (near Mills River, NC), Pigeon River (near Canton, NC), Yadkin River (near Patterson, NC), and Catawba River (near Pleasant Gardens, NC) historically have persistent cold waters during the summer (USGS 2014a). Examples of other locations where coldwater habitats occur in at least a portion of the stream, and where brook trout and other coldwater fish species have been detected during field surveys, include Big Laurel Creek, Brasstown Creek, Cane River, Cove Creek, Mitchell River, Nolichucky River, and the Nantahala River. These locations represent only a few of the coldwater habitats found in the state.

Figure 4.2.3-1 indicates the approximate location where coldwater habitats occur within the river basins of western North Carolina. The presence or absence of riparian buffers, discharge into the waters, or other local landscape conditions will influence water temperatures and aquatic communities. It is important to understand that not all of the streams, rivers, and impoundments that occur within the shaded area of Figure 4.2.3-1 are coldwater habitats nor have trout or other coldwater species present in the community.

4.2.3.3 Problems Affecting Habitats

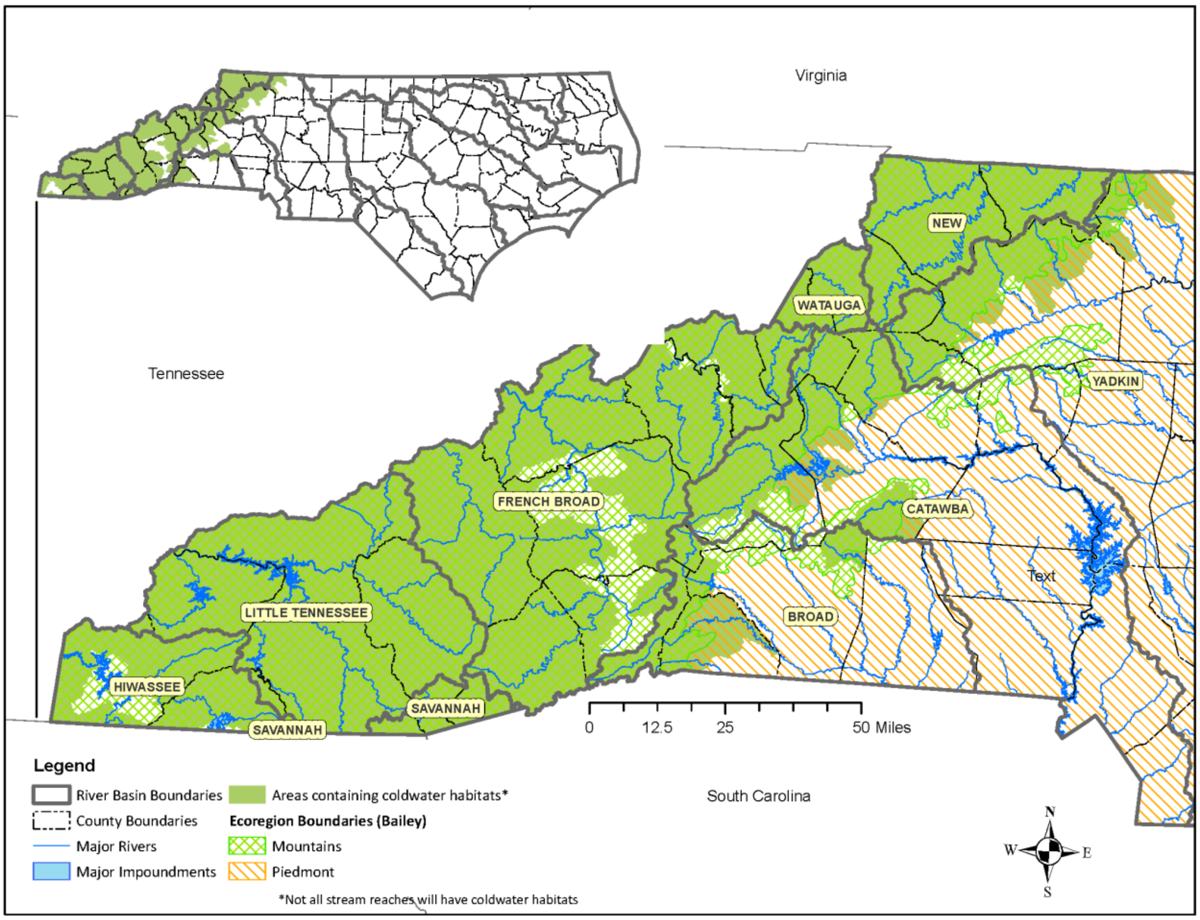
Chapter 5 Threats provides more information about 11 categories of threats most likely to impact North Carolina's wildlife and natural communities. The list of threats are based on definitions and classifications published by Salafsky et al. (2008, 2024). The following information focuses on current and anticipated threats for this habitat.

Water Quality. As with coolwater streams, erosion and the resultant sedimentation are the largest sources of nonpoint source pollution in most aquatic systems. Sources of erosion include disturbance from development activities and agriculture. Residential development, particularly in steep slope areas, is of particular concern because of increased erosion. Livestock access to streams contributes heavily to bank erosion, sedimentation, and nutrient input. Timber harvests and poorly constructed and maintained timber roads are additional sources of erosion if proper controls are not used and maintained.

Many of the water quality and water quantity impacts resulting from climate change are analogous to impacts from economic development and population growth in North Carolina. Climate change is predicted to decrease rainfall and therefore, limit water supply, while growth and development have been increasing and continue to increase water supply demands. Historical stream flow patterns are projected to be altered due to climate change impacts; however, these are already being altered due to rapid urbanization.

An increase in impervious surfaces due to roads, parking lots, homes, and businesses increases the amount and speed of runoff being delivered into aquatic systems. Runoff from urban areas often contains higher concentrations of nutrients (such as nitrogen and phosphorus), sediment, metals, hydrocarbons, and microbes. Decreased groundwater recharge between storms due to impervious surfaces leads to a decrease in stream base flows.

Figure 4.2.3-1. Location of coldwater habitats.



Invasive Species. Introduction of nonnative species creates competitive pressure on native populations. Yellowfin Shiner is native to the Savannah River Basin but has been introduced to the Little Tennessee River Basin, and their range could expand into other coldwater systems with warming water temperatures.

Climate Impacts. Lower water levels during dry times will increase stress to the system. Connectivity to contributing waters within the system will be restricted or eliminated by low- and no-flow conditions. Changes in flow regime will likely result in changes in the overall stream morphology and transport of sediment.

An increase in frequency and intensity of storms due to climate change will have a similar impact on stream systems by increasing pollutant loading. Increased storm intensity that causes flooding can lead to increased stormwater runoff and erosion. With increased stormwater runoff, there is an increase in loading of sediments, nutrients, and contaminants into streams and potential negative effects on biota, such as fish kills. With a change in intensity and variability of rainfall, there are potential changes to stream flow patterns, channel hydrodynamics, and the volume of groundwater (Band and Salvesen 2009; USEPA 2010; Bakke 2009).

4.2.3.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. While climate change is not the most severe threat to coldwater systems, a combination of synergistic effects with development and lack of forested riparian corridors could stress these systems to the point where several species are unable to persist.

Table 4.2.3-2 provides the results of a vulnerability assessment completed by the NCNHP (2010) for coldwater systems that compare climate change impacts in order of importance with other types of potential or known threats.

Table 4.2.3-2. Comparison of climate change with other threats to coldwater systems

Threat	Rank Order	Comments
Development	1	Direct, secondary, and cumulative effects from development. Residential development, particularly in steep slope areas, is of particular concern because of increased erosion.
Lack of riparian vegetation	1	Lack of riparian vegetation or inadequate width of forested buffers can cause streambank erosion and sedimentation. Vegetation also provides shading that reduces water temperature and is a source of detritus that is a food resource for macrobenthic species.
Pollution	2	Point and nonpoint sources—runoff and EDCs—are threats. Recent studies have shown that EDCs in treated wastewater can inhibit reproduction and cause feminization of mussels and fish. Christmas tree farms use high amounts of herbicides and pesticides that may persist in soil for long periods of time or run off into streams.
Cattle in Streams	2	Livestock access to streams contributes heavily to bank erosion, sedimentation, and nutrient input.
Climate Change	3	Coldwater systems may shrink in habitat and extent, making small streams more vulnerable to water temperature increases because of their low thermal capacity (Caissie 2006).

Table 4.2.3-2. Comparison of climate change with other threats to coldwater systems

Threat	Rank Order	Comments
Water Withdrawals	4	Water withdrawals can be problematic, particularly in streams with already low 7Q10 flows, because they may reduce available habitat for aquatic species. Irrigation withdrawals pose a threat to flow regime.
Conversion to agriculture/ silviculture	4	Conversion of land, both from forest to agriculture or silviculture, as well as from development projects, continues to threaten stream integrity, resulting in increased sediment, bank erosion, and stormwater runoff containing sediment and other potentially toxic materials. Timber harvests with improper erosion controls and poorly constructed and maintained timber roads can cause erosion.
Impoundment/ Dams	4	Effects are both direct and indirect, including loss of habitat, shifts in food web, and change in species composition. Numerous watersheds in the Mountains no longer contain trout assemblages likely due to a proliferation of ponds that not only block fish movements, but also cause decreased stream flows and increased water temperatures.
Invasive Species	5	Invasive plants in the riparian area can have negative impacts on stream systems by creating a monoculture (e.g., Japanese Knotweed) with poor nutrient inputs, reducing bank stability, and allowing too much sunlight to infiltrate, resulting in warmer stream temperatures. The Asian Clam or Rusty Crayfish may compete for space and resources, although specific interactions are largely unknown.

4.2.3.5 Impacts to Wildlife

Appendix 3 contains lists of SGCN and knowledge gap, management concern, or management need priority species. Appendix 3-18 provides a list of SGCN associated with coldwater habitats.

Coldwater stream communities contain several rare species that are at risk of extirpation or extinction because they are vulnerable to warming water temperatures and other water quality changes. Several SGCN and priority species have very limited distributions or, if widely dispersed, have small populations (e.g., Eastern Spiny Softshell Turtle, Loggerhead Musk Turtle, Junaluska and Longtail Salamanders). Isolation or habitat fragmentation could affect life cycle or prey components for a variety of species.

Trout populations in our state are already at the southern end of their range and the native brook trout should be a species considered vulnerable to extinction in this ecosystem group. They typically occupy the upper reaches of mountain headwater streams and few populations have the ability to migrate to colder waters. Typically, trout are unable to survive in waters where temperatures rise above 20°C–24°C during summer. Because of the already limited range of trout in North Carolina, it is unlikely these fish will be able to seek refuge from warming water temperatures. It should be noted that Weaver (2010) examined the effects of trout stocking on native nongame fishes and found no significant differences in fish density, species richness, species diversity, or fish microhabitat use associated with short-term effects of trout stocking.

Freshwater mussels rarely overlap habitat with trout; however, with changes to the temperature regimes in these systems, trout may be extirpated and freshwater mussels could expand or shift habitats. As water temperatures increase, freshwater mussels inhabiting coolwater systems could move into coldwater systems as their host fish move upstream.

These habitats are also important for a variety of mammals that are semi-aquatic and/or that have an aquatic food base (e.g., Water Shrews, Muskrats, Beavers, River Otters, and certain bats). Selected bird species rely upon aquatic habitats including rivers and streams to provide habitat or a food base. These include various waterfowl, wading birds, and certain songbirds like the Louisiana Waterthrush.

4.2.3.6 Recommendations

In addition to the following recommendations for coldwater systems, Section 4.2.2 has recommendations appropriate for all aquatic communities, statewide. Section 4.5 has recommendations specific to the river basins that contain coldwater streams.

Because coldwater systems occur primarily at higher elevations within Mountain ecoregion watersheds (usually as headwater streams) it is important to preserve their connectivity throughout the watershed. As water temperatures change and become warmer at lower elevations, many species that require colder temperature streams may not be able to migrate if there are barriers to movement. Barriers can include natural structures such as Beaver dams and man-made structures such as pipes, culverts, and dams.

Surveys

General surveys are needed to complete primary distribution and status for all species that use these aquatic species, especially for SGCN and other species believed to be declining.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Conduct baseline surveys to determine current distributions for the several SGCN associated with coldwater systems in western North Carolina that are known in only a few localities, and/or are considered rare or declining.		
Eastern Hellbender	Mudpuppy	Eastern Spiny Softshell
Junaluska Salamanders	Loggerhead Musk Turtle	Water Shrew
Longtail Salamanders		
• Gather better information about the status and distribution of more common species associated with coldwater stream habitats.		
Shovel-nosed Salamander	Three-lined Salamander	
• Investigate population status of native Brook Trout.		
Eastern Brook Trout		

Monitoring

Monitoring of aquatic taxa is critical to assessing species and ecosystem health and gauging the resilience of organisms to a changing climate. These monitoring efforts will inform future decisions on how to manage aquatic species. Long-term monitoring is needed to identify population trends and to assess performance of conservation actions. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Research

Research topics that facilitate appropriate conservation actions includes habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Research must also be conducted to determine vulnerability of priority species to specific threats and studies and should provide recommendations for mitigation and restoration. Aquatic species propagation is an area of current and ongoing research. Developing techniques for propagation of aquatic species is critical for preserving those species and their genetic stock, particularly those that are rare, at high risk of extinction or extirpation, and difficult to propagate in a laboratory setting.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Determine specific flow regimes necessary to support microhabitat for particular species.
Junaluska Salamander

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Gather better information regarding the inputs and influence of groundwater sources to accurately predict the influence of climate change on coldwater systems.
• Conduct genetic research to resolve taxonomic issues for aquatic species, such as the 'Acuminate Crayfish' complex (*Cambarus* sp. C) and a Lake Waccamaw *Lampsilis* mussel complex. 'Acuminate Crayfish' complex; Lake Waccamaw *Lampsilis* mussel complex
• Study the combined effect of land use changes and climatic effects on long-term stream temperature trends as they relate to native brook trout protection, restoration, and management. Eastern Brook Trout
• Investigate thermal tolerance for brook trout and other native coldwater species. Eastern Brook Trout; Eastern Hellbender
• Examine stream temperature and associated microclimatic responses to a range of shading variables from riparian vegetation.
• Determine the effect that Beaver ponds have on downstream movement of toxins and sediment.

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Increase the effective connectivity (i.e., gene flow) between headwater brook trout populations through removal of artificial barriers and promote habitat connectivity. Eastern Brook Trout

Partnerships and Cooperative Efforts

Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Plant riparian areas with native vegetation with a broad elevational range within a particular watershed and with broad hydrologic tolerance to promote resilience from climate change.

4.2.4 Coolwater Aquatic Communities

4.2.4.1 Ecosystem Description

Coolwater streams are found in small and large river systems in the Mountain ecoregion. Many have impoundments and reservoirs (see Section 4.2.13 Reservoirs & Impoundments for additional information). Many of the coolwater streams and rivers originate in high-elevation areas in the upper portion of watersheds as cold waters but transition to coolwater with a decrease in elevation or gradient and the addition of tributary waters.

The coolwater designation is based upon two general principles: temperature regime and fish community structure. Temperature regime can also be used to help classify coolwater streams where summer temperatures are predominantly warmer than 20°C (68°F) but typically do not exceed 25°C (76°F). This is a suggested temperature that will typically support the fish community structure (USACE 2003). Coolwater streams generally have a fish species composition that includes: Smallmouth Bass, Rock Bass, Walleye, Muskellunge, Creek Chub, River Chub, Bluehead Chub, Whitetail Shiner, White Sucker, Tennessee Shiner, Mirror Shiner, Warpaint Shiner, Northern Hog Sucker, Fantail Darter, Greenside Darter, and Greenfin Darter. This list is not inclusive and provides general guidance on aquatic community structure.

Riverine aquatic communities, which are identified in the 2005 WAP as a priority aquatic habitat, are a component of this habitat type (see Chapter 5) (NCWRC 2005). Bogs and associated wetlands and floodplain forests are two WAP priority habitats that also may be associated with coolwater stream communities; they provide habitat for wildlife that use adjacent terrestrial habitats.

4.2.4.2 Location of Habitat

Coolwater aquatic communities can be found in the upper Yadkin, Hiwassee, Little Tennessee, Savannah, French Broad, Watauga, New, Catawba, and Broad River basins. A review of US Geological Survey (USGS) real-time stream gauge data for water temperatures shows that Cheoah River (near Tapoco, NC), Hyco River (near McGehees Mill, NC), Wolf Island Creek (near Reidsville, NC), Candy Creek (near Monticello, NC), and Deep Creek (near Moriah, NC) historically have cool waters during the summer (USGS 2014a).

Other examples include the Valley River, Hiwassee River (below Mission Lake Dam), Little Tennessee River, Pigeon River (below the confluence of the East and West Forks Pigeon River), French Broad River (below Nicholson Creek and Davidson River), Nolichucky River, New River, and Johns River. The 2005 WAP includes riverine aquatic communities, which contain coolwater streams, as a priority habitat (see Chapter 5) (NCWRC 2005).

4.2.4.3 Problems Affecting Habitats

Chapter 5 Threats provides more information about 11 categories of threats most likely to impact North Carolina's wildlife and natural communities. The list of threats are based on definitions and classifications published by Salafsky et al. (2008, 2024). The following information focuses on current and anticipated threats for this habitat.

Water Quality. As with coldwater streams, erosion and the resultant sedimentation are the largest sources of nonpoint source pollution in this system. Sources of erosion include disturbance from development activities and agriculture. Residential development, particularly in steep-slope areas, is of particular concern because of increased erosion. Livestock access to streams contributes heavily to bank erosion, sedimentation, and nutrient input. Timber harvests and poorly constructed and maintained timber roads are additional sources of erosion if proper controls are not used and maintained.

Many of the water quality and water quantity impacts resulting from climate change are analogous to impacts from economic development and population growth in North Carolina. Climate change is predicted to decrease rainfall and therefore limit water supply; however, growth and development have increased and continue to increase water supply demands. Historical stream flow patterns are projected to be altered due to climate change impacts, but these are already being altered due to rapid urbanization.

An increase in impervious surfaces due to roads, parking lots, homes, and businesses, increases the amount and speed of runoff being delivered into aquatic systems. Decreased groundwater recharge between storms due to impervious surfaces leads to a decrease in stream base flows. Runoff from urban areas often contains higher concentrations of nutrients (such as nitrogen and phosphorus), sediment, metals, hydrocarbons, and microbes.

Coolwater systems may be more likely to experience a change in species composition as aquatic species shift their range or distribution, and sensitive species decline or are extirpated by changes in water quality and temperature. Aquatic species are particularly sensitive to temperature cues and warming waters could cause species in coolwater habitats to attempt moving upstream into previously cold waters if there is suitable habitat. Some mussel species, for example, are limited in distribution because of coldwater influences. Alternatively, species could become extirpated because they are unable to move before their current locations persistently become warmwaters.

Invasive Species. Introduction of nonnative species creates competitive pressure on native populations. Yellowfin Shiner, native to the Savannah River Basin, has been introduced to the Little Tennessee River Basin. Their range could expand into other coldwater systems with warming water temperatures. Changes in stream conditions could increase competition with fish species, particularly the federally threatened Spotfin Chub.

Climate Impacts. Research conducted by Eaton and Sheller (1996) and Mohseni et al. (2003) assessed the effects of climate warming on 57 species of fishes in streams across the US. Depending on minimum temperature tolerance assumptions, species requiring coolwater habitats could experience a 12%–15% decrease in available habitat (DeWan et al. 2010). When the connectivity between streams and rivers within drainage basins provide adequate dispersal corridors, species at the southern extent of their geographical distribution may shift their distributions northward into cooler habitats (Allan et al. 2005). Where adequate dispersal corridors are limited or restricted, access to or availability of cooler water habitats may limit the range of those species subject to narrow temperature tolerance (DeWan et al. 2010).

4.2.4.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. Aquatic systems have been under threat from a variety of perturbations in the past and many of those continue today. Conversion of land (both from forest to agriculture or silviculture, as well as from development projects), continues to threaten stream integrity resulting in increased sediment, bank erosion, and stormwater runoff containing sediment and other potentially toxic materials.

Considering current conditions in these systems, climate change is likely to have a synergistic effect with other threats that are of more immediate concern. Table 4.2.4-1 provides a review of expected climate change impacts in order of importance in comparison with other types of threats.

Table 4.2.4-1Comparison of climate change with other threatsto coolwater systems

Threat	Rank Order	Comments
Development	1	Residential development, especially in steep slope areas, is of particular concern because of increased erosion. Most coolwater streams are larger streams and rivers and many have wider valleys where land use is more susceptible to being developed than on steeper-sloped headwater streams. Row crops, agricultural grazing, and urban/suburban development are common. Increased presence of impervious surfaces due to roads, parking lots, homes, and businesses increases the amount and speed of runoff being delivered into aquatic systems.

Table 4.2.4-1Comparison of climate change with other threatsto coolwater systems

Threat	Rank Order	Comments
Sediment and Erosion	1	Stormwater runoff will amplify the loading of nutrients, sediment, and contaminants into streams, rivers, and reservoirs, which may alter overall channel design; have a negative effect on biota due to habitat changes, increased turbidity, and chemical exposure; and affect drinking water quality (Band and Salvesen 2009).
Pollution	1	Runoff from urban areas often contains higher concentrations of nutrients (such as nitrogen and phosphorus), sediment, metals, hydrocarbons, and microbes. An increase in frequency and intensity of storms due to climate change will have a similar impact on stream systems by increasing pollutant loading. Point and nonpoint sources—runoff and EDCs—are also threats.
Cattle in Streams	1	Livestock access to streams contributes heavily to bank erosion, sedimentation, and nutrient input.
Lack of riparian vegetation	1	Riparian vegetation serves as nutrient input to the stream community and helps regulate stream temperature by providing shade. Lack of riparian vegetation or inadequate width of forested buffer can cause streambank erosion and sedimentation.
Conversion to agriculture/ silviculture	2	Loss of forest cover can cause increased erosion and sedimentation and negatively impact aquatic systems. Poorly constructed and maintained timber roads are another source of erosion.
Water Withdrawals	2	Irrigation and water supply withdrawals pose a threat to flow regime. Water withdrawals can be problematic, particularly in streams with already low 7Q10 flows, because they may reduce available habitat for aquatic species. Decreased groundwater recharge between storms due to impervious surfaces leads to a decrease in stream baseflow.
Flood Regime Alteration	2	Many rivers that were once free-flowing are now flooded by reservoirs, severely fragmenting habitat and often isolating populations of species above and below the impoundment. Floodplains and wetlands are natural features designed for flood control through attenuation and dissipation of floodwaters. Development and other impacts can reduce this service.
Climate Change	3	Climate change is predicted to decrease rainfall and therefore, limit water supply. Effects will likely compound with other threats to increase the severity of several threats to aquatic systems.

Table 4.2.4-1Comparison of climate change with other threatsto coolwater systems

Threat	Rank Order	Comments
Invasive Species	4	Invasive plants in the riparian area can have negative impacts on stream systems by creating a monoculture (such as Japanese Knotweed) with poor nutrient inputs, reducing bank stability, and allowing too much sunlight to infiltrate, resulting in warmer stream temperatures. Invasive aquatic species, like the Asian Clam or Rusty Crayfish, may have negative effects on native species, such as competition for space and resources.

4.2.4.5 Impacts to Wildlife

Appendix 3 contains several tables listing SGCN and other species for which there are knowledge gaps and management concern priorities. Specifically, Table 3-18 identifies SGCN that use coolwater streams.

The temperature tolerance range of aquatic species can be specific and the availability of cool waters can be a limiting factor in determining where species can find appropriate habitat that do not exceed temperature tolerances, especially as average water temperatures experience warming trends (DeWan et al. 2010). Appalachian Elktoe is a freshwater mussel species that requires cool, clean, well-oxygenated waters, but appropriate aquatic habitat in its range is generally fragmented. Habitat fragmentation can disrupt life-cycle relationships of SGCN priority mussel species and their host fish because the mussels are unable to move into coolwaters as warming trends occur. But their host-fish species are more mobile and may move into new coolwater ranges (Opdam and Wascher 2004; DeWan et al. 2010).

Coolwater riverine habitats are important for a number of reptiles and amphibians, including certain turtles, frogs, and salamanders that utilize aquatic habitats during part or all of their life cycle. These habitats are also important for a variety of mammals that are semi-aquatic and/or have an aquatic food base (e.g., Water Shrews, Muskrats, Beavers, River Otters, and certain bats). Selected bird species (such as various waterfowl, wading birds, and certain songbirds like the Louisiana Waterthrush) also rely upon aquatic habitats to provide habitat or a food base.

4.2.4.6 Recommendations

It is important to preserve the connectivity of cool water systems because they provide a link to coldwater systems that will become refugia as water temperature gradients change and previously cool waters become persistently warmer. As water temperatures change, many species may not be able to migrate into cooler streams if there are barriers to movement or habitats are fragmented so that coolwater habitats are interspersed amongst warmer water habitats.

Section 4.2.2 provides recommendations appropriate for all aquatic communities, statewide. Actions specific to the river basins that contain coolwater streams are provided in Section 4.5.

Surveys

Distributional and status surveys are needed for all aquatic species but are especially needed for aquatic snails and crayfish.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Conduct stream surveys adjacent to areas identified for future development (i.e., edge of urban expansion) to establish baseline populations and identify problems before development expands.

Monitoring

Monitoring of aquatic taxa is critical to assessing species and ecosystem health and gauging the resilience of organisms to a changing climate. These monitoring efforts will inform future decisions on how to manage aquatic species. Long-term monitoring is needed to identify population trends and to assess performance of conservation actions. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Research must also be conducted to determine vulnerability of priority species to specific threats, and studies should provide recommendations for mitigation and restoration. Aquatic species propagation is an area of current and ongoing research. Developing techniques for propagation of aquatic species is critical for preserving those species and their genetic stock, particularly those that are rare, at high risk of extinction or extirpation, and difficult to propagate in a laboratory setting.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

Examine stream temperature and associated microclimatic responses to a range of shading variables from riparian vegetation.

Management Practices.

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Reduce impervious surfaces as one measure to control runoff and erosion. Research has shown that impervious levels of 8% to12% represent a threshold region where small changes in urbanization can cause major changes in stream condition (Wang et al. 2001). There are also many BMPs that may be alternatives to reduce runoff.

Partnerships and Cooperative Efforts.

Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Promote efforts to control stormwater management point source pollution.
• Land use planning and zoning laws are needed to guide development, land clearing activities, and hydrology alterations within floodplains. Planning such as this may for example route highways and other corridors that cross floodplains as closely as possible to existing corridors to avoid fragmenting an extensive corridor of forest.

4.2.5 Warmwater Aquatic Communities

4.2.5.1 Ecosystem Description

The warmwater designation is based upon two general principles: temperature regime and fish community composition. Temperature regime can be used to classify warmwater streams where summer temperatures are predominantly warmer than 25°C (77°F). This is based on suggested temperatures that define cold and coolwaters (USACE 2003). Warmwater streams can have a wide variety of fish species composition depending on landscape location, surrounding land use, elevation, substrate, depth, temperature gradients, and water quality. Examples of warmwater fish species in North Carolina include Blacknose Dace, Creek Chub, Pumpkinseed, Largemouth Bass, and White Sucker.

4.2.5.2 Location of Habitat

Warmwater streams are found throughout the state. Cold and coolwater streams and rivers that originate in the upper portion of watersheds in the Mountains, transition to warm waters with a decrease in elevation and as tributary waters combine to form larger systems. Examples include the lower reaches of the Broad River and Catawba River.

4.2.5.3 Problems Affecting Habitats

Chapter 5 Threats provides more information about 11 categories of threats most likely to impact North Carolina's wildlife and natural communities. The list of threats are based on definitions and classifications published by Salafsky et al. (2008, 2024). The following information focuses on current and anticipated threats for this habitat.

Dams. Impacts to aquatic species occur when habitats are modified and movement between habitats are blocked (Lessard and Hayes 2003). Dams change the overall physical, chemical, and biological structure of streams by modifying stream flows and changing lotic systems to lentic systems; influencing the export of water, sediment, and nutrients to downstream systems; altering water temperatures and thermal regimes; and disconnecting streams from their floodplains and riparian communities (Wang et al. 2011). The results of a study by Wang et al. (2011) indicate that both downstream and upstream dams influence fish assemblages in non-impounded stream segments; however, the study found the cumulative effects of other environmental factors such as stream size, adjacent land uses, water quality, and stream flow and thermal regimes may have a more significant influence on fish occurrence and abundance.

Thermal Stratification and Algal Blooms. Stratification is common during periods of low flow, mid- to late-summer on big rivers and results in hypoxic or anoxic conditions. Thermal stratification is rare in warmwater streams in Mountain and Piedmont stream due to the mixing effect of flows and lack of sufficient depth. During periods of low water flow and little wind, deeper pools within a river may become stratified with little or no vertical mixing. Under these conditions DO levels in the deeper water may be depressed and become unsuitable for many aquatic organisms. Algal blooms in the surface water can exacerbate DO depletion and result in local degradation of water quality. Such conditions are temporary and are readily alleviated by increased water flow or increased wind velocity.

In Coastal Plain streams stratification may occur due to saltwater intrusion occurring as a subsurface density flow. The denser saltwater does not mix with the less dense fresh water and as a result the water column becomes stratified. Oxygen depletion as well as toxic bacterial and algal blooms can be associated with this type of event, often leading to significant mortalities within the aquatic community.

Invasive Species. Warmwater streams provide pathways for invasion by non-native species. In the absence of obstructions such as dams, culverts, waterfalls etc, invasive species can travel long distances within a system and establish viable populations within the main stem river as well as tributaries. Once in a river system invasive species are difficult, if not impossible, to eradicate or even control.

Water Quality. Warmwater streams typically occur at lower altitudes with a relatively moderate topography. Thus the adjacent land is more likely to be used for purposes such as residential development, industry, commerce and agriculture. All of these are sources for discharges of various chemicals into the river, which can moderately or substantially affect biological communities. The moderate temperature regime of these waters often accelerates biological activity promoted by inputs of organic compounds resulting in degraded water quality.

Sedimentation is particularly problematic in warmwater streams. Development of riparian and adjacent areas can accelerate erosion and relatively low stream gradients can promote the deposition of eroded sediment within the stream channels. Sedimentation can decrease the depth, increase water temperatures and decrease the biological productivity of affected waters.

Rivers flowing through or near urban and suburban areas may receive incompletely processed pharmaceuticals from sewage treatment plants, that can affect the production of hormones in aquatic fauna.

4.2.5.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. Aquatic systems have been under threat from a variety of perturbations in the past and many of those continue today. Conversion of land, both from forest to agriculture or silviculture, as well as from development projects, continues to threaten stream integrity resulting in increased sediment, bank erosion, and stormwater runoff containing sediment and other potentially toxic materials. Considering current conditions in these systems, climate change is likely to have a synergistic effect with other threats that are of more immediate concern.

A comparison of climate-related impacts to other threats is not included because a vulnerability assessment for warmwater systems has not been conducted. However, development, sediment and erosion, and pollution are primary concerns, and results similar to the comparison for coolwater systems are expected (see Table 4.2.4.1 in Section 4.2.4).

4.2.5.5 Impacts to Wildlife

Fish can regulate their metabolism by changing location or congregating in response to thermal stratification that can occur seasonally or in response to artificial thermal effluent (e.g., power plant discharge) (Reynolds and Casterline 1979; Peterson and Rabeni 1996). The temperature tolerance range of aquatic species can be specific and the availability of warm waters that do not exceed tolerances can be a limiting factor in determining where species can find appropriate habitat, especially as average water temperatures experience warming trends (DeWan et al. 2010). Even though they may not normally congregate during the winter, fish may do so if warmer water is available instead of the traditionally colder water. This will result in increased vulnerability to predation and exposure to disease (Peterson and Rabeni 1996).

Many large warmwater rivers in the Piedmont ecoregion have hydropower dams that regulate daily flow. These fluctuations can result in streambed and bank instability, scouring, erosion, and turbidity and can discourage riparian vegetation, streambed vegetation, and algal growth (Walburg et al. 1983; Cushman 1985; Peterson and Rabeni 1996). These impacts may contribute to a reduction in macroinvertebrate prey and loss of emergent and submerged vegetation, which will affect fish productivity (Peterson and Rabeni 1996). The loss of vegetated and edge of channel habitats that serve as nursery areas for young fish can impact age classes, and species that have low reproduction rates may experience loss of entire years of reproductive potential (Peterson and Rabeni 1996).

Warmwater habitats are important for a number of reptiles and amphibians including certain turtles, frogs, and salamanders that utilize aquatic habitats during part or all of their life cycle. These habitats are also important for a variety of mammals that are semi-aquatic and/or that have an aquatic food base (e.g., Water Shrews, Muskrats, Beavers, River Otters, and certain bats). Many bird species also rely upon aquatic habitats including rivers and streams to provide habitat or a food base; these include various waterfowl, wading birds, and certain songbirds.

4.2.5.6 Recommendations

In the Mountains and upper Piedmont it is important to preserve the connectivity of warmwater systems where they connect with cold and cool water systems because they provide a link to refugia as water temperature gradients change and previously cool waters become persistently warmer. As water temperatures change, many species may not be able to migrate into waters with appropriate temperatures if there are barriers to movement or habitats are fragmented so that warmwater habitats are interspersed amongst habitats that do not meet thermal requirements.

Section 4.2.2 provides recommendations appropriate for all aquatic communities, statewide. Actions specific to the river basins that contain warmwater streams are provided in Section 4.5.

Surveys

Distributional and status surveys are needed for aquatic snails, crayfish, mussels, and fish (in order of general need).

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Conduct surveys to detect presence and collect life history and abundance data for freshwater snails and crayfish, as there is limited information available on these species. Snails Crayfish

Monitoring

Monitoring of aquatic taxa is critical to assessing species and ecosystem health and gauging the resilience of organisms to a changing climate. Long-term monitoring is needed to identify population trends and to assess performance of conservation actions. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web. Research must also be conducted to determine vulnerability of priority species to specific threats, and studies should provide recommendations for mitigation and restoration. Aquatic species propagation is an area of current and ongoing research. Developing techniques for propagation of aquatic species is critical for preserving those species and their genetic stock, particularly those that are rare, at high risk of extinction or extirpation, and difficult to propagate in a laboratory setting.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Gain a broad community-level perspective to simplify the in-stream flow assessments associated with hydropower projects. Research is needed to develop habitat suitability criteria to aid in the assessments (Lobb III and Orth 1991).

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Partnerships and Cooperative Efforts

Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable.

4.2.6 Groundwater, Springs, and Subterranean Water Systems

4.2.6.1 Ecosystem Description

Groundwater is present throughout North Carolina at varying depths below the land surface. The traditional definition for groundwater is subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated (Freeze and Cherry 1979). For this aquatic community description, we use the term “groundwater” to represent all subsurface waters generically, including saturated soils and underground streams. These systems may interact with or transition to other types of habitats (e.g., streams, lakes, wetlands) (Winter et al. 1998) which are described as separate natural communities in other sections of this chapter.

Groundwater is subsurface water stored in a zone of soil saturation and occurs beneath the water table (Freeze and Cherry 1979; Fetter 2001) and differs from surface waters because of the absence of light and the fact that organic matter and oxygen are imported from the surface (Hahn 2009). Groundwater recharge is the process where water infiltrated from the surface is added to the saturated zone; the top of the saturation zone is referred to as the water table (Domenico and Schwartz 1998; Campbell and Coes 2010). Groundwater forms a water table that can lie at the ground’s surface and contribute to the baseflow of a stream or it can be situated underground at varying depths, existing as subsurface flow. Some groundwater discharge is an interstitial habitat that is hydrologically linked to and contributes baseflow to wetlands, ponds, or lakes (Culver et al. 2012). Groundwater intersects with streams where the water table is at or slightly above the streambed (Gordon et al. 1992; Peterson and Rabeni 1996).

Springs are points of focused groundwater discharged at a small point on the land surface (van der Kamp 1995; McGinley 2013). They are generally stable in terms of water quality, temperature and flow (Fleury 2009). Springs can also form at the spots where karst waters emerge from the local underground drainage system and develop on the surface or in caves (Fleury 2009). They are made up of groundwater that has infiltrated at different times, from different places, and potentially under different conditions than currently exist (van der Kamp 1995). In contrast, seeps discharge to a larger area than a spring (McGinley 2013). Seepage springs are a diffuse discharge of gravity-fed water where the land surface is wet compared to surrounding areas, but there is no observable flow (Culver et al. 2012). Springs feeding into creeks and rivers can provide cold water microhabitats and, in some cases, can reduce overall water temperature. This in turn reduces thermal stress on aquatic species sensitive to warm waters.

Subterranean water develops in permeable layers of soil, sand, and rock. A subterranean system that carries groundwater in sufficient quantity to provide usable water supplies is called an aquifer (Hynes 1983; Barnes-Svarney and Svarney 2004; Kokkonen et al. 2011). Coastal Plain groundwater is found primarily in porous sand and limestone (carbonate rock), and is regionally classified as being shallow unconfined (surficial) aquifers or deeper confined aquifers (Smith and Chapman 2005;

USGS 2012a; Denver et al. 2014). All aquifers have an impermeable layer beneath them that stops the groundwater from infiltrating further. When the layers above it are permeable, it is an unconfined aquifer and when the permeable layer occurs between two impermeable layers, it is a confined aquifer (Domenico and Schwartz 1998; McGinley 2013). Precipitation in aquifer outcrop areas is a major source of recharge to aquifers under predevelopment and present-day conditions (Aucott 1996).

Many of the Coastal Plain aquifers are karst systems that have formed over geologic time scales through the dissolution of carbonate bedrock, resulting in the formation of the caves, sinkholes, springs, and subterranean streams that are typical features of a karst system (Fleury 2009; USGS 2012a). Aquifers in the central Coastal Plain area are formed from unconsolidated deposits of sand, silt, clay, and limestone (Heath and Spruill 2003). Aquifers in the Piedmont and Mountain ecoregions are found in Triassic Basin rocks that are covered by regolith (soil, saprolite, alluvium, and colluvium) (USGS 2012a). Karst systems and other subterranean resources should be considered non-renewable once they have been depleted or degraded, because they are formed by specific processes that occur over long geologic time periods (Gunn et al. 2000).

4.2.6.2 Location of Habitat

Because aquifers are geological features that are often used for drinking water, supply mapping information is generally available. Such principal aquifers include the Lower Cape Fear, Upper Cape Fear, Black Creek, Pee Dee, Castle Hayne, Yorktown, Surficial, and Bedrock aquifers. Minor aquifers in the State include the Lower Cretaceous, Beaufort, and Pungo River (NCDWR 2010b; USGS 2012a). Potentiometric surface maps for several Coastal Plain ecoregion aquifers are available from the NC Division of Water Resources (2015g). Springs are generally associated with stream systems, especially headwater streams, and other surface water bodies such as farm ponds.

4.2.6.3 Problems Affecting Habitats

One of the most important issues concerning groundwater systems is the increasing demand for water supplies due to growth and urbanization (Land et al. 2004). Groundwater extraction to meet this demand is often at unsustainable rates (Fleury 2009) and results in declining water levels, saltwater encroachment (in Coastal Plain systems), dewatering, and land subsidence (e.g., sink holes) (Land et al. 2004; Fleury 2009). Groundwater pressure can drop when there is rapid and excessive drawdown of an aquifer and the pore space holding the groundwater shrinks. This leads to compaction of the aquifer at depth (Fleury 2009). Voids can form in the soils and porous rock that once held water, which causes subsidence and collapse of the land surface (Patton and DeHan 1998; Fleury 2009).

According to the USGS, groundwater withdrawals from the Castle Hayne aquifer have caused land subsidence measuring as large as 7 inches, and has been documented (during the 33-year period from 1935–68) in the central Coastal Plain of North Carolina. Overall water-level declines are estimated to be as much as 20 feet near pumping centers (McSwain et al. 2014; USGS 2014b).

Mining operations can remove notable features from the landscape and alter the hydraulic gradients that contribute to groundwater systems. Quarrying often reduces spring discharge, causing drawdown of the water table, sinkholes, and the destruction of caves. Tailing ponds associated with mining operations may leak or collapse, and can become a source of toxic chemicals in local water supplies.

Because of their permeable rock structure and presence of sink holes, karst systems are especially vulnerable to pollution, water withdrawals, and changes in land use (Bakalowicz 2005; Calo and Parise 2009; Brinkmann and Parise 2012). Agricultural activities can degrade the quality of groundwater quality through the usage of fertilizers and pesticides and storage or disposal of livestock or poultry wastes on land (Freeze and Cherry 1979). Contamination from nitrate-based fertilizers used on agricultural lands can wash into groundwater that is a source of residential drinking-water wells (Fleury 2009).

Dripwater flows are critical both to cave biota and to the microclimates of the caves themselves, and if those flows carry surface-level contaminants, the entire cave environment can be affected (Fleury 2009). Human use of caves can alter the physical structure of the caves themselves, change the water chemistry or hydrology within the cave, or destroy cave structures and cave-dwelling organisms (Fleury 2009).

Another concern is the advance of the saltwater front from coastal waters into freshwater systems, commonly referred to as saltwater encroachment. For example, New Bern's freshwater wells have experienced saltwater encroachment since the late 1960s. A Cove City drinking-water well field was about 5 miles west of where the front was previously located and the start of withdrawals there in 1968 is believed to have resulted in a reversal of the saltwater zone hydraulic gradient. Since then the front has been advancing and represents what is essentially a permanent decrease in subterranean freshwater storage capacity (Heath and Spruill 2003; USGS 2012b).

4.2.6.4 Climate Change Compared to Other Threats

A comparison to other threats has not been conducted for this natural community type. Comparing climate change to other ecosystem threats helps define short- and long-term conservation actions and recommendations. While climate change is not the most severe threat to this natural resource, a combination of synergistic effects with other threats could stress these systems to the point of depletion.

4.2.6.5 Impacts to Wildlife

The unique characteristics of species associated with groundwater, springs, and subterranean water are referred to as troglomorphy: reduced or absent eyes and pigment and elongated, thin appendages (Culver and Pipan 2009; Culver et al. 2012). These obligate subterranean-dwelling aquatic species are considered stygobionts (Barr and Holsinger 1985; Culver et al. 2012). Obligate cave-dwelling animals are considered to be troglobites and include turbellarians, gastropods, millipedes, arachnids, pseudoscorpions, isopods, amphipods, beetles, fishes, and salamanders (Barr and Holsinger 1985).

There has been little research in North Carolina, but research conducted by Kenk (1935, 1972, 1977a, 1977b) and Culver with others (1969, 1971, 2004, 2006, 2008, 2009, –2010) that focused on subterranean systems in Washington, DC, Maryland, and Virginia provided information that may assist in understanding what type of subterranean species are present in North Carolina. According to Culver *et al.* (2012), two tidewater amphipods (*Stygobromus araeus* and *S.indentatus*) occur frequently enough to have permanent populations in some seepage springs and hypotelminorheic habitats (small isolated aquifers underlain by clay). One of the amphipods (*S. indentatus*) was included in a petition filed by the Center for Biological Diversity, requesting that the USFWS list the species for protection under the ESA. The petition lists the species as occurring in North Carolina. Culver *et al.* (2012) indicates the tidewater amphipod was found in a shallow well in Nash County, North Carolina.

4.2.6.6 Recommendations

Groundwater is a valuable resource often used for industry, commerce, agriculture, and most importantly drinking water (USGS 1995). Contaminants in the recharge zone can be transported in waters contributing to springs, wells (including drinking waters), and surface waters that provide aquatic habitats. All groundwaters need to be protected because contamination can cause water quality problems not only in these systems, but also to other waters connected to them that ultimately creates long-term negative impacts to aquatic species.

Section 4.2.2 provides recommendations appropriate for all aquatic communities, statewide. Information specific to the river basins where this community type occurs can be found in Section 4.5 of this chapter.

Surveys

Distributional and status surveys are necessary for species that utilize these waters, especially for invertebrates.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• These habitats need to be identified so they can be surveyed. Baseline surveys in and around these habitats for crayfish, mussels and snails are needed to document what species are utilizing these aquatic and semi-aquatic habitats.		
Crayfishes	Snails	Freshwater Mussels

Monitoring
Monitoring ecosystem health helps develop an understanding about its resilience to a changing climate. Monitoring efforts inform future decisions on how to manage and safe-guard the system. Long-term monitoring is needed to identify trends and to assess the performance of conservation actions. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Research
Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Research must also be conducted to determine vulnerability to specific threats, such as fracking and groundwater extraction. Recommendations for mitigation and restoration of degraded systems should be included.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Investigate the interactions between groundwater influence on crayfish, fish, snail, and mussel diversity and abundance.		
Crayfish	Freshwater Fish Freshwater Mussels	Snails

Management Practices
Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Partnerships and Cooperative Efforts
Conservation programs, incentives, partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. This includes protective measures that utilize existing regulatory frameworks to protect habitats and species. When insufficient measures of protection exist, new regulations should be developed.

4.2.7 Headwater Streams/Small Creeks

4.2.7.1 Ecosystem Description

The headwater stream and small creek community includes intermittent and first and second order streams and make up the largest proportion of drainage reaches in the landscape (Leopold et al. 1964; Meyer et al. 2007; Gothe et al. 2014). The majority of land area in North Carolina (approximately 80%– 85%), drains to headwater streams (Gregory 2009) and constitutes at least 80% of the nation's stream network (Meyer et al. 2003). Headwater streams are very important elements in the stream and river networks in terms of influencing water quality and quantity.

A stream classification system using DA as a break for size classes, similar to those described in the Northeast Aquatic Habitat Classification System and the National Fish Habitat Framework, has been applied to this aquatic community description. The hierarchical classification system shown in Table 4.2.1 defines headwater streams as having a drainage area (DA) of 40 square miles or less (Olivero and Anderson 2008; Olivero-Sheldon and Anderson 2013).

Stream size affects the aquatic biological assemblages within a stream reach (Vannote et al. 1980; Higgins et al. 2005; Olivero-Sheldon and Anderson 2013). Species diversity tends to be lower in headwater systems when base flow conditions are highly variable. Overall, species richness is typically lower than in small river systems and is often comprised of the most common generalist species; mussels are often absent from headwater streams. In these aquatic communities, the coarse organic matter from riparian vegetation provides the energy resources for what is often a consumer community dominated by shredding insects (Olivero-Sheldon and Anderson 2013). Benthic macroinvertebrates are a very important component of the community, and aquatic insect species richness can be very high even in headwaters in agricultural and urban landscapes (Moore and Palmer 2005; Meyer et al. 2007).

Headwater streams in the Mountain ecoregion are influenced by location on the landscape. Persistent water temperatures will determine whether they are considered coolwater systems or coldwater systems. Headwater streams found in other areas of the state are more likely to be considered warm water systems. Warmwater systems are those that have water temperatures that are persistently greater than 25°C (77°F). Water temperature contributes significantly to the species assemblages that occur in aquatic environments.

4.2.7.2 Location of Habitat

These systems can be found statewide but are more prevalent in the Mountain and Piedmont ecoregions. Headwater systems may be associated with small wetland systems and some originate at natural spring heads. Many streams in this community type are unnamed tributaries; however, examples include Morgan Creek, Parkers Creek, Little Creek, and White Oak Creek.

4.2.7.3 Problems Affecting Habitats

In North Carolina, headwater systems are vulnerable to impacts because they often occur in agricultural and urbanized environments and are less likely to be protected by regulatory requirements such as avoidance and minimization measures and conservation of riparian buffers. The North Carolina Ecosystem Response to Climate Change: NC Department of Environment and Natural Resources (NCDENR) Assessment of Effects and Adaptation Measures (NCNHP 2010) Report for Headwater Systems provides more information about the expected impacts of climate change and other threats to this community type.

Land Use. Headwater streams are primarily located on private lands and are more likely to be threatened by changes in land use practices. Land use change that results in greater areas of impervious surface can increase stormwater runoff of nutrients, sediment, and contaminants. The increased loads could affect water quality and habitat for aquatic species (Band and Salvesen 2009). Headwater systems in agricultural areas where BMPs, such as no-till farming, are used and where riparian buffers are maintained were found to have high macroinvertebrate richness compared to headwaters in urban areas (Moore and Palmer 2005). Small impoundments used for irrigation or as an amenity (e.g., swimming, fishing) are often located in headwater streams and may not be subject to dam safety rules that carry minimum flow requirements. Lack of minimum flows will exacerbate the effects of drought and where water levels become shallow the resulting high water temperature will kill aquatic species.

Riparian vegetation is critical to the overall stream and streambank stability. Lack of riparian vegetation or inadequate width of forested buffer can cause streambank erosion and sedimentation. In addition to stabilizing streambanks, riparian vegetation serves as a food and nutrient input to the stream community and helps regulate stream temperature by providing shade.

Water Quality. Headwater streams often make up as much as 85% of the total stream length within a drainage network and contribute both water, woody debris, and nutrients collected from adjacent landscapes downstream to larger streams (Peterson et al. 2001). Studies have shown that headwater streams retain and transform as much as 50% or more of the nitrogen inputs from their watershed, often within short distances and over short time periods (Peterson et al. 2001). Despite their small size, headwater streams serve an important function in regulating nitrogen uptake and processing that protects water quality. Small drainages, and especially headwater systems, are sensitive to local conditions such as nutrient loads in runoff (Peterson et al. 2001; Meyer et al. 2007). When nutrient loads are high, headwater streams can lose their capacity to retain and transform nitrogen locally, thereby allowing greater nutrient loads to flow into downstream waters where they contribute to water degradation and eutrophication (Peterson et al. 2001).

Erosion and the resultant sedimentation are the largest sources of nonpoint source pollution in most aquatic systems. Sources of erosion include disturbance from development activities and agriculture. Residential development can increase erosion during the construction process, but can also be a secondary cause of increased impervious surfaces in the watershed. Livestock access to streams contributes heavily to bank erosion, sedimentation, and nutrient input. Timber harvests and poorly constructed and maintained timber roads are additional sources of erosion if proper controls are not used and maintained.

Recent studies have shown that EDCs in treated wastewater can inhibit reproduction and cause feminization of mussels and fish. Although little is known about the effects of EDCs, additional studies are being conducted to document the levels of EDCs in discharges, and measures are being identified to reduce or eliminate EDCs from wastewater prior to discharge, should those discharge studies show increases in EDC levels (Conn et al. 2006; Kim et al. 2007; Kasprzyk-Hordern et al. 2008; Joss et al. 2006; Kolpin et al. 2002; Nowotny et al. 2007).

Aquatic species could experience shifts in their range or distribution and sensitive species may experience decline or extirpation due to changes in water quality and habitat. Piedmont headwater streams are already vulnerable to drought conditions with low DO or partial or complete drying of streams; climate-change induced drought will only increase this vulnerability. Aquatic species could become extirpated or may move further downstream into higher order streams. Therefore, these systems may experience a change in species composition.

Invasive Species. Invasive plants in the riparian area often have negative impacts on stream systems often times, by creating a monoculture with poor nutrient inputs, reducing bank stability and allowing too much sunlight to infiltrate, resulting in warmer stream temperatures. Invasive aquatic species, like the Basket Clam, may have negative effects on native species through competition for space and resources.

Climate Impacts. Many of the water quality and water quantity impacts resulting from climate change are analogous to impacts from economic development and population growth in North Carolina. Climate change is predicted to decrease rainfall and thereby limit water supply while growth and development have increased and continue to increase water supply demands. Historical stream flow patterns are projected to be altered due to climate change impacts; yet these patterns are already being altered due to rapid urbanization. An increase in impervious surfaces due to the proliferation of roads, parking lots, homes, and businesses increases the amount and speed of runoff being delivered into aquatic systems.

Increased air temperatures may lead to increased water temperatures and potentially lower DO levels because headwater streams tend to be small systems. Higher air and water temperatures can lead to increased evaporation, which results in less flowing water available for aquatic species. Hot spells can have the same effect as overall increased air temperatures but on a much more acute scale. These stream systems are vitally important to the overall health of the downstream watershed, yet are likely to experience potentially severe physical, chemical, and biological changes with temperature and DO alteration (DeWan et al. 2010; Karl et al. 2009; Band and Salvesen 2009).

Potential increased air temperatures and resulting increased water temperatures can lead to algal blooms in aquatic systems that diminish stream oxygen availability. The increased water temperature alone can cause a decline in DO and any decline in DO can lead to fish kills, whether as a direct result of increased water temperature or as a secondary effect of algal blooms. These effects are highly likely, in addition to complete drying of streams during drought conditions, in Piedmont headwaters streams (DeWan et al. 2010; Band and Salvesen 2009).

Potential changes in precipitation will contribute to severe and prolonged droughts resulting in decreased stream flow, decreased groundwater recharge, and increased evaporation. Reduced water flows will further contribute to warmer water temperatures and further stress water quality. Headwater streams could dry up, potentially leading to aquatic species extirpation (DeWan et al. 2010; Karl et al. 2009; Band and Salvesen 2009; USEPA 2010). During droughts, recharge of groundwater will decline as the temperature and spacing between rainfall events increase. Responding by increasing groundwater pumping will further stress or deplete aquifers and place increasing strain on surface water resources. Increased water withdrawals for agriculture could further stress surface water resources and available aquatic habitat.

Additionally, decreased groundwater recharge between storms due to impervious surfaces leads to a decrease in stream base flows. Runoff from urban areas often contains higher concentrations of nutrients (such as nitrogen and phosphorus), sediment, metals, hydrocarbons, and microbes. An increase in frequency and intensity of storms due to climate change will have a similar impact on stream systems by increasing pollutant loading. Therefore, challenges to water quality and water quantity as related to climate change are similar to those being confronted to accommodate growth and development. Adaptation strategies for water resource management could limit negative effects of both climate change and continuing development (Band and Salvesen 2009).

Storms. Increased storm intensity can lead to periodic flooding and therefore, increased stormwater runoff and increased erosion. With increased stormwater runoff there is an increase in loading of sediments, nutrients, and contaminants into streams and potential negative effects on biota. With a change in intensity and variability of rainfall, there are potential changes to stream flow patterns and channel hydrodynamics (Band and Salvesen 2009; USEPA 2010; Bakke 2008). An increase in the number of tropical events can lead to flash flooding, which causes many of the above-mentioned responses. Effects such as increased sediments and contaminants into aquatic systems, in addition to major disruption to channel design and hydrodynamics, potentially upset the physical, chemical, and biological structure of streams (Band and Salvesen 2009).

Because of potential changes in storm frequency and intensity, it is likely that channel hydrodynamics will be altered. Associated with channel hydrodynamics are changes in flow regime, sediment transport, and overall channel design. Changes may occur in aquatic species' habitats, and how or if these species adapt to changing habitats will require close monitoring to observe trends and help inform future management decisions (Bakke 2008).

4.2.7.4 Climate Change Compared to Other Threats

These stream systems are vitally important to the overall health of the downstream watershed, yet are likely to experience potentially severe physical, chemical, and biological changes with temperature and DO alteration (DeWan et al. 2010; Karl et al. 2009; Band and Salvesen 2009).

Table 4.2.7-1 provides a review of expected climate change impacts in order of importance in comparison with other types of threats.

Table 4.2.7-1. Comparison of climate change with other threats to headwater streams/small creeks

Threat	Rank Order	Comments
Development	1	An increase in impervious surfaces due to roads, parking lots, homes, and businesses, increases the amount and speed of runoff being delivered into aquatic systems, and decreased groundwater recharge between storms leads to a decrease in stream baseflow. Runoff from urban areas often contains higher concentrations of nutrients (such as nitrogen and phosphorus), sediment, metals, hydrocarbons, and microbes.
Erosion and Sedimentation	1	Streams in the Triassic Basin are particularly susceptible to erosion and are likely at greatest risk from erosion given proximity to many urban and suburban development centers. Erosion and the resultant sedimentation are the largest sources of nonpoint source pollution in most aquatic systems.
Climate Change	2	Headwater streams may shrink in habitat or extent. Higher temperatures and increased drought conditions will cause many headwater streams to dry up.
Lack of riparian vegetation	2	Lack of riparian vegetation or inadequate width of forested buffer can cause streambank erosion and sedimentation. In addition to stabilizing streambanks, riparian vegetation serves as a food/nutrient input to the stream community and helps regulate stream temperature by providing shade.

Table 4.2.7-1. Comparison of climate change with other threats to headwater streams/small creeks

Threat	Rank Order	Comments
Logging/Exploitation	2	While bank vegetation is usually undisturbed, logging is a major threat to streams if proper erosion controls are not used and maintained. Poorly constructed and maintained timber roads also contribute to erosion.
Flood Regime Alteration	3	High and low flow extremes pose a threat.
Invasive Species	4	Invasive plants in the riparian area often have negative impacts on stream systems by creating a monoculture with poor nutrient inputs, reducing bank stability, and allowing too much sunlight to infiltrate, causing warmer stream temperatures. Invasive aquatic species, like the Asian Clam, may have negative effects on native species, such as when competing for space and resources.
Cattle in Streams	4	Livestock access to streams contributes heavily to bank erosion, sedimentation, and nutrient input.
Pollution	5	The majority of headwater streams are on lands in private ownership making them at risk from land use practices that may increase stormwater runoff of nutrients, sediment, and contaminants. Endocrine-disrupting chemicals in treated wastewater can inhibit reproduction and cause feminization of mussels and fish (Conn et al. 2006; Kim et al. 2007; Kasprzyk-Hordern et al. 2008; Joss et al. 2006; Kolpin et al. 2002; Nowotny et al. 2007). Runoff from impervious surfaces carries lawn pesticides, road oil, and other pollutants from developed areas into surface waters.

4.2.7.5 Impacts to Wildlife

Appendix 3 provides lists of SGCN and other priority species. Table 3-18 in Appendix 3 identifies the aquatic wildlife SGCN associated with this community.

Headwater systems offer a range of habitats that can support an abundance and diversity of species, depending on water depth and seasonality of flows, hydrologic regime, temperature, water chemistry, substrate types, and connectivity to downstream systems (Meyer et al. 2007). Biodiversity will be influenced by the presence of species unique to headwater systems and whether connectivity within the DA allows species that seasonally use headwaters for particular life history stages (e.g., spawning, nursery areas) to move upstream from larger streams (Meyer et al. 2007). Headwater systems, especially those associated with springs and seeps, are likely to have a high diversity of insects, especially those genera with an aquatic life history cycle. Research conducted at Coweeta Hydrologic Laboratory in western North Carolina collected at least 51 families and 145 genera of aquatic insects in eight headwater streams during three decades of sampling (Meyer et al. 2007).

Climate change effects, especially drought and higher temperatures, will likely have a significant impact on headwater stream communities, possibly creating a shift where several perennial streams will become intermittent or ephemeral systems. This potential shift will result in the loss of aquatic species diversity. Aquatic species could experience shifts in their range or distribution and sensitive species may experience decline or extirpation due to changes in water quality and habitat. Headwater streams could dry up, potentially leading to aquatic species extirpation (DeWan et al. 2010; Karl et al. 2009; Band and Salvesen 2009; USEPA 2010).

Potential increased air temperatures and resulting increased water temperatures can lead to algal blooms in aquatic systems, which diminish stream oxygen availability. The increased water temperature alone can cause a decline in DO and any decline in DO can lead to fish kills, whether as a direct result of increased water temperature or as a secondary effect of algal blooms.

Maintaining water quality is important for the species that rely upon headwater streams for habitat as well as for those species which rely indirectly on the system as provision of habitat for their prey. Wetlands associated with headwater streams are important as breeding sites for amphibian species and can also be important breeding habitat for crayfishes. Concentrated stormwater flows can strip salamander eggs from river banks and vegetation, reducing reproductive success.

Riparian areas serve as thermal refugia because they provide stream shading and have higher water content than upland areas. Animals with thermoregulatory limitations have refugia which will become increasingly important with anticipated increases in air temperatures. Drought and loss of vegetated cover will reduce available refugia for these species.

Riparian areas associated with headwater streams provide habitat for terrestrial wildlife species and are a linkage between aquatic and terrestrial systems which serve as corridors for movement of terrestrial wildlife species (Seavy et al. 2009; NCWRC 2002; Wenger 1999). Some birds may use headwater stream communities and associated with small wetlands for nesting and feeding areas.

4.2.7.6 Recommendations

Section 4.2.2 provides recommendations appropriate for all aquatic communities, statewide. Actions specific to the state's river basins are provided in Section 4.5.

Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience, such as: protecting watersheds for clean water, flood attenuation, and decreased erosion and sedimentation; providing ecological corridors for species movement throughout the landscape in response to changing habitats; preserving existing habitats to help prevent forced migration (Band and Salvesen 2009).

Surveys

Distributional and status surveys are needed for aquatic snails, crayfish, mussels, and fish (in order of general need).Identify the location of headwater systems and associated small wetland communities in the Piedmont ecoregion.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Initiate distribution surveys for all amphibian species associated with headwater communities.

  Dwarf Salamander | Mole Salamander | Eastern Tiger Salamander
  Four-toed Salamander.

- Gather information about the status and distribution of more common species associated with Piedmont headwater and associated wetland habitats.

  Common Ribbonsnake | Three-lined Salamander

Monitoring

Monitoring of aquatic taxa is critical to assessing species and ecosystem health and gauging the resilience of organisms to a changing climate. These monitoring efforts will inform future decisions on how to manage aquatic species. Long-term monitoring is needed to identify population trends and to assess performance of conservation actions. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Determine population trends and persistence of small wetland breeding amphibian populations.

  Dwarf Salamander | Mole Salamander | Eastern Tiger Salamander
  Four-toed Salamander

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Research must also be conducted to determine vulnerability of priority species to specific threats, and studies should provide recommendations for mitigation and restoration. Aquatic species propagation is an area of current and ongoing research. Developing techniques for propagation of aquatic species is critical for preserving those species and their genetic stock, particularly those that are rare, at high risk of extinction or extirpation, and difficult to propagate in a laboratory setting.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Study the efficacy and practicality of "toad tunnels" and other wildlife crossings that allow passage under roadways and help maintain connectivity between headwater community (including associated wetlands) metapopulations.
• Determine minimum upland buffers required to sustain at-risk amphibian populations.
• Investigate the effects of large scale snagging (removal of downed trees) within the rivers after hurricanes.

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Use stormwater management techniques that strive to restore or maintain the pre-development hydrograph.

Partnerships and Cooperative Efforts

Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable.

4.2.8 Large Creeks/Small Rivers

4.2.8.1 Ecosystem Description

Large creeks and small river communities represent the next stream order above headwater streams and typically consist of third- and fourth-order perennial systems. These aquatic systems have a DA of 200 to 3,800 square miles. They may have fragmented habitats due to mill dams and other structures but are generally too small to contain major operational hydroelectric dams. Species richness increases significantly in these systems and larger and more diverse fish and mussel assemblages are found as compared to the headwater stream community.

4.2.8.2 Location of Habitat

Small river communities can be found statewide. Those located in the Mountain ecoregion may contain coolwater or coldwater systems depending on where they occur in the landscape. Those found in other areas of the state are warmwater systems, where water temperatures are persistently greater than 25°C (77°F).

Examples of this community type include the Little River, Eno River, and Swift Creek in the Neuse Basin, Upper Tar River, and portions of the Uwharrie River, Deep River, and Dan River. Adjacent terrestrial habitats such as small wetland communities and floodplain forests are components of this community and are described in Section 4.3 (wetlands) and Section 4.4 (terrestrial uplands).

4.2.8.3 Problems Affecting Habitats

Land Use. Aquatic systems in North Carolina have been threatened by a variety of perturbations in the past, and many of those same threats continue today. Converting land uses from natural forest to agriculture or silviculture production and residential and commercial development continues to threaten stream integrity because of related increases in sediment, bank erosion, and stormwater runoff containing sediment and other potentially toxic materials.

Riparian vegetation is critical to the overall stream and streambank stability and moderation of water temperatures. Lack of riparian vegetation or inadequate width of forested buffer can cause streambank erosion and sedimentation. In addition to stabilizing streambanks, riparian vegetation serves as nutrient input to the stream community and helps regulate stream temperature by providing shade. Lack of sufficient vegetation cover contributes to rising water temperatures, especially where water depths are shallow enough that the entire water column is subject to solar heating.

There are few contiguous blocks of protected habitats in the Piedmont ecoregion so small river systems are threatened by land use practices that may increase stormwater runoff of nutrients, sediment, and contaminants. The increased loads could affect water quality and habitat for aquatic species, as well as drinking water supplies for municipalities (Band and Salvesen 2009). Many rivers that were once free-flowing are now flooded by reservoirs, severely fragmenting habitat and often isolating populations of species above and below the impoundment. Indirect effects to the unimpounded portions of the system include disruption of natural thermal and hydrologic regimes and a reduction in downstream flows. These impacts will have a negative impact on aquatic habitat and will reduce base flow available for drinking water for downstream municipalities. Drought conditions over the past several years have required many municipalities to evaluate their water supply and capacity to meet demand. Residential and commercial growth in urban areas generates new demands for water supplies. An increase in the number of proposed reservoirs is a potential consequence of reduced water supply and increased demand.

Water Quality. Erosion and the resultant sedimentation are the largest sources of nonpoint source pollution in most aquatic systems. Sources of erosion include disturbance from development activities and agriculture land uses. Residential development can increase erosion during the construction process and is a source of increased impervious surfaces in the watershed which can also increase erosion. The Piedmont ecoregion is highly developed and most watersheds have high percentages of impervious surfaces that contribute to increased runoff, stream and bank erosion, pollution inputs, and increased flashiness of streams and rivers. Livestock access to streams contributes heavily to bank erosion, sedimentation, and nutrient input. Timber harvests and poorly constructed and maintained timber roads are additional sources of erosion if proper controls are not used and maintained.

Potential increased air temperatures and therefore increased water temperatures can lead to algal blooms in aquatic systems which diminishes stream oxygen availability. The increased water temperature alone can cause a decline in DO that can lead to fish kills, whether as a direct result of increased water temperature or as a secondary effect of algal blooms (DeWan et al. 2010; Band and Salvesen 2009).

Many of the water quality and water quantity impacts resulting from climate change are analogous to impacts from economic development and population growth in North Carolina. Climate change is predicted to decrease rainfall and therefore, limit water supply. Growth and development, however, have been increasing and will continue to increase water supply demands. Historical stream flow patterns—already being altered due to rapid urbanization—are projected to be further altered due to climate change impacts.

An increase in impervious surfaces due to roads, parking lots, homes, and businesses increases the amount and speed of runoff being delivered into aquatic systems. Decreased groundwater recharge between storms due to impervious surfaces leads to a decrease in stream base flows. Runoff from urban areas often contains higher concentrations of nutrients (such as nitrogen and phosphorus), sediment, metals, hydrocarbons, and microbes.

Invasive Species. The introduction of any invasive species is cause for concern, and the prevalence of warmer water temperatures may increase the likelihood of the invasion of additional exotic species, once thought to be non-threatening because the winters were too cold for their survival. While exotic species invasion is a concern, there is insufficient research to understand the effects to this community. The Asian Clam is found in aquatic systems throughout the state but its effects on native mussels are largely unknown. Flathead Catfish are a concern because of direct predation on native species. Nutria are considered a serious pest species in the United States because they eat a variety of wetland and agricultural plants and their burrowing damages streambanks, impoundments, and drainage systems.

Invasive plants in the riparian area can have negative impacts on stream systems by creating a monoculture (such as Japanese Knotweed) with poor nutrient inputs that reduces bank stability and allows too much sunlight and therefore, creates warmer stream temperatures. Exotic insect pests may be a significant factor in small river communities because they negatively impact native vegetation, thereby allowing nonnative species to flourish.

Climate Impacts. Potential changes in precipitation have numerous and varied effects. Severe and prolonged droughts may decrease stream flow, decrease groundwater recharge, and increase evaporation, resulting in impacts to streams of this theme. A decrease in overall summer precipitation will likely cause reduced water flows, which will contribute to warmer water temperatures and further stress water quality. This is particularly important in the context of seasonal droughts because during low-flow periods, nutrients may become concentrated and flush out of systems more slowly (DeWan et al. 2010; Karl et al. 2009; Band and Salvesen 2009; USEPA 2010).

Increased air temperatures may lead to increased water temperatures and potentially lower DO levels. Higher air and water temperatures can also lead to increased evaporation, which results in less flowing water available for aquatic species. Hot spells can have the same effect as overall increased air temperatures but on a much more acute scale. Algal blooms are possible in these systems and can exacerbate DO problems, particularly when flows are low (DeWan et al. 2010; Karl et al. 2009; Band and Salvesen 2009; USEPA 2010).

An increase in frequency and intensity of storms due to climate change will have a similar impact on stream systems by increasing pollutant loading. Increased storm intensity that causes flooding can lead to increased stormwater runoff and erosion. With increased stormwater runoff, there is an increase in loading of sediments, nutrients and contaminants into streams and potential negative effects on biota, such as fish kills. With a change in intensity and variability of rainfall, there are potential changes to streamflow patterns, channel hydrodynamics, and the volume of groundwater (Band and Salvesen 2009; USEPA 2010; Bakke 2008).

An increase in the number of tropical events can lead to flash flooding, which causes many of the abovementioned responses, and landslides, which are of particular concern in mountainous, high-elevation areas. Landslides lead to increased sediments and contaminants into aquatic systems, in addition to major disruption to channel design and hydrodynamics, potentially upsetting the physical, chemical, and biological structure of streams (Band and Salvesen 2009).

Because of potential changes in storm frequency and intensity, it is likely that channel hydrodynamics will be altered. Associated with channel hydrodynamics are changes in flow regime, sediment transport, and overall channel design. The current pattern of riffles, runs, and pools may be altered, creating changes in aquatic species' habitats. Increased storm intensity may cause increased erosion with large amounts of sediment that move downstream, which can then deposit into pools or bury riffles. Additionally, storms may cause the felling of riparian trees, particularly in areas with narrow riparian areas. Increased woody debris in these streams will also change channel hydrodynamics as well as available habitat. Determining how or if species adapt to changing habitats will require close monitoring to observe trends and to help inform future management decisions (Bakke 2008).

4.2.8.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. While climate change is not the most severe threat to large creeks and small rivers, a combination of the synergistic effects that come with development and lack of riparian corridors could stress these systems to the point where several species are unable to persist.

Table 4.2.8-1. Comparison of climate change with other threats to large creeks/small rivers

Threat	Rank Order	Comments
Development	1	Development causes direct, secondary, and cumulative effects. Residential development can increase erosion during the construction process and as a secondary result of increased impervious surfaces in the watershed. Growth and development increase water supply demands, and streamflow patterns are being altered due to rapid urbanization. An increase in impervious surfaces due to roads, parking lots, homes, and businesses also increases the amount and speed of runoff being delivered into aquatic systems. Decreased groundwater recharge between storms due to impervious surfaces contributes to reductions in stream baseflow.

Table 4.2.8-1. Comparison of climate change with other threats to large creeks/small rivers

Threat	Rank Order	Comments
Lack of riparian vegetation	1	Loss of riparian vegetation contributes to streambank erosion and sedimentation. Riparian vegetation serves as a food/nutrient input to the stream community and helps regulate stream temperature by providing shade.
Pollution	2	Erosion and the resultant sedimentation are the largest sources of nonpoint source pollution in most aquatic systems. Runoff from urban areas often contains higher concentrations of nutrients (such as nitrogen and phosphorus), sediment, metals, hydrocarbons, and microbes. Point and nonpoint sources—runoff and EDCs—are also threats.
Water Withdrawals	2	Irrigation and water supply withdrawals pose a threat to flow regime.
Flood Regime Alteration	2	High and low flow extremes pose a threat.
Livestock	3	Livestock access to streams contributes heavily to bank erosion, sedimentation, and nutrient input.
Logging/ Exploitation	3	Clearing of riparian areas is problematic. Timber harvesting can increase erosion if proper controls are not used and maintained, in addition to damage caused by poorly constructed and maintained timber roads.
Climate Change	4	Climate change-related challenges to water quality and quantity are similar to those being caused by growth and development. Climate change effects will likely amplify other threats and increase their severity in aquatic systems.
Conversion to agriculture/ silviculture	4	Loss of forest cover can increase erosion and sedimentation, as well as negatively impact aquatic systems.
Invasive Species	5	Invasive plants in the riparian area can have negative impacts on stream systems by creating a monoculture with poor nutrient inputs that reduces bank stability, thereby allowing too much sunlight and warmer stream temperatures. Invasive aquatic species, like the Asian Clam, may have negative effects on native species due to competition for space and resources. Specific interactions are unknown.
Impoundments	6	Water supply needs could increase number of impoundments and their disruptions to flow regime and aquatic habitat.

4.2.8.5 Impacts to Wildlife

Appendix 3 provides lists of SGCN and other priority species. Table 3-18 in Appendix 3 provides a list of species associated with this aquatic habitat.

Small river communities provide a number of important habitats, life cycles, or prey components to a vast assemblage of terrestrial, semi-aquatic, and aquatic wildlife. Wetlands associated with riverine systems can be important breeding sites for some amphibian and crayfish species. Birds may use riverine and adjacent terrestrial communities for nesting and feeding areas.

Because of the link between freshwater mussels and fish, phenological disruptions are a possibility, but exact mechanisms or effects for many species are still uncertain at this time. Freshwater mussel larvae (glochidia) are dependent on host fish for transformation into juveniles. Host fish species are known for some mussel species, yet unknown for others. Temperature cues play a large role in the release of glochidia from female mussels and also in the movement and migrations of fish. Therefore, with changing temperatures predicted with climate change, there could be phenological disruptions affecting the reproductive capacity of freshwater mussels.

Aquatic species could experience shifts in their range or distribution and sensitive species may experience decline or extirpation due to changes in water quality and habitat. Recent studies have shown that endocrine disrupting compounds (EDCs) in treated wastewater can inhibit reproduction and cause feminization of mussels and fish (Blaise *et al.* 2003, Gagne *et al.* 2010, Langston 2020). Aquatic species are particularly sensitive to temperature cues and recent research has shown that many species of freshwater mussels may already be living at the upper thermal tolerances of their early life stages (glochidia and juveniles) (Pandolfo et al. 2010). Extreme temperature events could be especially harmful. These systems may experience a change in species composition due to various changes in habitat and water quality.

4.2.8.6 Recommendations

Considering current conditions in large streams and small rivers, climate change is likely to have a synergistic effect with other threats that are of more immediate concern, such as the development and lack of/removal of riparian vegetation. Piedmont small river system communities will probably persist but species assemblages will likely change. Very few specific climate change-related impacts have been identified, and the rare species and their habitats are expected to persist.

Section 4.2.2 provides recommendations appropriate for all aquatic communities, statewide. Actions specific to the state's river basins are provided in Section 4.5 of this chapter.

Surveys
Distributional and status surveys are needed for aquatic snails, crayfish, mussels, and fish (in order of general need).

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Determine the distribution and abundance of aquatic species, especially aquatic reptiles.
  Eastern Mudsnake | Gulf Coast Spiny Softshell | Striped Mud Turtle
- Gather better information about the status and distribution of common amphibian and reptile species associated with riverine habitats..
  Three-lined Salamander | Common Ribbonsnake
- Expand research, survey, and monitoring efforts beyond collecting presence–absence data, to look at long-term trends across species groups, habitats, and the effects of management actions.
- Mussel surveys to document distribution and status of priority species.
  Creeper | Green Floater | Yellow Lampmussel
  Triangle Floater

Monitoring
Monitoring of aquatic taxa is critical to assessing species and ecosystem health and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage aquatic species. Long-term monitoring is needed to identify population trends and to assess performance of conservation actions. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Research
Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Research must also be conducted to determine vulnerability of priority species to specific threats and studies to provide recommendations for mitigation and restoration. Aquatic species propagation is an area of current and ongoing research. Developing techniques for propagation of aquatic species is critical for preserving those species and their genetic stock, particularly those that are rare, at high risk of extinction or extirpation, and difficult to propagate in a laboratory setting.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Conduct studies to document the levels of EDCs in wastewater discharges and identify measures that will reduce or eliminate EDCs from wastewater prior to discharge.

- Determine the impacts of “snagging” (removing woody debris after storms) on wildlife populations.

- Conduct research to investigate Nutria population densities, population growth rates, dispersal range, and extent of property damage from burrowing and herbivory.

  Nutria

- Determine the effect Beaver ponds have on downstream movement of pollutants (toxins and sediments).

  Beaver dams

- Investigate the interactions and impacts of invasive and native species (e.g., Carolina Madtom and Flathead Catfish).

  Madtom species   Flathead Catfish

- Conduct research on life history of potamodromous priority species (e.g. V-lip Redhorse).

  Redhorse species

- Investigate the effects of large scale snagging (removal of downed trees) within the rivers after hurricanes.

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Seek opportunities to restore canebreak communities through controlled burning or other management strategies.

  Canebrake Communities

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Maintain large trees around reservoirs for potential eagle nests, and maintain forest cover in the tailrace below dams for eagle foraging. Eagles
• Participate in mutual planning with adjacent states for regional species concerns, because some priority species are likely to expand their range due to climate change impacts.
• Plant riparian areas with vegetation with a broad elevational range within a particular watershed. Also plant vegetation with broad hydrologic tolerance to promote resilience from climate change.
• Identify dams to remove that could restore free-flowing habitats for priority fish and mussels. Barrier removal

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change and promote ecosystem resilience overall.

4.2.9 Medium River Communities

4.2.9.1 Ecosystem Description

Medium river communities drain watersheds 200 to 3,800 square miles in size and have coolwater systems (Section 4.2.4) where they drain Mountain ecoregion watersheds and warmwater systems (Section 4.2.5) everywhere else in the state. The Nature Conservancy notes that medium rivers have an average bankfull width of 115 feet (Anderson et al. 2014). The aquatic communities will have a higher proportion of warmwater species relative to coolwater species (Aquatic Habitat Guides 2015).

4.2.9.2 Location of Habitat

Medium river communities are found statewide in all ecoregions. Examples include Fishing Creek, Contentnea Creek, portions of Deep and Dan rivers, and the Smith, Mayo, Haw, Black, Broad, Nolichucky, Little Tennessee, and Tuckasegee rivers.

The 2005 WAP described riverine aquatic communities as a priority habitat (see Chapter 5) (NCWRC 2005). Adjacent terrestrial systems that may be hydrologically connected to medium river communities include floodplain forests, tidal swamp forests, and various wetland communities. These terrestrial systems provide habitat for species that also rely upon rivers for habitat (e.g., American Beaver, River Otter, various insects), as well as those species which rely indirectly upon the habitat by virtue of provision of habitat for their prey (NCWRC 2005).

4.2.9.3 Problems Affecting Habitats

Medium river communities in North Carolina have been threatened by a variety of perturbations in the past, similar to threats to small and large rivers, and many of those same threats continue today.

Land Use. Converting land uses from natural forest to agriculture or silviculture production and residential and commercial development continues to threaten stream integrity. Deforestation and increased impervious surfaces cause increases in sedimentation, bank erosion, and stormwater runoff containing sediment and other pollutants. Erosion and the resultant sedimentation are the largest sources of nonpoint source pollution in most aquatic systems. The increased loads could affect water quality and habitat for aquatic species, as well as drinking water supplies for municipalities (Band and Salvesen 2009). Sources of erosion include disturbance from development activities and agriculture.

Residential development can increase erosion during the construction process, but also as a secondary result of increased impervious surfaces in the watershed. Most watersheds in the Piedmont are already highly developed and development pressure is likely to increase in the Coastal Plain, which will lead to an increase in impervious surfaces, increasing runoff, stream and bank erosion, pollution inputs and increased flashiness of rivers. An increase in impervious surfaces due to roads, parking lots, homes, and businesses increases the amount and speed of runoff being delivered into aquatic systems. Decreased groundwater recharge between storms due to impervious surfaces leads to a decrease in stream base flows.

Riparian vegetation is critical to overall stream and streambank stability and moderation of water temperatures. Lack of riparian vegetation or inadequate width of forested buffers can cause streambank erosion and sedimentation. In addition to stabilizing streambanks, riparian vegetation contributes nutrients to the stream community, provides large woody debris that increases habitat complexity, and helps regulate stream temperature by providing shade. Lack of sufficient vegetation cover contributes to rising water temperatures, especially where water depths are shallow enough that the entire water column is subject to solar heating.

Impoundment. Dam construction on medium rivers has altered hydrology and morphology. Many rivers that were once free-flowing are now dammed, severely fragmenting habitat and often isolating populations of aquatic species upstream and downstream of the impoundments. Indirect effects to portions of the system downstream of dams include disruption of natural hydrologic and thermal regimes. Increases in water surface area of impoundments and the resulting increases in evaporation rates, in addition to water withdrawals, reduces the amount of water available downstream. Low dissolved oxygen levels can also impair habitat downstream of dams.

Water Quality. Changes in land use patterns within a watershed cause changes in water quality; land use alterations closer to stream channels typically have more impact. Runoff from urban areas often contains higher concentrations of nutrients (such as nitrogen and phosphorus), sediment, metals, hydrocarbons, and microbes. Allowing livestock access to rivers can contribute to bank erosion, sedimentation, and nutrient input. Timber harvest and poorly constructed and maintained timber roads are additional sources of erosion if proper controls are not used and maintained.

Climate change has the potential to increase air temperatures; therefore increased water temperatures can lead to algal blooms which reduce stream oxygen availability. The increased water temperature alone can cause DO declines that can lead to fish kills, whether as a direct result of increased water temperature or as a secondary effect of algal blooms (DeWan et al. 2010; Band and Salvesen 2009).

Invasive Species. Medium river communities in our state contain invasive species in addition to the native flora and fauna. These invasive species impact native species through competition, predation, and hybridization. They can also alter habitat and transmit diseases. The introduction of any invasive species is cause for concern, and the prevalence of warmer water temperatures in the future may increase the likelihood of the invasion of additional exotic species, once thought to be non-threatening because the winters were too cold for their survival.

Invasive aquatic animal species, such as Basket Clams, Mystery Snails, Red Swamp Crayfish, and Nutria may have negative effects on native species through competition for space and resources and as disease vectors. The Basket Clam is an exotic species found in aquatic systems throughout the state; its effects on native mussels are largely unknown. Flathead Catfish are a concern because of direct predation on native species. Nutria are considered a serious pest species in the United States because they eat a variety of wetland and agricultural plants and their burrowing damages streambanks, impoundments, and drainage systems.

Invasive plants in the riparian area can have negative impacts on stream systems by creating a monoculture (such as Japanese Knotweed) with poor nutrient inputs that reduces bank stability and shading and therefore, creates warmer stream temperatures. Alligator weed creates floating mats that disrupt DO levels. Invasive aquatic plants such as Asian Dayflower, Hydrilla, Water Hyacinth, and Giant Salvinia could pose more of a threat to these systems with a warmer climate. Exotic insect pests may be a significant factor in river communities because they negatively impact native vegetation (Kenis *et al*. 2009, Diesburg *et al.* 2021), thereby altering riparian habitats or allowing nonnative species to flourish. For instance, Hemlock Woolly Adelgid infestations have significantly impacted Eastern Hemlock forests in Appalachian forest riparian zones.

Climate Impacts. Climate change is likely to have a synergistic effect with other, more impending threats to medium river systems, such as development and lack of/removal of riparian vegetation. Aquatic systems have been under threat from a variety of perturbations in the past and many of those continue today. Many of the water quality and water quantity impacts resulting from climate change are analogous to impacts from economic development and population growth in North Carolina. Climate change is predicted to alter seasonal precipitation patterns that can limit water supply. Growth and development, however, have been increasing and will continue to increase water supply demands. Historical stream flow patterns—already being altered due to rapid urbanization—are projected to be further altered due to climate change impacts.

Potential changes in precipitation may have numerous and varied effects. Severe and prolonged droughts may decrease stream flow, decrease groundwater recharge, and increase evaporation, resulting in impacts to medium rivers. A decrease in overall summer precipitation will likely cause reduced water flows, which will contribute to warmer water temperatures and further stress water quality. This is particularly important in the context of seasonal droughts because during low-flow periods, nutrients may become concentrated and flush out of systems more slowly (DeWan et al. 2010; Karl et al. 2009; Band and Salvesen 2009; USEPA 2010).

Increased air temperatures may lead to increased water temperatures and potentially lower DO levels. Higher air and water temperatures can also lead to increased evaporation, which results in less flowing water available for aquatic species. Hot spells can have the same effect as overall increased air temperatures but on a much more acute scale. Algal blooms are possible in these systems and can exacerbate DO problems, particularly when flows are low (DeWan et al. 2010; Karl et al. 2009; Band and Salvesen 2009; USEPA 2010).

An increase in frequency and intensity of storms due to climate change will have a similar impact on stream systems by increasing pollutant loading. Increased storm intensity that causes flooding can lead to increased stormwater runoff and erosion. With increased stormwater runoff, there is an increase in loading of sediments, nutrients and contaminants into streams and potential negative effects on biota, such as fish kills. With a change in intensity and variability of rainfall, there are potential changes to streamflow patterns, channel hydrodynamics, and the volume of groundwater (Band and Salvesen 2009; USEPA 2010; Bakke 2008).

Drought conditions over the past several years have required many municipalities to evaluate their water supply and capacity to meet demand. Residential and commercial growth in urban areas generates new demands for water supplies. An increase in the number of proposed reservoirs and surface water withdrawals is a potential consequence of reduced water supply and increased demand.

Potential changes in storm frequency and intensity will likely alter channel hydrodynamics, specifically. changes in flow regime, sediment transport, and overall channel design. The current pattern of riffles, runs, and pools may be altered, creating changes in aquatic species' habitats. Increased storm intensity may cause increased erosion with large amounts of sediment that move downstream, which can then deposit into pools or bury riffles. Additionally, storms may cause the felling of riparian trees, particularly in areas with narrow riparian areas. Increased woody debris in these streams will also change channel hydrodynamics as well as available habitat. Determining how or if species adapt to changing habitats will require close monitoring to observe trends and to help inform future management decisions (Bakke 2008).

4.2.9.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. In the past, aquatic systems have been under threat from a variety of perturbations and many of those continue today. Conversion of land, both from forest to agriculture or silviculture, as well as from development projects, continues to threaten stream integrity resulting in increased sediment, bank erosion, and stormwater runoff containing sediment and other potentially toxic materials. Considering current conditions in these systems, climate change is likely to have a synergistic effect with other threats that are of more immediate concern. Table 4.2.9-1 provides a review of expected climate change impacts in order of importance in comparison with other types of threats.

Table 4.2.9-1Comparison of climate change with other threats to medium river communities

Threat	Rank Order	Comments
Development	1	Residential development, particularly in steep slope areas, is of particular concern because of increased erosion. Most coolwater streams are larger streams and rivers and many have wider valleys where land use is more susceptible to being developed than on steeper sloped headwater streams. Row crops, agricultural grazing, and urban/suburban development are common. Increased impervious surfaces due to roads, parking lots, homes, and businesses increase the amount and speed of runoff being delivered into aquatic systems.
Sediment and Erosion	1	Stormwater runoff will amplify the loading of nutrients, sediment, and contaminants into streams, rivers, and reservoirs, which may alter overall channel design, have a negative effect on biota due to habitat changes, increased turbidity, and chemical exposure, and affect drinking water quality (Band and Salvesen 2009).
Pollution	1	Runoff from urban areas often contains higher concentrations of nutrients (such as nitrogen and phosphorus), sediment, metals, hydrocarbons, and microbes. An increase in frequency and intensity of storms will contribute to increased pollution loading. Point and nonpoint sources—runoff and EDCs—are also threats.
Livestock in Streams	1	Livestock access to streams contributes heavily to bank erosion, sedimentation, and nutrient input.
Lack of riparian vegetation	1	Riparian vegetation serves as nutrient input to the stream community and helps regulate stream temperature by providing shade. Lack of riparian vegetation or inadequate width of forested buffer can cause streambank erosion and sedimentation.
Conversion to agriculture/silviculture	2	Loss of forest cover can cause increased erosion and sedimentation and negatively impact aquatic systems. Poorly constructed and maintained timber roads are another source of erosion.
Water Withdrawals	2	Irrigation and water supply withdrawals pose a threat to flow regime. Water withdrawals can be problematic, particularly in streams with already low 7Q10 flows, because they may

Table 4.2.9-1Comparison of climate change with other threats to medium river communities

Threat	Rank Order	Comments
		reduce available habitat for aquatic species. Decreased groundwater recharge between storms due to impervious surfaces leads to a decrease in stream baseflow.
Flood Regime Alteration	2	Many rivers that were once free-flowing are now flooded by reservoirs, severely fragmenting habitat and often isolating populations of species upstream and downstream of the impoundment. Floodplains and wetlands are natural features designed for flood control through attenuation and dissipation of floodwaters. Development and other impacts can reduce this service.
Climate Change	3	Climate change is predicted to decrease rainfall and therefore limit water supply. Effects will likely compound with other threats to increase the severity of other threats to aquatic systems. Increased frequency and severity of tropical systems will alter riparian and instream habitats and can reduce water quality.
Invasive Species	4	Invasive plants in the riparian area can have negative impacts on stream systems by creating a monoculture (such as Japanese Knotweed) with poor nutrient inputs, reducing bank stability, and allowing too much sunlight and therefore warmer stream temperatures. Invasive aquatic species, like the Asian Clam or Rusty Crayfish, may have negative effects on native species, such as competition for space and resources.

4.2.9.5 Impacts to Wildlife

Appendix 3 includes a list of SGCN and other priority species for which there are knowledge gap and management concern priorities. Appendix 3-18 identifies SGCN that use medium river communities.

The temperature tolerance range of aquatic species can be specific and the availability of warm waters that do not exceed tolerances can be a limiting factor for where species can find appropriate habitat, especially as average water temperatures experience warming trends (DeWan et al. 2010). Warmwater habitats are important for a number of reptiles and amphibians including certain turtles, frogs, and salamanders that utilize aquatic habitats during part or all of their life cycle. These habitats are also important for a variety of mammals that are semi-aquatic and/or that have an aquatic food base (e.g., Water Shrews, Muskrats, Beavers, River Otters, and certain bats). Selected bird species, such as various waterfowl, wading birds, and certain songbirds, also rely upon aquatic habitats (including rivers and streams) to provide habitat or a food base.

4.2.9.6 Recommendations

It is important to preserve the connectivity of warmwater systems because they provide a link to cool and coldwater systems that will become refugia as water temperature gradients change and previously cool waters become persistently warmer. As water temperatures change, many species may not be able to migrate into waters with appropriate temperatures if there are barriers to movement or habitats are fragmented so that warmwater habitats are interspersed amongst habitats that do not meet thermal requirements. Section 4.2.2 provides recommendations appropriate for all aquatic communities, statewide. Actions specific to the state’s river basins are provided in Section 4.5.

Surveys

Distributional and status surveys are needed for aquatic snails, crayfish, mussels, and fish (in order of general need).

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Conduct surveys to determine distribution and status of priority freshwater mussel species.
  Green Floater   Triangle Floater
- Conduct baseline surveys to document distribution and status of aquatic snails.
  Panhandle Pebblesnail
- Conduct surveys to determine distribution and status of priority freshwater fish species.
  Bull Chub   Mimic Shiner   V-lip Redhorse

Monitoring

Monitoring of aquatic taxa is critical to assessing species and ecosystem health and gauging the resilience of organisms to a changing climate. Long-term monitoring is needed to identify population trends and to assess performance of conservation actions. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Research must also be conducted to determine vulnerability of priority species to specific threats and studies should provide recommendations for mitigation and restoration. Aquatic species propagation is an area of current and ongoing research. Developing techniques for propagation of aquatic species is critical for preserving those species and their genetic stock, particularly those that are rare, at high risk of extinction or extirpation, and difficult to propagate in a laboratory setting.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Assess habitats for augmentation and relocation potential for freshwater fish SGCN and other priority species. Carolina Madtom
• Study habitat use and life history characteristics of aquatic snail SGCN and other priority species.
• Investigate the effects of large scale snagging (removal of downed trees) within the rivers after hurricanes.

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable.

4.2.10 Large River Communities

4.2.10.1 Ecosystem Description

Large river communities are those with over 3,800 square miles DA. They occur statewide and are the largest and highest order rivers in the Piedmont and Coastal Plain ecoregions. Many originate in the Piedmont and are some of the most fragmented aquatic systems because they have been utilized for major hydroelectric projects. After passing over the fall line that divides the Piedmont and Coastal Plain ecoregions they transition into more typical Coastal Plain rivers with sandy substrates and wider floodplains. Large river communities are warmwater systems, where summer water temperatures are persistently greater than 25°C (77°F).

4.2.10.2 Location of Habitat

Certain reaches of the Hiwassee, French Broad, and Little Tennessee rivers can be categorized as having large river communities. Examples in the Piedmont ecoregion include the Yadkin Pee Dee River (downstream of the confluence of the South Yadkin and Yadkin rivers), Catawba River (downstream of Lake James), and the Neuse, Tar, Cape Fear, and Roanoke rivers upstream of- the Fall Line. Examples of large river communities in the Coastal Plain ecoregion are found in the Cape Fear, Chowan, Lumber, Neuse, Pasquotank, Roanoke, Tar-Pamlico, and White Oak River basins.

Adjacent terrestrial systems that may be hydrologically connected to this riverine community include floodplain forests, tidal swamp forests, and wetland communities. These communities provide habitat for species that rely upon rivers and streams for habitat, as well as those species which rely indirectly upon the habitat by virtue of provision of habitat for their prey.

4.2.10.3 Problems Affecting Habitats

Land Use. Aquatic systems in North Carolina have been threatened by a variety of perturbations in the past and many of those same threats continue today. Converting land uses from natural forest to agriculture or silviculture production and residential and commercial development continues to threaten stream integrity because of related increases in sediment, bank erosion, and stormwater runoff containing sediment and other potentially toxic materials.

Riparian vegetation is critical to the overall stream and streambank stability and moderation of water temperatures. Lack of riparian vegetation or inadequate width of forested buffer can cause streambank erosion and sedimentation. In addition to stabilizing streambanks, riparian vegetation serves as nutrient input to the stream community and helps regulate stream temperature by providing shade. Lack of sufficient vegetation cover contributes to rising water temperatures, especially where water depths are shallow enough that the entire water column is subject to solar heating.

Erosion and the resultant sedimentation are the largest sources of nonpoint source pollution in most aquatic systems. Sources of erosion include disturbance from development activities and agriculture. Residential development can increase erosion during the construction process, but also as a secondary result of increased impervious surfaces in the watershed. Development pressure is likely to increase in the Coastal Plain, which will lead to a proliferation in impervious surfaces, increasing runoff, stream and bank erosion, and pollution inputs. Most watersheds in the Piedmont are already highly developed and have high percentages of impervious surfaces, leading to increased runoff, stream and bank erosion, pollution inputs, and increased flashiness of streams and rivers.

Navigation Dredging. The US Army Corps of Engineers regularly maintain navigation channels by dredging waterways through coastal inlets, sounds, estuaries, and large rivers (Rosati and Kraus 2009). Channelization can homogenize habitats as bed material and sediments are removed. Coastal dredging can also increase saltwater intrusion leading to changes in species composition and ghost forests on land.

Impoundment. Dam construction has altered flows and river hydrology and morphology. Dams along the Yadkin, Pee Dee, and Catawba Rivers are subject to coldwater releases and peaking flow regulation through licenses issued by the Federal Energy Regulatory Commission. Many rivers in the Piedmont that were once free flowing are now flooded by reservoirs, severely fragmenting habitat and often isolating populations of species upstream and downstream of the impoundment. Indirect effects to the unimpounded portions of the system include disruption of natural thermal and hydrologic regimes and a reduction in downstream flows. These impacts will have a negative influence on aquatic habitat as well as reducing the base flow available for drinking water for downstream municipalities.

Water Quality. Increased stormwater runoff will amplify the loading of nutrients, sediment, and contaminants into streams, rivers, and reservoirs. The increased loads could affect water quality and habitat for aquatic species, as well as drinking water for municipalities. Stormwater controls and retrofits will become increasingly important (Band and Salvesen 2010).

Storms. Because of potential changes in storm frequency and intensity, it is likely that channel hydrodynamics will be altered. Changes in flow regime, sediment transport, and overall channel design are associated with channel hydrodynamics. The current pattern of riffles, runs, and pools may be altered, creating changes in aquatic species' habitats. In these large rivers, gravel and sand bars may be displaced and formed in other locations and reservoirs may experience increased sediment deposits. How or if species adapt to changing habitats will require close monitoring to observe trends and help inform future management decisions (Bakke 2008).

Invasive Species. The introduction of any invasive species is cause for concern and the prevalence of warmer water temperatures may increase the likelihood of exotic species becoming established that were previously thought to be non-threatening because the winters were too cold for survival.

Invasive plants in the riparian area can have negative impacts on stream systems by creating a monoculture with poor nutrient inputs, reducing bank stability, and reducing shading (warmer stream temperatures). Alligator Weed creates floating mats that disrupt DO levels. Asian Dayflower, Hydrilla, Water Hyacinth, and Giant Salvinia could pose more of a threat to these systems with a warmer climate.

Invasive aquatic animal species, such as Basket Clams, Mystery Snails, Red Swamp Crayfish, and Nutria may have negative effects on native species through competition for space and resources and as a disease vector. The Basket Clam is an exotic species found in aquatic systems throughout the state. However, its effects on native mussels are largely unknown. Mystery Snails are established downstream of Falls Lake (Neuse River basin) and have been collected in reservoirs on the Catawba, Yadkin-Pee Dee, Roanoke, and Neuse rivers and in the Pee Dee, and Neuse River proper, between Tillery and Blewett Falls Reservoirs. These large snails feed primarily on algae and diatoms and have been known to clog water intake screens in other parts of the United States, but effects on native mollusks are largely unknown. They have the potential to serve as vectors for the transmission of parasites and diseases. Flathead Catfish are a concern because of direct predation on native species.

Climate Impacts. Very few specific climate change-related impacts have been identified, and the rare species and their habitats are expected to persist. Climate change is likely to have a synergistic effect with other, more immediate concerns in these systems, such as development and lack of/removal of riparian vegetation. Aquatic systems have been under threat from a variety of perturbations in the past and many of those continue today.

Sea level rise is likely to impact the lower reaches of large Coastal Plain rivers because inundation is predicted to varying degrees. The combined increase of inland flooding due to higher precipitation events with elevated sea levels will exacerbate coastal inundation. Saltwater intrusion into currently freshwater streams will shift the transition from freshwater to brackish water further upstream. As the chemical composition of currently freshwater systems changes, associated freshwater wetlands could be converted to salt marshes as saltwater moves farther upstream into these rivers (Band and Salvesen 2009; USEPA 2010; Bakke 2008; Burkett et al. 2000). Changes in salinity and tidal influence will likely change the overall species composition in these systems. Recent surveys of tributaries to the Albemarle Sound, Tar River, and Neuse River found Dark Falsemussel (*Mytilopsis leucophaeta*), a brackish water bivalve, are present farther upstream than have occurred historically.

Drought conditions over the past several years have required many municipalities to evaluate their water supply and capacity to meet demand. Residential and commercial growth in urban areas generates new demands for water supplies. An increase in the number of proposed reservoirs is a potential consequence of reduced water supply and increased demand.

Potential increased air temperatures will influence water temperatures and can lead to algal blooms in aquatic systems, which in turn diminishes stream oxygen availability. The increased water temperature alone can cause a decline in DO and any decline in DO can lead to fish kills, whether as a direct result of increased water temperature or as a secondary effect of algal blooms. This phenomenon may be increasingly expressed within reservoirs on large Piedmont rivers (DeWan et al. 2010; Band and Salvesen 2009).

4.2.10.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. Sea level rise already impacts large rivers at their terminus along the Atlantic coast. Other climate change impacts may not be as severe a threat, but a combination of synergistic effects with other existing conditions could stress these systems to the point where several species are unable to persist. Table 4.2.10-1 provides a review of expected climate change impacts in order of importance in comparison with other types of threats.

Table 4.2.10-1 Comparison of climate change with other threats to large river communities.

Threat	Rank Order	Comments
Development	1	Direct, secondary, and cumulative effects from development include increased sediment, bank erosion, and stormwater runoff containing sediment and other potentially toxic materials.
Flood Regime Alteration	2	Alterations such as reduced flooding and impervious surfaces that increase flashy flow in combination with changes in precipitation will have a big effect on these systems. Alteration of hydrology due to dam creation and wetland draining are also affecting this habitat type.
Pollution	2	Runoff from urban areas often contains higher concentrations of nutrients (such as nitrogen and phosphorus), sediment, metals, hydrocarbons, and microbes. Erosion and the resultant sedimentation are the largest sources of nonpoint source pollution in most aquatic systems. Increased stormwater runoff will amplify the loading of nutrients, sediment and contaminants. The increased loads could affect water quality and habitat for aquatic species, as well as drinking water for municipalities. Point and nonpoint sources—runoff and EDCs—are also threats. Confined animal operations and animal waste lagoon discharges are a potential source of contamination if not properly managed and maintained. In particular, nutrient loads have the

Table 4.2.10-1 Comparison of climate change with other threats to large river communities.

Threat	Rank Order	Comments
		potential to greatly increase with the construction of new poultry processing facilities on the coast.
Climate Change	3	Sea level rise, drought, increased storm activity, and higher temperatures are threats to large Coastal Plain rivers.
Water Withdrawals	3	Irrigation, water supply, and energy development withdrawals pose threats to flow regime. Streamflow is likely to be reduced during droughts, and recharge of groundwater will decline as the temperature and spacing between rainfall events increase. Increased demands for drinking water supply will further stress or deplete aquifers and place increasing strain on surface water resources. Increasing evaporation and plant water loss rates alter the balance of runoff and groundwater recharge which is likely to lead to saltwater intrusion into shallow aquifers. Water withdrawals can be problematic, particularly in streams with already low 7Q10 flows, because they may reduce available habitat for aquatic species.
Lack of riparian vegetation	3	Loss of riparian vegetation causes numerous problems which are outlined throughout this Plan. Of particular concern is the loss of shading and a source of detritus for food webs, the increased potential for runoff of sediments into stream channels, and increased potential for bank erosion.
Invasive Species	3	Invasive plants in the riparian area can have negative impacts on stream systems by creating a monoculture with poor nutrient inputs, reducing bank stability, and reduced shading (warmer stream temperatures). Alligator weed creates floating mats that disrupt DO levels. Asian Dayflower, Hydrilla, Water Hyacinth, and Giant Salvinia could pose more of a threat to these systems with a warm climate. Invasive aquatic animal species, such as the Flathead Catfish, Basket Clam, Red Swamp Crayfish, and Nutria may have negative effects on native species, such as competition for space and resources.
Energy development	4	Hydropower impoundments could become more prevalent as population growth exerts higher demands for energy resources. Impoundments contribute to fragmentation and loss of important stream habitats (e.g., riffles, runs).

4.2.10.5 Impacts to Wildlife

Appendix 3 includes a list of SGCN and other priority species for which there are knowledge gap and management concern priorities. Appendix 3-18 identifies SGCN that use large river communities.

Weather extremes (such as drought, floods, tropical depressions, hurricanes) that are expected to be amplified by climate change can have profound effects on fishery production in large Coastal Plain rivers.

Chronically warmer temperatures and lower DO levels will increase stress on aquatic organisms and disrupt trophic relationships. Aquatic species could experience shifts in their range or distribution and sensitive species may experience decline or extirpation due to changes in water quality and habitat.

Aquatic species are particularly sensitive to temperature cues and recent research has shown that many species of freshwater mussels may already be living at the upper thermal tolerances of their early life stages (glochidia and juveniles) (Pandolfo et al. 2010). Because of the link between freshwater mussels and fish, phenological disruptions are a possibility, but exact mechanisms or effects are not well understood. Freshwater mussel larvae (glochidia) are dependent on host fish for transformation into juveniles. Host fish species are known for some mussel species, yet unknown for others. Temperature cues play a large role in the release of glochidia from female mussels and also in the movement and migrations of fish. Therefore, with changing temperatures predicted with climate change, there could be phenological disruptions affecting the reproductive capacity of freshwater mussels.

Riverine habitats are especially important to herpetofauna that utilize aquatic habitats during part or all of their life cycle. Most of the listed priority amphibian and reptile species associated with riverine habitat have limited distributions, unknown distributions, or widely dispersed but small populations. Isolation or fragmentation of particular habitat stretches occupied by those species could have significant long-term effects upon the sustainability of those populations.

Increased storm intensity can lead to flooding and therefore, increased stormwater runoff and increased erosion. With increased stormwater runoff, there is an increase in loading of sediments, nutrients and contaminants into streams and potential negative effects on biota. Long-duration flooding has had impacts on ground-nesting bird species. Severe flooding can also interfere with successful transport of larval anadromous fishes hatched during the spring to downstream nursery areas. Abnormally high spring flows have been shown to coincide with reduced summer abundance of young-of-year striped bass in the Roanoke River (Hassler et al. 1981; Manooch III and Rulifson 1989).

As a salt wedge moves upstream into the lowest Coastal Plain reaches, it is likely that existing freshwater fauna may be replaced with more estuarine water species. If salinity levels increase gradually, there could be adaptation by some freshwater species to this change. Additionally, freshwater species could migrate upstream to escape the increased salinity if suitable habitat and water quality parameters are available in smaller systems and connectivity between streams is available. Range shifts can be expected to increase competition for resources.

Red Swamp Crayfish is prevalent in the Coastal Plain and although effects on native crayfish are not fully understood, it is likely that competition for resources will occur. Herbivory and burrowing damage from Nutria are concerns because they eat a variety of wetland and agricultural plants and their burrowing damages streambanks, impoundments, and drainage systems. Nutria have expanded their range from the Coastal Plain into the central Piedmont. Nutria may be a vector for diseases (e.g., tuberculosis and septicemia) or parasites (e.g., *Giardia, Fasciola*, Liver Flukes, and nematodes), with fecal contamination in water the likely pathway (Carr 2010).

4.2.10.6 Recommendations

Section 4.2.2 provides recommendations appropriate for all aquatic communities, statewide. Actions specific to the state's river basins are provided in Section 4.5.

Large river communities provide a number of important habitats, life cycle, or prey components to a vast assemblage of terrestrial, semi-aquatic, and aquatic wildlife. The lower reaches of Coastal Plain large rivers are more vulnerable to the effects of climate change, especially rising sea levels and saltwater intrusion, which will likely change the overall species composition in these systems. Important actions to promote resilience are to protect and maintain floodplains and riparian vegetation. Piedmont large river systems are likely to be impacted by continued development and the water quality issues associated with runoff and withdrawals.

Surveys

Distributional and status surveys are needed for aquatic snails, crayfish, mussels, and fish (in order of general need).

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Carry out surveys to document the distribution, relative abundance, and status of many wildlife species associated with riverine habitats. Priorities for conducting surveys need to focus on species believed to be declining, at risk, or mainly dependent on riverine communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Conduct additional surveys for species for which current distribution information is already available or for species that are considered common.
• Conduct mussel surveys in large rivers to determine distribution and status of priority species. Eastern Pondmussel / Tidewater Mucket / Yellow Lampmussel

Monitoring

Monitoring of aquatic taxa is critical to assessing species and ecosystem health and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage aquatic species. Long-term monitoring is needed to identify population trends and to assess the performance of conservation actions. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Develop or enhance long-term monitoring for amphibians, reptiles (Taylor and Jones 2002), and bat species (Ellis et al. 2002) that use riparian areas of large rivers.
• Continue existing programs and expand monitoring of anoxic and hypoxic water conditions, particularly during spring anadromous fish spawning, summer droughts, and before and after tropical storms
• Install new and maintain existing USGS flow/water quality monitoring stations to collect real-time discharge and DO data.

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Research must also be conducted to determine vulnerability of priority species to specific threats and studies should provide recommendations for mitigation and restoration. Aquatic species propagation is an area of current and ongoing research. Developing techniques for propagation of aquatic species is critical for preserving those species and their genetic stock, particularly those that are rare, at high risk of extinction or extirpation and difficult to propagate in a laboratory setting.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Conduct studies to determine how large riverine habitats and the species that occupy the habitat recover or change after major flooding events from hurricanes.
• Conduct research to investigate population densities, population growth rates, dispersal range, and extent of property damage from Nutria burrowing and herbivory.
• Investigate the interactions between invasive aquatic species and native species to determine impacts on distribution, reproduction, and survival.
• Promote SAV surveys and vegetation restoration efforts.
• Promote research to investigate removal methods for invasive catfish (e.g., Blue and Flathead Catfish).

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Manage flow regimes in Coastal Plain rivers as much as possible to mirror the pre-dam hydrograph.
• Promote flood plain connectivity and remove infrastructure from the flood plain.
• Promote riparian habitat conservation to create or maintain habitat complexity.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Increase buffer widths to mitigate impacts from pollution into river systems and to maintain habitat at the edge of these aquatic communities that will provide cover and foraging areas for many wildlife species using riverine habitat.
• Pursue land acquisition and easements through cooperation with land trusts in an effort to increase the width of riparian buffers and create larger patches of connected habitat.
• Identify critical habitats that are important to specific life history stages (i.e., spawning habitat) for species and promote the conservation of these areas.

4.2.11 Stream Swamp Systems

4.2.11.1 Ecosystem Description

Small stream swamp communities are found in the lower Coastal Plain ecoregion and represent aquatic habitats of small to medium streams, larger swamp systems, and artificial ditches that are not included in the large river community description. Due to the lack of elevation change, floodwaters generally drain slower in these systems, thereby increasing the duration and extent of interface between the aquatic habitat and adjacent land as compared to floodplain communities that are found in other ecoregions. Substrate in these systems is typically sand or organic matter and many waters have high quantities of tannins. Although ditches are artificial habitats, they are included in this theme because they frequently have hydrologic connection to natural streams and over time the aquatic communities resemble these natural systems.

4.2.11.2 Location of Habitat

Examples of this community type include Town Creek, Great Coharie Creek, and Juniper Creek in the Coastal Plain. Priority habitats identified in the 2005 WAP that are similar to this community include the Mid-Atlantic Coastal Plain Riverine Aquatic Communities and Tidal Swamp Forest and Wetlands (see Chapter 5) (NCWRC 2005).

4.2.11.3 Problems Affecting Habitats

Land Use. Aquatic systems in North Carolina have been threatened by a variety of perturbations in the past and many of those same threats continue today. For example, ditches used to drain stream swamp communities will alter local hydrology, eliminate aquatic habitats and alter terrestrial communities that depend on hydrologic input from the swamp, and can be a conduit for saltwater intrusion, depending on landscape position. Converting land uses from natural forest to agriculture or silviculture production and residential and commercial development continues to threaten stream integrity. The threat comes from related increases in sediment, bank erosion, and stormwater runoff containing sediment and other potentially toxic materials. Floodplains and wetlands associated with stream swamp communities are natural features designed for flood control and dissipating floodwaters. Floodplain development interferes with this natural capacity and worsens downstream flooding, scour, and erosion.

Riparian vegetation is critical to the overall stream and streambank stability and moderation of water temperatures. Riparian areas include land adjacent to water bodies (e.g., floodplains) and are critical to the overall stream and streambank stability. In addition to erosion control, riparian areas allow for sediment and pollutant deposition (by dissipating energy from runoff and allowing for filtration); infiltration of water runoff to allow for groundwater recharge; regulation of stream temperature by providing shade; attenuation of storm flows (flood control); carbon sequestration by mature woody vegetation; and increased stream habitat complexity by contributing woody debris. They also provide habitat for terrestrial wildlife species and serve as corridors for movement of terrestrial wildlife species (Seavy et al. 2009; NCWRC 2002; Wenger 1999).

Lack of sufficient vegetation or inadequate width of forested buffer contributes to rising water temperatures, especially where water depths are shallow enough that the entire water column is subject to solar heating. In addition to stabilizing streambanks, riparian vegetation serves as a food/nutrient input to the stream community and helps regulate stream temperature by providing shade.

Water Quality. Erosion and the resultant sedimentation are the largest sources of nonpoint source pollution in most aquatic systems. Development activities and agriculture can be the most significant sources of erosion and sediment. Timber harvests and poorly constructed and maintained timber roads are additional sources of erosion if proper controls are not used and maintained. Increased stormwater runoff will amplify the loading of nutrients, sediment, and contaminants into streams, rivers, and reservoirs. The increased loads could affect water quality and habitat for aquatic species, as well as drinking water for municipalities. Stormwater controls and retrofits will become increasingly important (Band and Salvesen 2009).

Algal blooms are possible in these systems and can exacerbate DO problems, particularly when flows are low. Increased water temperature, resuspension of bottom sediment during storms, and increased nutrient content of freshwater and coastal waters can increase pathogen replication, persistence, survival, and transmission (DeWan et al. 2010; Karl et al. 2009; Band and Salvesen 2009; US EPA 2010).

Confined animal operations are common in the Coastal Plain ecoregion and may have significant impacts on water resources. Livestock access to streams contributes heavily to bank erosion, sedimentation, and nutrient input. Animal waste lagoon discharges are a potential source of contamination if not properly managed and maintained.

Invasive Species. The introduction of any invasive species is cause for concern and the prevalence of warmer water temperatures may increase the the presence of exotic species that were previously thought to be non-threatening because the winters were too cold for survival. The Asian Clam is found in aquatic systems throughout the state; however, its effects on native mussels are largely unknown. Red Swamp Crawfish are prevalent in the Coastal Plain and although effects on native crayfish are not fully understood, it is likely that competition for resources such as food and space are potential impacts. Flathead Catfish are a concern because of direct predation on native species.

Climate Impacts. Increased air temperatures may lead to increased water temperatures and potentially lower DO levels. Stream swamp communities experience periodic temperature increases and DO decreases that may be exacerbated by changing climate conditions. Higher air and water temperatures can also lead to increased evaporation, which results in less flowing water available for aquatic species to use. Hot spells can have the same effect as overall increased air temperatures but on a much more acute scale.

According to DeWan et al. (2010), hydrologic regimes in the Coastal Plain are likely to be much more sensitive to changes in precipitation than to changes in temperature. Potential changes in the amounts and timing of precipitation have numerous and varied effects. Decreases in overall summer precipitation will likely cause reduced water flows, which will further contribute to warmer water temperatures and stress water quality. This is particularly important in the context of seasonal droughts, because nutrients may become concentrated and flush out of systems more slowly during low flow periods. Severe and prolonged droughts may decrease streamflow, decrease groundwater recharge, and increase evaporation, resulting in impacts to streams of this theme. Additionally, upstream headwaters and other small streams contributing flow to stream swamp communities could dry up, posing potential impacts to aquatic species and downstream flow regimes (DeWan et al. 2010; Karl et al. 2009; US EPA 2010).

Increased storm intensity can lead to flooding and increased stormwater runoff and erosion. With increased stormwater runoff there is also an increase in sediments, nutrients, and contaminants loading into streams and potential negative effects on biota. The increased loads could affect water quality and habitat for aquatic species, as well as drinking water for municipalities. Stormwater controls and retrofits will become increasingly important (Band and Salvesen 2009). With a change in intensity and variability of rainfall, there are potential changes to stream flow patterns, channel hydrodynamics, lake levels, and the volume of groundwater from aquifers (Band and Salvesen 2009; US EPA 2010; Bakke 2008).

Channel hydrodynamics include flow regime, sediment transport, and overall channel design and can be altered by changes in storm frequency and intensity. Some streams in this aquatic system have a pattern of riffles, runs, and pools, and will exhibit overall changes to the quantity and quality of these habitats. Other streams and swamps have relatively slack water and comparatively few riffles and runs and they may exhibit a shifting of sand bars. Storms may cause the felling of riparian trees, particularly in areas with narrow riparian areas. Increased woody debris in these streams will alter channel hydrodynamics as well as available habitat.

An increase in the number of tropical events can lead to flooding, which causes many of the above-mentioned responses. Effects such as increased sediments and contaminants into aquatic systems, in addition to major disruption to channel design and hydrodynamics, potentially upset the physical, chemical, and biological structure of streams. Tropical events may also exacerbate problems associated with saltwater intrusion (Band and Salvesen 2009).

Sea level rise is likely to impact stream swamp communities, as the combined increase of inland flooding due to higher precipitation events coupled with elevated sea levels will exacerbate coastal inundation. Additionally, saltwater intrusion into freshwater streams is a possibility as sea level rises. The chemical composition of freshwater systems could change and freshwater wetlands and swamps could be converted to salt marshes (Band and Salvesen 2009; US EPA 2010; Bakke 2008; Burkett et al. 2000).

4.2.11.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. While climate change is not the most severe threat to stream swamp communities, a combination of synergistic effects with development and lack of riparian corridors could stress these systems to the point where several species are unable to persist. Many of the threats that affect other stream communities discussed in this chapter will also impact stream swamp systems and the comments provided should be considered valid for this aquatic community. Table 4.2.11-1 provides a review of expected climate change impacts in order of importance in comparison with other types of threats.

Table 4.2.11-1 Comparison of climate change with other threats to stream swamp systems.

Threat	Rank Order	Comments
Development	1	Direct, secondary, and cumulative effects from development include increased sediment, bank erosion, and stormwater runoff containing sediment and other potentially toxic materials.
Groundwater Depletion	2	During droughts, water levels will decline as temperature increases and rainfall events decrease. Any increase to pumping or water withdrawals can cause depletion and low DO due to low flow conditions.
Logging/Exploitation	2	While bank vegetation is usually undisturbed, logging is a major threat to streams in the Coastal Plain. Loss of forest cover can cause increased erosion and sedimentation and negatively impact aquatic systems.
Water Withdrawals	2	Irrigation, water supply, and energy development withdrawals pose a threat to flow regime.
Climate Change	2	Sea level rise, as a result of climate change, is a major threat to Coastal Plain aquatic systems.
Pollution	3	Point and nonpoint sources—runoff and EDCs—are threats. Erosion and the resultant sedimentation are the largest sources of nonpoint source pollution in mostaquatic systems. Runoff from urban areas often contains higher concentrations of nutrients, such as nitrogen and phosphorus, sediment, metals, hydrocarbons, and microbes.
Lack of riparian vegetation	3	Loss of riparian vegetation contributes to stream bank erosion and sedimentation. Riparian vegetation serves as a food/nutrient

Table 4.2.11-1 Comparison of climate change with other threats to stream swamp systems.

Threat	Rank Order	Comments
		input to the stream community and helps regulate stream temperature by providing shade.
Livestock	4	Livestock access to streams contributes heavily to bank destabilization and erosion, sedimentation, and nutrient input. Concentrated animal feeding operations result in periodic fish kills from spills and reduced water quality from spreading animal manure on surrounding fields.
Invasive Species	4	Invasive plants and animals are potential problems, although specific interactions are unknown. Red swamp crayfish thrive in this habitat and outcompete native crayfish

4.2.11.5 Impacts to Wildlife

Appendix 3 includes a list of SGCN and other priority species for which there are knowledge gap and management concern priorities. Appendix 3-18 identifies SGCN that use stream swamp systems.

Rapid changes in water temperature will have direct impacts on the physiology and metabolic rates of freshwater biota (Allan et al. 2005), which are dominated by cold-blooded organisms with no physiological ability to regulate their body temperature. Aquatic species are particularly sensitive to temperature cues and recent research has shown that many species of freshwater mussels may already be living at the upper thermal tolerances of their early life stages (glochidia and juveniles) (Pandolfo et al. 2010). Eaton et al. (1995) reported maximum temperature tolerance estimates for 30 species of freshwater fishes occurring in the United States. Temperature tolerance ranges are species-specific, and the availability of cooler waters may become limiting to some species in their current range in a warmer climate.

Aquatic species could experience shifts in their range or distribution and sensitive species may experience decline or extirpation due to changes in water quality and habitat. The ability of freshwater organisms to move to new locations is constrained by the connectivity of streams and rivers within drainage basins and by the connectivity between suitable habitat types within an aquatic system.

Saltwater intrusion is expected to impact large rivers initially, and the extent to which saltwater will reach small streams and swamps is yet to be determined. However, if these smaller systems experience saltwater intrusion, existing freshwater fauna may be replaced with more brackish water species and, if salinity levels increase gradually, there could be adaptation by some freshwater species to this change. Additionally, if these systems remain freshwater, but large rivers at confluences with these smaller systems are brackish water, it could lower genetic diversity and available habitat for species that moved between large and small river systems in the Coastal Plain. Also, there may be a change in the number of freshwater streams and swamps in this community type as some may become brackish or saltwater systems.

Because of the link between freshwater mussels and fish, phenological disruptions are a possibility, but exact mechanisms or effects are not understood. Freshwater mussel larvae (glochidia) are dependent on a host fish for transformation into juveniles. Host fish species are known for some mussel species, but not well understood. Temperature cues play a large role in the release of glochidia from female mussels and also in the movement and migrations of fish. With changing temperatures predicted with climate change there could be phenological disruptions affecting the reproductive capacity of freshwater mussels.

Recent studies have shown that EDCs in treated wastewater can inhibit reproduction and cause feminization of mussels and fish. Although little is known about the effects of EDCs, additional studies are being conducted to document the levels of EDCs in discharges. Wastewater treatment facilities need to incorporate appropriate measures to reduce or eliminate EDCs from wastewater prior to discharge should those discharge studies show increases in EDC levels (Conn et al. 2006; Kim et al. 2007; Kasprzyk-Hordern et al. 2008; Joss et al. 2006; Kolpin et al. 2002; Nowotny et al. 2007).

While this community represents riverine aquatic habitats, there are terrestrial species that utilize this resource. Several priority bird species are threatened by rising sea levels through habitat conversion from saltwater intrusion; loss of nesting, foraging, or cover habitats from inundation; and impacts that reduce prey species found in this habitat. For example, the Little Blue Heron and Wood Stork prefer freshwater pools, inland swamp, or mudflats and usually nest further inland (LeGrand et al. 2012). Inundation and saltwater intrusion will reduce habitat quality and availability and potentially displace birds when currently occupied habitats are converted to brackish systems.

Most of the listed priority amphibian and reptile species associated with riverine aquatic habitats have limited distributions, or little is known about their distribution, or they are widely dispersed but have small populations. Isolation or fragmentation of particular habitat stretches occupied by those species could have significant long-term effects upon the sustainability of those populations in North Carolina.

Temperature may have significant effects on developmental pathways or behaviors influencing reproduction and survival. For example, sex determination in hard-shell turtles is largely temperature dependent (Bull 1980, Bull et al. 1982). Rising temperatures can also affect metabolic and growth rates in insects and other ectotherms (Dukes et al. 2009; Sheridan and Bickford 2011), resulting in faster development and shorter lifecycles in some cases. Increased winter temperatures and frost-free days may also affect overwinter survival of some insects and pathogens (Dukes et al. 2009), resulting in increased population sizes that contribute to outbreaks.

4.2.11.6 Recommendations

Section 4.2.2 provides recommendations appropriate for all aquatic communities, statewide. Actions specific to the river basins that contain stream swamp communities are provided in Section 4.5.

Monitoring of aquatic taxa is critical to assessing species and ecosystem health and gauging the resilience of organisms to a changing climate. These monitoring efforts will inform future decisions on how to manage aquatic species. In addition to monitoring, there are several research questions that need to be answered about certain species or taxa of aquatic organisms.

Surveys

Distributional and status surveys are needed for aquatic snails, crayfish, mussels, and fish (in order of general need).

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Conduct surveys to determine distribution and status of crayfish SGCN and priority species with a focus on burrowing crayfish.

  Devil Crayfish | Digger Crayfish | Pamlico Crayfish

- Conduct surveys to determine status and distribution of freshwater fish that are swamp system specialists.

  Banded Sunfish | Ironcolor Shiner | Swampfish

- Baseline surveys are needed to document distribution and status for all aquatic snail SGCN and other priority species.

- Determine the components of foraging bat communities along rivers.

- Establish species-specific surveys to improve our knowledge of the status and distribution of the Least Bittern, American Bittern, Yellow Rail, and Black Rail at all times of the year (Conway et al. 2004).

Monitoring

Monitoring of aquatic taxa is critical to assessing species and ecosystem health and gauging the resilience of organisms to a changing climate. These monitoring efforts will inform future decisions on how to manage aquatic species. Long-term monitoring is needed to identify population trends and to assess performance of conservation actions. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Monitor water quality downstream of large agricultural farms (including livestock and poultry operations).
• Establish mist net stations for passerine birds in this habitat type at all times of the year.

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Research must also be conducted to determine vulnerability of priority species to specific threats and studies should provide recommendations for mitigation and restoration. Aquatic species propagation is an area of current and ongoing research. Developing techniques for the propagation of aquatic species is critical for preserving them and their genetic stock. This is especially true for those that are rare, at high risk of extinction or extirpation, and difficult to propagate in a laboratory setting.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Verify the genetic makeup of the Sandhills Salamander, which has yet to be formally described. Sandhills Salamander
• Examine the extent and impact of exotic species introductions; conduct research on effective control measures for the most problematic exotics. Red Swamp Crayfish
• Conduct research on fire management in marsh habitats to determine optimal frequency, timing, and firing techniques (e.g., flanking fire, back fire) to benefit priority birds.
• Conduct a systematics study to differentiate between the two subspecies of Least Shrew. Least Shrew

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Examine habitat use and conduct nesting habitat research on the Black Rail and then on other marshbirds using telemetry (Bogner and Baldassarre 2002).
- Investigate the past, current, and potential future impact of Nutria.
- Investigate the effect of Beaver ponds on downstream movement of pollutants (toxins and sediment).

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- The best benefit for Coastal Plain riverine aquatic communities would be to maintain and enhance riparian buffers.
- Determine the impacts of snagging (removing woody debris after storms) on wildlife populations.
- Explore techniques for restoration of tidal swamp forest and wetlands.
- Explore the biological controls recommended for some aquatic plants species, as they can be a problem, particularly in impounded waters and in slower moving waters.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the greatest extent possible to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Continue working with conservation partners and land trusts to protect these habitats.

4.2.12 Natural Lakes

4.2.12.1 Ecosystem Description

Natural lakes include Carolina bays and depressions in peatlands that may have been created by deep peat burns or some other cause. Most are oval in shape, but a few are elongate and appear to be simply wide places along creeks. This ecosystem group also includes deeper water systems that lack vegetation as well as the vegetated natural shoreline communities.

Most have tannin-stained water and have low productivity. Algae, primarily green algae or diatoms, are the primary plants, although a variety of aquatic vascular plants can be present. Fish abundance and diversity are typically low. A variety of insects and other invertebrate animals spend some or all of their life cycle in the water.

The natural lake shoreline community type includes areas of emergent aquatic plants along lake margins and in wetland areas affected by changes in the lake's hydrology. It is a heterogeneous type with much variation. Most shorelines are marshy, dominated by emergent plants such as Maidencane. A few examples are well-developed swamp forests, dominated by Sweetgum, cypress, or a mixture of trees. The forested shorelines of several lakes are important nesting sites for colonial waterbirds such as herons.

While most lakes are naturally very acidic, Lake Waccamaw has limestone outcrops within the lake that give the water a neutral pH and high calcium content. A much higher diversity of animals is present, including many more fish species and a diverse mollusk fauna. Seven species of mussels, snails, and fish are endemic to this one lake, or to the lake and the upper Waccamaw river system.

4.2.12.2 Location of Habitat

Natural lakes are found only in the Coastal Plain ecoregion. There are 22 natural lakes and examples of systems that provide important wildlife habitat, including Lake Mattamuskeet (Hyde County), Lake Ellis Simon (Craven County), and Lake Waccamaw (Columbus County).

4.2.12.3 Problems Affecting Habitats

Development. Development and loss of associated riparian habitats are primary concerns. Shorelines are often trampled and shoreline erosion and mowing is a concern in many areas. Point and non-point source pollution sources from residential areas and other sources (e.g., watercraft engines) are prevalent, and non-point source pollution from agriculture and logging is possible, potentially leading to algal blooms and low dissolved oxygen events. Disturbance by boats and personal watercraft creates wakes and associated noise pollution that disturb water birds and water fowl. Lake Mattamuskeet has experienced declines in water quality as a result of agriculture practices within the watershed and introduced fish species.

Invasive species. Phragmites has become established in many of the state's natural lakes and has replaced native shoreline vegetation. Hydrilla and lyngbya has been introduced into Lake Waccamaw and intensively managed with herbicides. The threat of invasive vegetation is a major threat to the natural lakes within the Coastal Plain.

Runoff. Surface waters, including natural lakes, often receive wastes, sediments, and pollutants from runoff because of their position in the landscape (Dudgeon et al. 2006). Changes in hydrology and water chemistry affect water quality. High water levels can create shoreline damage (e.g., erosion, flooding) while prolonged low water levels may contribute to water quality issues and impact delivery of lake ecosystem services (Foulds 1977; Wildman et al. 2011; Crase et al. 2008; Molinos et al. 2015).

Climate. Water levels may be low during droughts and periods of high temperatures and lakes may become stratified with little or no vertical mixing within the water column. Under these conditions DO levels in deeper waters may be depressed and become unsuitable for many aquatic organisms. Algal blooms in the surface water can exacerbate DO depletion and result in local degradation of water quality. Such conditions are temporary and are usually alleviated by increased water flow or increased wind velocity.

Water level fluctuations may also lead to changes in patterns of boundary mixing (i.e., the process of enhanced mixing near the lateral boundaries of a lake which affects sediment resuspension and vertical nutrient fluxes), induced mainly in stratified lakes by internal wave activity at the depth of the thermocline. Progressively declining water levels would be expected to lower the thermocline and therefore displace boundary mixing (Zohary and Ostrovsky 2011; Molinos et al. 2015). Persistance of these issues can exacerbate water quality problems by contributing to long-term eutrophication in natural lakes (Hambright et al. 2004; Molinos et al. 2015).

Water Use. Water withdrawals for irrigation during summer droughts can cause low DO availability when reduced water levels result in higher water temperatures, especially along littoral edges. Combined with extended climate related heat spells, drought, and increased storm severity (e.g., lighting strikes) there may be an increase in wildfire occurrences that prompt the need for water withdrawals lake water to fight the fires.

4.2.12.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. While climate change is not the most severe threat, synergistic effects combined with other existing conditions could stress these systems to the point where several species are unable to persist.

The most important effect of climate change on lakes is likely to be the occurrence of more extreme rainfall events and more frequent droughts. Table 4.2.12-1 compares climate change with other existing threats.

Table 4.2.12-1. Comparison of climate change with other threats to natural lakes.

Threat	Rank Order	Comments
Pollution	1	Point and non-point source pollution from residential and agriculture areas and other sources (e.g., 2-stroke watercraft engines) are prevalent, and non-point source pollution from agriculture and logging is possible for several sites. This pollution leads to algal blooms and low DO events (NCWRC 2005).
Development	1	Development destroys or disturbs shoreline vegetation, often extending well into the lake because of docks and boat activity associated with them. Shoreline construction creates impermeable surfaces that alter runoff into the lake, often involves artificial drainage or fill that further alters water flow, and is a source of pollution by nutrients, pathogens, and toxic chemicals. Most of these problems continue after construction, so past development remains an ongoing stress.
Invasive Species	2	Invasive species are the greatest threat for some lakes. Phragmites invasion is already a problem and could increase. Herbivory and burrowing damage from Nutria are concerns because they eat a variety of wetland and agricultural plants and their burrowing damages streambanks, impoundments, and drainage systems.
Impoundments	3	If long-term average rainfall does not change, average lake levels will probably remain around the same, though increased evaporation might decrease water levels to some degree. Many lakes already have water control structures at their outlets, and have water levels that are partly artificially manipulated. Artificial control of lake levels by dams, ditches, or water control structures could affect overall water elevations.
Logging/Exploitation	4	Non-point source pollution from agriculture and logging is possible for several sites and can lead to algal blooms and low DO events (NCWRC 2005).
Climate Change – Sea Level Rise	4	Several lakes, including Milltail Lake, Whipping Creek Lake, Swan Creek Lake, and Hidden Lake, lie near sea level and are connected to the sounds by creeks. Several of the more unique lakes of the central Pamlimarle Peninsula are connected to the sounds by canals, increasing the risk of damage to them. The small lakes in Dare and Tyrrell County will almost certainly be lost because of

Table 4.2.12-1. Comparison of climate change with other threats to natural lakes.

Threat	Rank Order	Comments
		rising sea level. The large lakes of the Pamlimarle Peninsula, such as Lake Mattamuskeet and Lake Phelps, lie at the highest elevations in the area, but may be affected if sea level rise is greater than the mid-level scenario. Saltwater from storm surges reach Lake Mattamuskeet, temporarily increasing salinity.
Climate Change	4	Climate change will potentially have a direct influence on availability of thermal habitats in aquatic environments, which in turn can become a constraint to feeding habitat access and subsequent consequences on species growth (DeWan et al. 2010).

4.2.12.5 Impacts to Wildlife

Appendix 3 includes a list of SGCN and other priority species for which there are knowledge gap and management concern priorities. Appendix 3-18 identifies SGCN that use natural lake systems.

In particular, natural lakes and immediately adjacent cover (especially the smaller ponds) provide habitat for wading birds and shorebirds for foraging, and also important breeding sites for species such as Green Herons. Common Yellowthroats and Red-winged Blackbirds are typical nesters in vegetation along shorelines, and swallows and swifts often forage over lakes and ponds. Bald Eagles and Ospreys nest and/or forage at these sites and waterfowl roost, loaf, and feed during migration and winter. Double-crested Cormorants are becoming common year-round residents at most coastal lakes. Anhingas are sometimes seen during summer, nesting at millponds and/or natural lakes. In addition, these water bodies are popular destinations for human recreational activities such as canoeing, fishing, crabbing, and swimming.

Multi-year droughts in the last several decades have produced long periods of low water. Most lakes are large enough that water level fluctuations are expected to affect the shoreline but not have major effects on the majority of the aquatic community. However, because the slope of most lake beds is very shallow, a large band of lake bed can become exposed during a multi-year drought. Mussels and any other sessile animals near the shore may be affected. Low water may combine with the effect of warmer water to produce low oxygen levels that will stress the aquatic community.

Temperature and DO concentrations control the distribution of fish species in lakes (Stefan et al. 2001 in DeWan et al. 2010), which will have significant impacts on shallow waters as ambient temperatures increase. In ponds and lakes deep enough to exhibit summer thermal stratification, warmwater habitat will increase in depth, potentially forcing cool water organisms into deeper waters (Allan et al. 2005 in DeWan et al. 2010; Ficke et al. 2007). In Mohseni et al. (2003), changes in habitat for cool and warmwater fishes was dependent on the assumptions for minimum temperature tolerance (32°F vs. 35.6°F) and ranged from a 12% to a 15% decrease in habitat for coolwater fishes and a 0% to a 31% increase in habitat for warmwater fishes (DeWan et al. 2010).

Development and loss of associated riparian habitats are concerns where Bald Eagles have found shorelines to use as perch/foraging sites. Lake Ellis Simon in Craven County is productive and holds a sizable Anhinga colony. These sites and immediately adjacent cover provide foraging and breeding habitats for species such as Green Herons. Terrestrial animals that use lake communities for forage, refugia, or during parts of the reproductive cycle will also be affected by any changes in aquatic habitat or species community structure.

Exotic species (e.g., Hydrilla, Asian Clam, Common Carp) negatively affect native frogs and turtles due to decreased native plant and animal diversity. Avian Vacuolar Myelinopathy (AVM) is a disease that affects birds that use these habitats. It has killed nearly 100 Bald Eagles in the southeast and is associated with a novel Cyanobacterial species found in aquatic plants such as Hydrilla.

4.2.12.6 Recommendations

Priority should be placed on protecting the remaining undeveloped, unprotected natural lakes and controlling invasive species on those that are protected to promote resilience. Section 4.2.2 provides recommendations appropriate for all aquatic communities, statewide. Actions specific to the Coastal Plain portions of river basins that contain natural lakes are provided in Section 4.5.

Surveys

Distributional and status surveys are needed for aquatic snails, crayfish, mussels, and fish (in order of general need).

Monitoring

Monitoring of aquatic taxa is critical to assessing species and ecosystem health and gauging the resilience of organisms to a changing climate. These monitoring efforts will inform future decisions on how to manage aquatic species. Long-term monitoring is needed to identify population trends and to assess performance of conservation actions. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Establish monitoring sites in Carolina Bay lakes to track changes over time in species assemblages.

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Research must also be conducted to determine vulnerability of priority species to specific threats and studies should provide recommendations for mitigation and restoration. Aquatic species propagation is an area of current and ongoing research. Developing techniques for propagation of aquatic species is critical for preserving those species and their genetic stock, particularly those that are rare, at high risk of extinction or extirpation, and difficult to propagate in a laboratory setting.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Promote research to genetically describe endemic species.
  Lake Phelps Killifish
- Investigate how invasive species impact native species assemblages.
  Lyngbya
  Flathead Catfish
  Hydrilla
- Investigate pathways excess nutrients and toxins enter natural lakes and identify measures to reduce inputs.

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Promote SAV surveys to monitor native vegetation and identify invasive species and restoration opportunities.
• Promote research investigating eradication of phragmites in shoreline habitats.

Conservation Programs and Partnerships
Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

4.2.13 Reservoirs & Impoundments

4.2.13.1 Ecosystem Description

Reservoirs and impoundments are found statewide and vary greatly in size; however, the systems considered in this community description include waterbodies of approximately 100 acres or larger. These systems formed when dams were built on large riverine systems, most often constructed to generate hydroelectric power or provide drinking water for nearby communities. The diverse nature of the impounded streams and rivers contributes to their unique configuration, flow pattern, water chemistry, and biota. Water depths in many of these systems may be subject to some fluctuation because water is released to maintain downstream flow regimes or to release flood waters. Farm ponds and smaller lakes constructed as local storm water or flood control facilities are not included in this description.

These man-made systems will likely have a combination of maintained shoreline with hardened structures and natural shoreline covered by vegetation. Where the shorelines are marshy, such as shallow margins and wetlands affected by the lake’s hydrology, the vegetation is expected to include emergent aquatic plants while the upper banks will be covered by a mix of herbaceous and woody vegetation. Reservoirs, mill ponds, and other impounded waterbodies provide habitat for a variety of fully and semiaquatic species including reptiles, amphibians, and aquatic mammals. They provide habitat that supports prey species and area foraging areas for many terrestrial species, such as birds and bats.

4.2.13.2 Location of Habitat

There are numerous reservoirs and impoundments with various sized drainage areas located across the state. Notable examples include the B. Everett Jordan Lake Dam on the Haw River (Cape Fear River Basin); Hiwassee Lake Dam on the Hiwassee River (Hiwassee River Basin); East Fork, Cedar Cliff, and Bear Creek dams on the Tuckasegee River (Little Tennessee River Basin); Falls of the Neuse Dam on the Neuse River (Neuse River Basin); Lake Gaston and Roanoke Rapids Lake dams on the Roanoke River (Roanoke River Basin); and the Tillery/Norwood and Blewett Falls Lake dams on the Pee Dee River (Yadkin-Pee Dee River Basin).

4.2.13.3 Problems Affecting Habitats

The protection of aquatic ecosystems under an expanding human population is of global concern and water quantity is becoming a major issue for urbanizing landscapes (Armstrong et al. 2001). Aquatic systems in North Carolina have been threatened by a variety of perturbations in the past and many of those same threats continue today. Water impoundment imposes fundamental changes on natural landscapes by transforming rivers into reservoirs. The dramatic shift in physical conditions accompanying the loss of flow creates novel ecological and evolutionary challenges for native species (Haas et al. 2010).

Land Use. Aside from converting extensive reaches of stream habitat into standing water, reservoirs flood large areas of land, change the magnitude and timing of water flows, reduce the sediment load, form barriers for fish migration, and extirpate shallow-water species through fluctuation of water levels (Malmqvist and Rundle 2002). Impoundments on major rivers and tributaries drastically alter the hydrologic regime of many North Carolina waterways and result in habitat fragmentation, blockage of fish migration routes, and physical habitat alterations.

Erosion and sedimentation are the primary forms of nonpoint source pollution affecting many surface waters. Sources of erosion are primarily ground disturbance from development activities (residential, commercial, transportation, and utility construction) and agriculture. Other nonpoint sources of pollution include the quantity and quality of runoff from built-up areas and roadways. Sediments can build up behind an impoundment and over time can cause a degradation of underwater habitat quality above the dam. Plant diversity can be altered by sediment pollution. Streambank and other erosion from poorly managed cattle pastures (primarily caused by lack of fenced buffers along streams) and erosion from row crops contribute most of the sediment from agriculture. Timber harvest with insufficient erosion controls may be another source of sediment.

Many species associated with lakes and aquatic habitats rely on shoreline vegetation for shelter, foraging, breeding, and nesting. Shrubs and trees growing around shorelines provide important nesting, roosting, and feeding sites for birds, especially colonial waterbirds such as herons. Development of lake shores causes loss and fragmentation of this riparian habitat. In many cases, reservoirs and impoundments are subject to management for recreational activities such as boating and fishing. Excessive human use of lake shores can lead to increased trampling and erosion of the banks. Human intrusion can disrupt natural behaviors of animals using this habitat.

Water Quality. Pollution can cause problems for many aquatic organisms and their predators. Heavy metals can be a particular concern because they can bioaccumulate in animal tissues. Smaller water bodies near agricultural or residential areas can suffer from excess nutrient run-off, leading to algal blooms and low DO levels. Contaminants can be carried by sediment that washes into surface waters.

Changes in hydrology and water chemistry can impact water quality negatively. Nonpoint source pollution and the effects of dams and impoundments pose historic and current threats to freshwater mollusks (Bogan 1993; Neves et al. 1997; Richter et al. 1997). Impacts from hydropower development in large river basins have altered and degraded a substantial portion of habitat for most native aquatic species, primarily in large streams and rivers. Irregular flooding during the growing and nesting seasons can affect the reproductive success and survival of species that depend on this habitat type.

The mainstem Hiwassee and Nottely rivers, for example, are significantly altered by direct and indirect impacts from impoundment. Fifty-seven miles of historically free-flowing riverine habitats are now either seasonally or permanently flooded by Chatuge, Mission, Hiwassee, and Appalachia reservoirs or are affected indirectly by impoundment. The unimpounded reaches of the Nottely and Hiwassee rivers are affected by cold water, altered hydrologic regimes, and periodic low levels of DO due to hypolimnetic discharges and peaking power production releases from Chatuge and Nottely dams. Impoundment and thermal alteration may further affect native species by fragmenting suitable habitat and isolating historically contiguous populations in tributaries.

Invasive Species. Reservoirs can be a barrier to upstream movement of invasive aquatic species, but more often they act as stepping-stones for the dispersal of exotic and nonnative species across landscapes. Exotics are species that are not native to the United States, and species that are not native to North Carolina, but that may be native to other areas of the United States, are considered nonnatives. Havel and colleagues (2005) conducted a study called "Do Reservoirs Facilitate Invasions into Landscapes?" that examines how reservoirs might facilitate the spread of invasives across landscapes. Populations often become invasive because there are no natural predators or conditions to control growth. A variety of passively dispersing species have invaded reservoirs, spread through interconnected waterways and been unwittingly transported on boating equipment and in bait buckets. Exotic plant species such as Hydrilla, Giant Salvinia, Lyngbya, and Purple Loosestrife can form large mats that displace native vegetation and entangle boat motors. Exotic aquatic animals such as the Basket Clam, carp (e.g., Common, Grass, Bighead) and snails (e.g., Chinese and Japanese Mysterysnails, Red-Rim Melania) are often vectors for parasites and diseases that can affect native species.

Climate Impacts. Many of the water quality and water quantity impacts resulting from climate change are analogous to impacts from economic development and population growth in North Carolina. Climate change is predicted to decrease rainfall and therefore limit water supply, while growth and development have been increasing and continue to raise demands for water supply. Historical stream flow patterns are projected to be altered due to climate change impacts; however, these are already being altered due to rapid urbanization.

Global warming scenarios predict a possible decrease in precipitation and increase in evaporation (Jacobs et al. 2000), which together with sediment accumulations in our aging reservoirs is likely to propel new constructions such as those being considered and pursued in the southeastern region of the country (Kashiwagi and Miranda 2009). During drought periods when stream flows are reduced in the study streams, fish in reaches above impoundments are apparently forced downstream to seek shelter in the impoundment, or survive in wetland areas that provide temporary refuge (Kashiwagi and Miranda 2009). Despite annual fluctuations, fish communities of unimpounded headwater streams can remain fairly stable over time but require connectivity with the downstream community to preserve their integrity (Moyle and Vondracek 1985; Ross et al. 1985).

4.2.13.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. While climate change in many cases is not the most severe threat, a combination of synergistic effects with other existing conditions could stress aquatic systems to the point where native species are unable to persist.

A comparison of climate-related impacts to other threats is not included in this description because the NCNHP vulnerability assessments completed in 2010 did not include reservoirs and impoundments as a community type. Concerns are expected to be similar to the comparison results for other aquatic systems; however, sedimentation and erosion, invasive species, and pollution are primary concerns for this community type.

4.2.13.5 Impacts to Wildlife

Appendix 3 provides a list of SGCN and other priority species for which there are knowledge gap and management concern priorities. Appendix 3-18 identifies SGCN that use reservoirs and impoundments.

Habitat Impacts. Impoundments are major contributors to habitat degradation and fragmentation in aquatic ecosystems (Baxter 1977; Dynesius and Nilsson 1994; Downing et al. 2006), threatening many freshwater taxa (Dudgeon et al. 2006). Reservoir construction in the United States reached its peak in the 1960s (Pringle et al. 2000) and more than 50 years have passed since habitat alteration may have affected fish populations in impounded riverine systems. Habitat modification, combined with stocking practices, has contributed to the replacement of unique local assemblages with widespread species that are better able to tolerate human activities, which can lead to homogenization of freshwater biota (Rahel 2002). Comparison of historical and contemporary fish assemblages indicate that the structure of fish assemblages upstream of inundated reaches have been altered in most impounded systems (Franssen and Tobler 2013).

Water Use. The condition of stream ecosystems depends on the appropriate quantity, quality, timing, and temporal variability of water flow to which aquatic species have adapted (Poff et al. 1997; Bunn and Arthington 2002). Water withdrawal can lead to reduced stream flow (Weiskel et al. 2007), and the presence of impoundments can further impact temporal variability of stream flow through their water storage capacities (Poff et al. 1997). Results from Kanno and Vokoun’s 2010 study of New England streams evaluating the effects of water withdrawals and impoundments on fish assemblages suggest that water withdrawals have contributed to measurable alterations of fish assemblages. These impacts should be considered when developing in stream flow regulation and aquatic conservation (Kanno and Vokoun 2010).

Impoundment. In their 2011 study of the effects of a small dam on freshwater mussel growth in Alabama, Singer and Gangloff found numerous locations where mussels were abundant and larger in size in reaches immediately downstream from the small dams. Analysis of length-at-age data using multiple growth models found that mill reach mussels grew faster than both up- and downstream populations, and evidence suggests that this phenomenon is geographically and taxonomically widespread in eastern North America. These results suggest that some small impoundments enhance conditions for freshwater mussel growth and some older dams may warrant protection or restoration if downstream reaches support imperiled mussel populations (Singer and Gangloff 2011).

Thermal stratification of impoundments occurs mostly during the warmer seasons, when direct solar radiation and increased air temperatures heat surface layers faster than deeper layers (Sherman 2000; Sherman et al. 2007) resulting in the formation of a lighter, warmer surface layer of water (epilimnion) and a cold bottom layer (hypolimnion) (Smith and Smith 1998). Many impoundments have fixed-level off-takes that are situated below the thermocline, hence releasing waters from the colder hypolimnion which causes downstream coldwater pollution (Sherman 2000; Preece and Jones 2002; Marshall et al. 2006). The biological impacts of coldwater pollution on warmwater fishes have been documented in a number of studies (Clarkson and Childs 2000; Todd et al 2005; Sherman et al 2007; Olden and Naiman 2010) and include impeded spawning, lower survival rates, retarded growth rates, and displacement of native species (Martinez et al 1994; Clarkson and Childs 2000; Todd et al 2005; Sherman et al 2007; Miles and West 2011).

Invasive Species. Introduction of species native to the state into areas where they normally would not occur creates competitive pressure on the native local populations. For example, the Piedmont Shiner, native to the Broad River, and Yellowfin Shiner, native to the Savannah River Basin, have been introduced to the Little Tennessee River Basin where they compete with native species for food, spawning, and cover resources. Their range could expand into other coldwater systems with warming water temperatures associated with discharges or changes to riparian buffers.

4.2.13.6 Recommendations

Section 4.2.2 provides recommendations appropriate for all aquatic communities, statewide. Recommendations specific to the river basins that contain reservoirs and impoundments are provided in Section 4.5.

Surveys

Distributional and status surveys are needed for aquatic snails, crayfish, mussels, and fish (in order of general need).

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Determine the status and distribution of reservoir-associated birds and help identify threats to populations.

Osprey	Swallows

Priority Conservation Action, Examples of Focal Species or Focal Habitats

Herons Rails

- Survey for shorebird migration activity on large reservoirs (e.g., Falls Lake, Kerr Lake) in spring, summer and fall.

- Conduct frog call surveys and support the volunteer and citizen science programs that participate in these surveys.

- Conduct mussel surveys to determine distribution and status of priority species.

  Tidewater Mucket Triangle Floater

Monitoring

Monitoring aquatic taxa is critical for assessing species and ecosystem health and gauging the resilience of organisms to a changing climate. These monitoring efforts will inform future decisions on how to manage aquatic species. Long-term monitoring is needed to identify population trends and to assess performance of conservation actions. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Continue monitoring Bald Eagle breeding activity.

  Bald Eagle

- Conduct monitoring for waterbirds and rails to help determine population trends.

- Monitor Pond Turtles and Common Ribbonsnakes to track population trends.

  Aquatic turtles Common Ribbonsnake

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Research must also be conducted to determine vulnerability of priority species to specific threats and studies should provide recommendations for mitigation and restoration. Aquatic species propagation is an area of current and ongoing research. Developing techniques for the propagation of aquatic species is critical for preserving those species and their genetic stock, particularly those that are rare, at high risk of extinction or extirpation, and difficult to propagate in a laboratory setting.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Track and identify problems associated with avian vacuolar myelinopathy that cause mortality in American coots, other waterfowl and Bald Eagles (Augspurger et al. 2003).

  American Coot
  Bald Eagle
  Waterfowl

- Assess the impacts of Federal Energy Regulatory Commission-mandated changes in water releases at hydroelectric dams on priority species.

- Study the impacts of commercial collecting of turtles on population dynamics, and the impact that the 2004 turtle law may have on the trade.

  Turtles

- Investigate the potential to use reservoirs as source populations for priority mussels (e.g., Lake Gaston).

Management

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Maintain natural shoreline vegetation and the structure of adjacent terrestrial habitats if possible (many wetland-related amphibian and reptile species rely on both aquatic and drier upland sites for their life history and seasonal migrations).

- Retain or create snags, logs, rocks, and other structures used by basking reptiles.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Reduce disturbance and development along raceways and near Bald Eagle nest trees.
  Bald Eagle
- Identify invasive and exotic species, their impacts on native wildlife, and practical methods for removal or control.
- Plant native vegetation where appropriate to provide aquatic and terrestrial habitat and to reduce erosion and sedimentation.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Limit lakeshore development at sites where there is no protected buffer land.
- Acquire lakeshore buffer lands (as was done at Jordan and Falls reservoirs) to exclude development.
- Implement conservation strategies where appropriate to protect downstream reaches of relic dams where there are known populations of priority mussel species.

4.2.14 Estuarine Aquatic Communities

4.2.14.1 Ecosystem Description

Estuarine aquatic communities are represented by the sounds and near-shore waters along North Carolina's coast. North Carolina's estuarine aquatic communities represent the largest estuarine systems along the US Atlantic coast and include the Albemarle, Pamlico, Core, Back, Croatan, Currituck, Roanoke, and Bogue Sounds. These sounds are collectively a part of the Albemarle-Pamlico National Estuary Partnership (APNEP), a cooperative effort jointly sponsored by NC and Virginia state resource agencies. They receive freshwater drainage from rivers and tributaries of the White Oak, Neuse, Tar-Pamlico, Roanoke, Pasquotank, and Chowan River basins.

Estuaries in the southern portion of the state flow more directly into the ocean, creating small but important areas of estuarine aquatic habitats within the lower reaches of the Cape Fear and within the Lumber River basin. Near-shore waters are those located within three nautical miles of North Carolina's coastal land area and are marine waters. Through tidal influences and storm surge events, near-shore waters contribute saline water to the estuaries. This mixing of freshwater from rivers and tributaries with saline waters from near-shore and ocean marine waters contributes to seasonal and temporal variability of salinity in the brackish waters within the estuaries. This habitat is closely associated with estuarine and freshwater marsh wetland communities (See Section 4.3.2).

Coastal waters represent a range of water salinities that depend on freshwater inputs from rivers and streams and mixing from wave driven motions and subsurface flow. Coastal freshwaters generally have salinity levels between 0 and 0.5 ppt as defined by the Venice System (Cowardin et al. 1979). Average ocean water salinity levels are between 25 and 35 ppt (Reshetiloff 2004). Salinity is typically less than 5 ppt in the sounds and can be vertically homogeneous in the water column according to the South Atlantic Fishery Management Plan (SAFMC 1998). Coastal shallow water temperatures along the North Carolina coast typically reach 31°C–33°C (Burkholder et al. 1992a, 1994; Mallin et al. 2000a).

The NC Coastal Habitat Protection Plan (CHPP) refers to estuarine waters as essential fish habitat (EFH) (Deaton et al. 2010). EFH supports the different life cycles of approximately 1,000 aquatic species managed under the South Atlantic Fisheries Management Plan (SAFMP), including anadromous species such as striped bass, herring species, and sturgeon species that migrate to freshwaters to reproduce (SAFMP 1998). The CHPP and SAFMPs describe five EFH components of the estuarine aquatic communities in North Carolina and are described below:

- Soft Bottom is the unconsolidated, unvegetated sediment that occurs in freshwater, estuarine, and marine systems. It is an important component of designated Primary Nursery Areas (PNAs), Anadramous Fish Spawning Areas (AFSA), and Anadramous Nursery Areas (ANA) (Street et al. 2005).

- Shell Bottom habitats are the oyster beds, rocks, reefs, and bars found in estuarine intertidal or subtidal areas. It is composed of surface shell concentrations of living or dead oysters (*Crassostrea virginica*), hard clams (*Merceneria merceneria*), and other shellfish (Street et al. 2005).

- Ocean Hard Bottom varies in topographic relief from a relatively flat, smooth surface to a scarped ledge with vertical, sloped, or stepped relief. It is formed of exposed rock, consolidated sediments, or relic reef, and may be covered by algae, sponges, corals, other live animals, and live plants attached to the hard surface (Street et al. 2005).

- Submerged Aquatic Vegetation (SAV) is defined as bottom vegetated by living structures of submerged, rooted vascular plants, (i.e., roots, rhizomes, leaves, stems, propagules), as well as temporarily unvegetated areas between vegetated patches. Native aquatic grasses are the primary species and can occur in fresh, brackish, and saline waters. SAV beds can be transient communities comprised of a few plants or many and cover small patches or extensive areas. They provide important habitat for most fish and shellfish species in the sounds, while also creating oxygen and removing excess nutrients in the water (APNEP 2012).

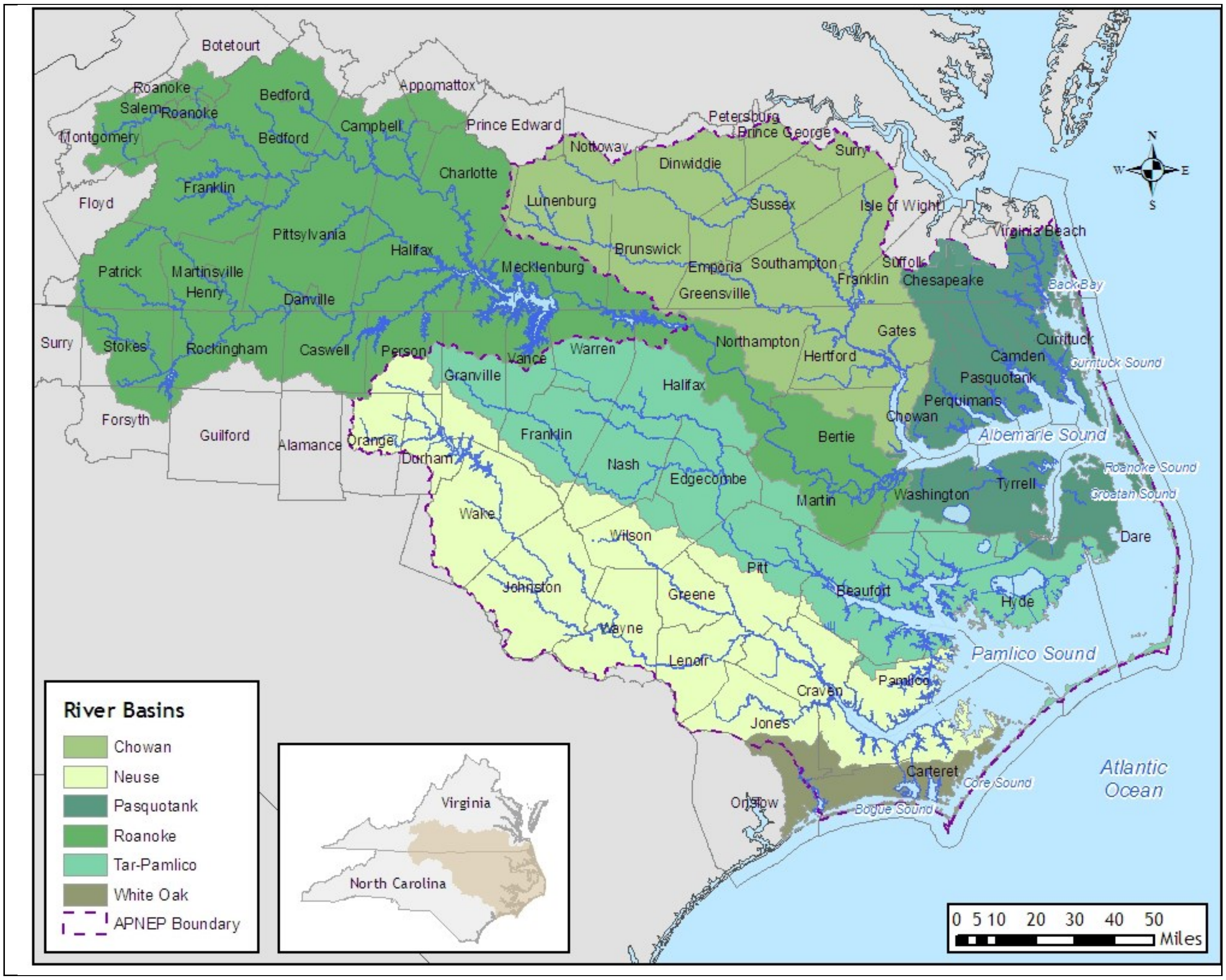
- Water Column is an aquatic environment and its physical, chemical, biological characteristics, and connectivity to other habitats will determine which species use it.

4.2.14.2 Location of Habitat

The Albemarle-Pamlico estuary system is comprised of eight sounds, including Back, Bogue, Core, Croatan, Currituck, and Roanoke sounds, and is located along the Atlantic coast of North Carolina and southern Virginia. The Albemarle Sound is located at the confluence of several freshwater rivers, with the largest being the Chowan and Roanoke rivers. The sound is separated from ocean saltwaters by the northern Outer Banks barrier islands and freshwater drainages help maintain the fresh to brackish waters in the sound. The Pamlico Sound is located between the mainland and Outer Banks barrier islands and hydrologically connects the freshwaters of the Neuse and Tar-Pamlico river basins to the Atlantic Ocean. To the north end it is linked with Albemarle Sound and joins the Oregon Inlet. The south end connects to Core Sound. Figure 4.2.14-1 shows the location of the Albemarle-Pamlico estuary system.

The Cape Fear and Lumber River estuaries comprise the two most southern estuarine areas in North Carolina. The Cape Fear River watershed, the largest in the state, encompasses many large metropolitan areas and drains into the ocean near the town of Southport. The estuary includes the tidally influenced portion of the lower river as well as a number of small sound and bay areas in New Hanover and Brunswick counties. Estuarine areas associated with the Lumber River occur in lower Brunswick County as well as in South Carolina, where the river joins the Pee Dee to eventually enter the ocean at Winyah Bay.

Figure 4.2.14-1. Location of the Albemarle-Pamlico National Estuary System. (source: Comprehensive Conservation and Management Plan 2012-2022, APNEP).



4.2.14.3 Problems Affecting Habitats

The CHPP compiles the latest scientific information on all habitats within the river basins that drain into coastal North Carolina and provides information on management needs that protect, enhance, and restore associated fish populations (Deaton et al. 2010). This section provides highlights representing a small portion of the information provided in the CHPP; please refer to the CHPP for complete information.

Land Use. Land-use patterns along the coast will continue to change with population growth and increases in property values. Development of coastal land is expected to continue, especially in Pamlico, Chowan, Bertie, Washington, Brunswick, and Carteret counties, which are being marketed as the "Inner Banks." Land conversion for development and shoreline alterations are a major cause of wetland loss in estuarine systems (Deaton et al. 2010).

Historically, the major causes of wetland loss and degradation have been conversion to agriculture, silviculture, and upland development (including road construction). Ditching and draining for agriculture is currently maintained by drainage districts to accommodate existing agriculture and forestry operations. Residential and commercial development continues to create wetland impacts, with approximately 1,700 acres of permitted impacts occurring between 2001 and 2008 (Deaton et al. 2010). In North Carolina, proposed and completed bridge projects cause loss and degradation of SAV habitat, wetlands, and adjacent uplands. However, a lack of updated wetland and shoreline maps makes tracking the changes to this resource difficult.

Dredging. Dredging for creation or maintenance of navigational channels and inlets will result in degradation or elimination of SAV habitat. The change in bottom depth, bottom sediment characteristics, and water clarity that accompanies dredged channels prevents or discourages future growth or establishment of SAV. Dredged channels connecting marinas and small docking facilities (including boat ramps) to major navigation channels are another source of SAV habitat loss and degradation. Vertical shoreline stabilization and docking facilities associated with marinas may also impact SAV (Stevenson and Confer 1978; Funderburk et al. 1991; Deaton et al. 2010).

Energy Development. Although wind farms are generally considered a source of green energy, the construction of towers and infrastructure can impact immediate and adjacent marine or estuarine habitats (Byrne Ó Cléirigh et al. 2000; Deaton et al. 2010). Legislative requirements in North Carolina call for utilities to develop renewable and alternative energy resources and will increase the likelihood that offshore wind turbines or oil drilling remain a threat to coastal habitats. There is an increasing interest in the development of wind farms in Albemarle and Pamlico sounds, as well as off the coast of Cape Hatteras and Cape Lookout, as these areas have some of the most abundant wind resources in the state (Deaton et al. 2010; Kalo and Schiavinato 2009). Offshore mining would disturb the ocean bottom and drill operations would introduce oil and chemical contaminants to the water column. Wind turbines pose a risk of strikes to seabirds and waterfowl.

Water Quality. Sources of water quality degradation cover a wide range of structures (houses, businesses, impervious surfaces), facilities (marinas, boat ramps), and conditions (temperature, runoff). Marinas are located immediately adjacent to shorelines where upland pollutants coming from boats, parking lots and hull maintenance areas can often flow directly into coastal waters (Deaton et al. 2010). Water quality impacts can be caused by nutrient enrichment, turbidity, toxic chemicals, desalinization, marine debris, microbial contamination, DO deficiencies, and high concentrations of toxic metals in the water column and bottom (McAllister et al. 1996; Deaton et al. 2010).

Of all the sources of sediment loading, sedimentation from agriculture has been cited as one of the largest contributors to water pollution in the southeastern states (SAFMC 1998; Deaton et al. 2010). Other upland sources of runoff and contaminants also contribute to water quality degradation in estuarine aquatic communities. For instance, development and associated runoff and sewage inputs in the upper end of a watershed and confined animal operations (primarily swine, poultry) and associated nutrient and microbial contamination in the lower end of a watershed contribute significantly to poor water quality (Deaton et al. 2010).

Algal blooms tend to occur when nutrient loads are not flushed because water flow is slow, water depths are low, and where mixing of the water column is reduced due to salinity and/or temperature gradients. Blue-green algae are usually associated with blooms in freshwater areas and they have lower nutritional value to aquatic life than other types of algae. Dinoflagellates and other flagellated algae are usually responsible for algal blooms in estuarine and marine waters (Smayda 1989; NC Sea Grant 1997; Mallin et al. 2000b; Deaton et al. 2010). Some dinoflagellate species release toxic chemicals into the water column that harm fish and shellfish by affecting their nervous systems and paralyzing their respiratory systems (Tyler 1989; Deaton et al. 2010).

Invasive Species. Foreign organisms in the discharge of ships' ballast water at or near ports have resulted in the introduction and spread of nonnative invertebrate animals, algae, bacteria, and dinoflagellates (Deaton et al. 2010). Removal of dams and other passage barriers (locks) create a pathway for nonnative species to move between freshwaters and brackish water environments, including movement upstream from brackish estuarine waters into river drainages as a saltwater wedge expands into freshwaters.

The water mold *Aphanomyces invadans* is an invasive fungal pathogen that infects schooling fish species in low-salinity or fresh water and is suspected to have been introduced to the United States through another infected invasive species, the Northern Snakehead Fish (Blazer et al. 2002; Deaton et al. 2010).

The Australian Spotted Jellyfish can consume large quantities of plankton, eggs, and larvae in the water column and has been found in Bogue Sound and at Sunset Beach. The invasion of the Indo-Pacific lionfish in marine waters off North Carolina will likely impact estuarine aquatic communities through direct predation, competition, and overcrowding (Deaton et al. 2010).

There are also a number of noxious weeds that can be found in fresh and moderately brackish waters of slow moving streams or waters protected from strong tidal currents and wave action. These include Eurasian Watermilfoil, Alligator Weed, and the Common Reed (see Appendix E for scientific names). The most troublesome species in low salinity, estuarine waters is Eurasian Watermilfoil (Deaton et al. 2010).

Climate Change. Climate change will influence water quality, salinity, water depth, and temperature, which will in turn alter fish distribution and abundance (Deaton et al. 2010). There are expected increases in temperature and sea level for the immediate future based on a history of measurement data (Bin et al. 2007; Bin 2008; UNCW 2008; Deaton et al. 2010). Long-term changes in temperature and salinity suggest expansion of some species at the expense of others. There is also a predicted increase in storm events and other extreme weather conditions (i.e., drought) (Deaton et al. 2010).

If sea level rises too quickly, natural coastal wetland accretion processes may not keep pace. Increasing frequencies and severity of coastal storms and storm surge will contribute to inlet breaches along barrier islands and lead to significant increases in salinities in Pamlico Sounds and its tributaries. There could also be a loss of barrier islands and wetlands as coastal areas are submerged by rising water elevation. Marsh islands provide shelter that protects SAV beds from wind and wave action during the growing season (Deaton et al. 2010).

Warming trends pose a threat to Eelgrass because it is growing near its southern limits; however, studies suggest the decline in Eelgrass is offset by increases in shoal grass beds (Deaton et al. 2010). When water temperatures are above 25°C–30°C (77°F–86°F), Eelgrass does poorly. Eelgrass thrives only where water temperatures are lower (i.e., deeper areas and tidal flats with continuous water flow) (SAFMC 1998; Deaton et al. 2010).

4.2.14.4 Climate Change Compared to Other Threats

Current research suggests that climate change and associated sealevel rise will be a significant stressor in the region for the near future (APNEP 2012). Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. While climate change is a threat to estuarine aquatic communities, it is likely that a combination of synergistic effects with other ongoing threats will be the source of stress to this system to the point where several species are unable to persist. Table 4.2.14-1 provides a review of expected climate change impacts in order of importance in comparison with other types of threats.

Table 4.2.14-1. Comparison of climate change with other threats to estuarine aquatic communities.

Threat	Rank Order	Comments
Bottom Trawl Fishing Gear	1	The weight and movement of bottom trawl fishing gear disturbs bottom sediments, displaces SAVs, and damages shell and hard bottom habitats. Mobile species may temporarily disperse but cumulative

Table 4.2.14-1. Comparison of climate change with other threats to estuarine aquatic communities.

Threat	Rank Order	Comments
		impacts from repeated use of bottom trawl gear in the same areas can lead to long-term habitat loss.
Dredging	1	Dredging disturbs and damages soft, shell, and hard bottoms, SAV beds, and suspends sediments that cause turbidity within the water column. Localized impacts may allow dispersal of mobile species but long-term damage can occur to bottom habitats.
Pollution	1	Pollution includes chemicals and toxins from point source discharges (e.g., industrial effluents and smoke stacks, stormwater discharges, wastewater treatment facilities) and nonpoint sources (e.g., roads, surface water runoff, marinas, boatyards). Aging infrastructure and rising sealevels are two challenges that must be addressed to reduce bacteria, viruses, and other microorganisms from entering public waters through identified sources (APNEP 2012).
SAV Loss	1	Loss of SAV beds or meadows reduces connectivity between spawning areas, primary nursery areas, and water column habitats for larval, juvenile, and adult aquatic species (DiBacco et al. 2006).
Shoreline Hardening	2	Hardened shorelines will prevent natural migration of marsh habitats toward inland areas as inundation occurs from rising sea levels. Use of natural and living shorelines should be encouraged and regulatory impediments removed.
Baseflow Reductions	2	Low flow conditions can occur due to drought, hydraulic drawdown, and upstream impoundment. Reductions in freshwater inputs from rivers and tributaries will allow influence salinities. Saltwater intrusion and concentrations upstream are likely to increase. Occurrence of temperature stratification and anoxic conditions are likely to increase.
Offshore Development	3	Mineral mining, gas and oil exploration, and wind energy turbines will damage bottoms, introduce contaminants into the water column, and displace species assemblages through loss of habitat.
Climate Change	3	Climate change impacts will be cumulative and to some degree mitigation options are limited. Mobile species can be expected to disperse to more favorable conditions.
Invasive Species	4	Warmer water can allow range expansion of nonnative species into open waters previously not colonized.
Infrastructure	5	Dams block the passage of diadromous fish species and limit access to upstream spawning habitat for anadromous fish species.

4.2.14.5 Impacts to Wildlife

Appendix 3 includes a list of SGCN and species for which there are knowledge gap and management concern priorities. Appendix 3-18 identifies non-marine SGCN and federally listed protected marine species that use estuarine aquatic communities.

Seagrass habitats are one of the most productive systems in the world, providing not only cover and forage resources for numerous organisms but also as an important carbon dioxide sink relative to other terrestrial and aquatic habitats (Deaton et al. 2010). In North Carolina, annual Eelgrass beds are common in shallow, protected estuarine waters in the winter and spring when water temperatures are cooler.

The South Atlantic Fishery Management Council reports 40 species of fish and invertebrates have been captured on seagrass beds in North Carolina. Larval and juvenile fish and shellfish such as Gray Trout, Red Drum, Spotted Seatrout, Summer and Southern Flounder, Blue Crabs, Hard Shell Clams, and Bay Scallops utilize the SAV beds as nursery areas. SAV meadows are also frequented by adult Spot, Spotted Seatrout, Bluefish, Menhaden, Summer and Southern Flounder, Pink and Brown Shrimp, Hard Shell Clams, and Blue Crabs. Offshore reef fishes include Black Sea Bass, Gag, various snapper species, and Spottail Pinfish. They are the sole nursery grounds for Bay Scallops in North Carolina (SAFMC 1998). Negative interactions between commercial fishery operations and wildlife often include Diamondback Terrapins, endangered sea turtles, Red-throated Loons, and other diving birds getting caught and drowning in crab pots, fishing gear, and gill nets. Recreational boaters may accidentally strike turtles, Manatees, and birds that use estuarine waters.

Meteorological processes influence coastal and estuarine circulation, which influences larval transport in the estuarine system and colonization of nursery locations for flounder species. For flounder, a combination of winds determine the overall supply of larvae to the system and some combination of wind and river discharge determines migration and settlement into specific nursery locations (Taylor et al. 2010).

Concentrations of prey organisms (worms, algae, crustaceans, mollusks, other invertebrates) associated with soft, shell, and ocean bottoms provide forage for numerous species of fish, shrimp, and crabs (NCDMF 2010, 2015). Ospreys, egrets, herons, gulls, and terns feed on fauna in SAV beds, while swans, geese, and ducks feed directly on the grass itself. Green sea turtles utilize Seagrass beds and juveniles may feed directly on the Seagrasses (SAFMC 1998). Increased salinity will affect species assemblages and influence food-web dynamics by reducing available habitat for species adapted to a specific range in water chemistries.

Warming trends can impact corals and SAVs (CSCOR 2012) and disrupt normal processes such as timing of phytoplankton blooms and larval development (NFWPCAS 2012), thus affecting food chain dynamics. Larval dispersal will be affected by changes in water circulation patterns, flooding, and intense storm events (DiBacco et al. 2006; Cowen and Sponaugle 2009; Tisseuil et al. 2012), which will influence geographic distribution of marine species (Block et al. 2011; Haase et al. 2012).

4.2.14.6 Recommendations

SAV beds and water column habitats act as nursery areas for most planktivorous larvae and juvenile pelagic species (e.g., Bluefish, River Herring, Menhaden, Spanish Mackerel) (NCDMF 2010). In addition to fully aquatic species, these habitats are also important foraging areas for sea turtles and migratory and resident pelagic seabirds and waterfowl associated with open water areas. Section 4.2.2 provides recommendations appropriate for all aquatic communities, statewide. Actions specific to the river basins that contribute waters to estuarine aquatic communities are provided in Section 4.5.

Surveys

Distributional and status surveys are needed for aquatic snails, crayfish, mussels, and fish (in order of general need).

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Facilitate the mapping of significant ecological, bathymetric, geologic, demographic, and cultural features (APNEP 2012).
• Conduct surveys of fish populations, including collecting fish samples for toxicological and water quality studies, to evaluate the efficacy of management practices, detect changes in fish communities, and to identify trends which may be occurring within the fishery resources.

Monitoring

Monitoring of aquatic taxa is critical to assessing species and ecosystem health and gauging the resilience of organisms to a changing climate. These monitoring efforts will inform future decisions on how to manage aquatic species. Long-term monitoring is needed to identify population trends and to assess performance of conservation actions. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Develop and maintain an integrated monitoring network to collect information for assessment of ecosystem outcomes and management actions associated with the implementation of management actions (APNEP 2012).

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Facilitate the development of protocols and conduct rapid assessments to determine presence and potential threat of invasive species (APNEP 2012).
• Develop sensors for biological and chemical sensing to determine status and trends, as well as tagging and tracking of wildlife (NIEPS 2010).
• Coordinate and enhance water quality, physical habitat, and fisheries resource monitoring (including data management) from headwaters to the nearshore ocean.

Research

Most species and their interrelationship associated with this habitat are poorly understood. Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Research must also be conducted to determine vulnerability of priority species to specific threats and studies should provide recommendations for mitigation and restoration. Aquatic species propagation is an area of current and ongoing research. Developing techniques for propagation of aquatic species is critical for preserving those species and their genetic stock, particularly those that are rare, at high risk of extinction or extirpation, and difficult to propagate in a laboratory setting.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Support research on adapting to impacts associated with climate change and sea level rise (APNEP 2012).
• Facilitate risk assessments of targeted personal care and pharmaceutical products in the aquatic system (APNEP 2012).
• Facilitate risk assessments of heavy metals and other toxic contaminants in sediments (APNEP 2012).

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Assess the impact on fisheries productivity from changes in estuarine habitats due to climate change (NIEPS 2010).

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Planning and locating wastewater treatment facilities to areas above sea level will minimize or eliminate risks (APNEP 2012).
- Restore areas capable of supporting SAVs. This will require study of effective restoration techniques, bathymetric mapping, water quality monitoring, and other efforts (APNEP 2012).
- Develop and refine ecological flow requirements for each major river (APNEP 2012) that drains to estuarine waters.
- Reduce potential water pollution by protecting critical buffer areas of upstream drainages, sound planning, adopting low impact development (LID) criteria, and other best practices.
- Establish contaminant management strategies for waters not meeting water quality standards. Strategies that address pathogens, toxics, and nutrients are needed, not just the traditional total maximum daily load (TMDL) plans which primarily manage industrial point sources and municipal stormwater (APNEP 2012).
- Where practical, restore marsh habitat by filling drainage ditches and install tide gates in agricultural fields so that sea water does not flow inland through them (DeWan et al. 2010).
- Consider closing fisheries for declining species during the spawning season.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the greatest extent possible to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Facilitate the development of state and local policies that support the use of LID practices to reduce runoff (APNEP 2012).
• Facilitate the use of BMPs on agricultural and silvicultural lands (APNEP 2012). Runoff can carry sediments, nitrogen, phosphorus, pesticides, and other substances into the sounds.
• Facilitate protection of designated anadromous fish spawning areas and inland primary nursery areas from marina impacts (APNEP 2012).
• Establish marsh habitats in cleared areas that are likely to become wetlands in the future due to inundation or frequent flooding.
• Protect conservation corridors that run from shorelines inland to facilitate habitat migration (DeWan et al. 2010).
• Establish oyster reefs and SAV beds offshore to help buffer shorelines (DeWan et al. 2010; Pearsall and Poulter 2005).
• Consider establishing marine reserves to provide refuge from fishing pressure, facilitate adult migration patterns and larval dispersal pathways, and support fisheries restoration efforts (DiBacco et al. 2006).

4.3 Wetland Natural Communities

4.3.1 Introduction

Wetlands perform many ecosystem services, including flood protection and pollution control, and they provide essential breeding, rearing, and foraging sites for numerous fish and wildlife species. Wetlands are defined by hydrology (wetness), plant community composition, and soil characteristics (FGDC 2013; Cowardin et al. 1979). From a landscape perspective, they function as transitional lands between terrestrial and aquatic systems where the water table is at or near the land surface or where the land is covered by shallow water (FGDC 2013; Cowardin et al. 1979).

Wetlands are regulated under the Clean Water Act, Sections 404 and 401, and the USACE has regulatory authority over impacts to sites that have been delineated as jurisdictional resources (USACE 1987). Wetlands that fall under regulatory authority have one or more of three attributes: they support predominantly hydrophytic vegetation at least periodically; the substrate is predominantly undrained hydric soil; or the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season each year (FGDC 2013). Hydrophytic vegetation are plants that grow in water or on a substrate (e.g., soil) that is at least periodically deficient in oxygen as a result of excessive water content (Cowardin et al. 1979). Hydric soils are wet long enough to periodically produce anaerobic conditions, thereby influencing the growth and type of plants that occur (Cowardin et al. 1979).

There are several methods for characterizing wetlands that are based on dominant vegetation communities, dominant soil characteristics, or dominant hydrologic factors. One method defines them based on the relationship between hydrology, geomorphology, and function (Brinson 1993). The approach places emphasis on the importance of abiotic features such as the chemical characteristics of water, habitat maintenance, and water storage and transport. In this document wetland communities are defined based on descriptions by Schafale and Weakley (1990) and Schafale (2012), which use dominant vegetation characteristics and hydrology as a basis for their descriptions.

Wetland community descriptions are provided in alphabetical order in Sections 4.3.1 through 4.3.11. Floodplain communities have been included in this section as a wetland community type; however, depending on the location of some floodplains the landscape may also be interspersed with upland communities.

4.3.2 Bogs and Fens

4.3.2.1 Ecosystem Description

Mountain and Piedmont bogs are among the rarest natural communities in the Southern Appalachians and in North Carolina. Unlike northern bogs of glacial origin, Southern Appalachian bogs form in poorly drained depressions or on gentle slopes, generally in relatively flat valley bottoms which are not subject to flooding. They may vary from being permanently wet to intermittently dry and are generally fed by seepage. They are underlain by wet organic or mucky mineral soils, which are very acidic.

The factors responsible for creating and maintaining bog communities are not well known. Grazing has been nearly universal in bogs, and few examples exist in pristine condition. Most are experiencing invasion of shrubs or trees at the expense of the herbaceous zones. This tendency toward rapid succession suggests that some form of periodic or chronic natural disturbance, now disrupted, may have kept the bogs open. Potential past disturbances include flooding by Beavers, grazing by herds of large mammals, fires, and clearing by Native Americans.

Classification of the Natural Communities of North Carolina, 4th Approximation (Schafale 2024) notes there are several subtypes for this community.

- Swamp Forest-Bog Complex (Typic, Spruce subtypes)
- Southern Appalachian Bog (Typic, Low Elevation, Long Hope Valley, Skunk Cabbage subtypes)
- French Broad Valley Bog
- Low Mounain Seepage Bog
- Southern Appalachian Fen (Bluff Mountain, Glades subtypes)

The Southern Appalachian bog and Southern Appalachian fen subtypes have a mosaic or zoned pattern of shrub thickets and herb-dominated areas, mostly underlain by sphagnum mats. Trees may be scattered throughout or may dominate on the edges. The shrub and herb layers of the bog, while not highly diverse, are uniquely adapted to the acidic, nutrient-poor environment of the bog and may include numerous rare species. Fens occur on high pH (basic) soils but otherwise have the same vegetative zones as bogs. Southern Appalachian fen subtypes are known in North Carolina only at Bluff Mountain and The Glades (in Ashe County).

Swamp forest-bog complex types occur along streams and are dominated by trees but may have boggy herbs and sphagnum moss in canopy openings.They generally occur at elevations above 3,500 feet.

4.3.2.2 Location of Habitat

Mountain bogs (including fens and 'wet meadow' bogs) are distributed throughout the Mountains and upper Piedmont of North Carolina, with examples as far east as Forsyth and Gaston Counties. Most of the known occurrences of Southern Appalachian bogs and fens are situated above the Blue Ridge escarpment, in the northwestern (Ashe and Alleghany) and southern (Henderson, Transylvania) counties. On the other hand, 'wet meadow' bogs can be found in the western half of the Piedmont and throughout the Mountain counties. Over 60% of the wetlands identified in the Southern Appalachian Assessment (SAMAB 1996) occurred on privately owned lands and it is likely that overall, the percent of mountain bog habitat in private ownership is even greater.

4.3.2.3 Problems Affecting Habitats

Chapter 5 Threats provides more information about 11 categories of threats most likely to impact North Carolina's wildlife and natural communities. The list of threats are based on definitions and classifications published by Salafsky et al. (2008, 2024). The following information focuses on current and anticipated threats for this habitat.

Invasive Species. Invasive species are already a problem in some areas and may increase with drought and warmer temperatures. Some bogs are subject to invasion by exotic plants such as Japanese Stiltgrass, Multiflora Rose, and Asian Dayflower. Many of these communities contain pines, hemlocks, or spruces, which are susceptible to insect pests.

Climate Impacts. Besides stream flooding, overland runoff from adjacent uplands during severe storms would be a problem in many bogs. The nutrient input and potential scouring of severe floods would be detrimental to bog communities. Droughts would have significant effects on competitive relationships among species and on the community as a whole. Many bogs may reduce in size if margins dry out due to drought. Some estimates indicate that fewer than 500 acres of mountain bogs in North Carolina remain (USFWS 2002).

Drought and warm temperatures may allow generalists and upland species to invade. Many of the rare species associated with mountain bogs and fens are herbs and are vulnerable to competition from woody species and more aggressive habitat generalists. If changes in hydrology make these sites drier, this problem is likely to be exacerbated.

Fragmentation. The most common types of fragmentation occur when streams are impounded to form lakes, highways are built across inhabited wetlands, and wetland habitat units are drained for agricultural use or development. Roads that bisect Bog Turtle wetlands are the single most detrimental threat to turtle populations. Highway mortality is high in areas where turtles must cross roads to get from one wetland to another (Somers et al. 2000).

Successional Conversion. Bog communities can undergo ecological succession, from open canopy fens and bogs to closed canopy swamps (where hydrologic conditions do not change), leading to the loss of habitat suitable for Bog Turtles and other species dependent on these types of wetlands (Klemens 1993; Herman and Tryon 1997; Rosenbaum et al. 2007).

Beavers represent an additional unknown factor in mountain bogs and fens. Many sites, including a number of protected sites, have been affected by beaver ponds in recent years. Beaver impoundments may kill bog plants, including rare species. However, some characteristic species, such as bog turtles, may benefit from them in the long run (NCNHP 2024).

4.3.2.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. While climate change is not the most severe threat, a combination of synergistic effects with other existing conditions could stress these systems to the point where several species are unable to persist.

Climate change effects such as droughts and severe flooding may be particularly problematic in these communities. Climate change, however, is not likely to be as detrimental compared to impacts caused by a number of immediate threats that can cause more drastic destruction than climate change is likely to. The largest scale problem affecting mountain bogs and wetlands in general has been and continues to be the conversion of these habitats to other land uses. Table 4.3.2-1 summarizes the comparison of climate change with other existing threats.

Table 4.3.2-1. Comparison of climate change with other threats to mountain bogs and fens

Threat	Rank Order	Comments
Development	1	Significant amounts of mountain bog habitat have been destroyed by development (roads, housing, or other development). Ongoing residential and commercial development and conversion to pasture or agriculture continues to destroy or degrade examples, through direct and indirect effects. Conservation of riparian buffers will benefit these communities as well as aquatic communities of the streams.
Invasive Species	2	Droughts in the present climate appear to have exacerbated the ongoing invasion of upland and generalist wetland plants in some bogs. Protected examples are subject to ecological problems such as invasion by woody plants or by exotic species.
Groundwater Depletion	2	Caused by hydrological alteration that includes loss of ground water input or entrenchment/channelization of streams that lowers water tables. Drainage, water diversion, and ground water depletion make

Table 4.3.2-1. Comparison of climate change with other threats to mountain bogs and fens

Threat	Rank Order	Comments
		these wetlands more vulnerable to drought and increased temperatures than they would otherwise be.
Flood Regime Alteration	3	Many bogs are located in bottomland locations that do not regularly flood but which would flood in extreme events. Damaging floods, scouring, and nutrient/sediment input are threats to mountain bogs and fens.
Impoundments	4	Beaver control measures should be considered at sites where potential loss of rare species may occur due to the creation of impoundments or use of certain rare plants as food by the Beavers. These measures include use of pond levelers, protective screening of rare plants, or as a last resort, removal of the Beavers. Where extirpation of rare species is not expected, however, development of Beaver pond complexes should be allowed, particularly where it may lead to restoration of higher water tables or clearings that favor the regeneration of wetland herbs and shrubs
Climate Change	5	The level of threat posed by climate change is unclear, while the other threats are ongoing and result in more drastic effects. Drought is likely to exacerbate ongoing problems and warmer temperatures may as well.
Conversion to agriculture/ silviculture	6	Many bog sites were historically converted to pastures and farms, primarily through draining, filling, or impoundment.

Mountain bogs and fens face a number of immediate threats that can cause more drastic destruction than climate change is likely to. Climate change exacerbates many of the ongoing problems. Many examples are not protected, and ongoing residential and commercial development and conversion to pasture or agriculture continues to destroy or degrade examples, through direct and indirect effects. While less frequent, some have been destroyed by artificial ponds (NCNHP 2024).

4.3.2.5 Impacts to Wildlife

Appendix 3 provides a list of SGCN and other priority species for which there are knowledge gaps and management concerns. Appendices 3-17 (wildlife) and 3-19 (plants) identifies SGCN that depend on or are associated with this habitat type.

Some of the wildlife species associated with mountain bogs require open, herbaceous habitat (e.g., Bog Turtles, Golden-winged Warblers, Meadow Voles, Meadow Jumping Mice, Bog

Lemmings) while others prefer closed canopy wetlands (salamanders). In fact, for the Bog Turtle and the Southern Bog Lemming, bogs are the primary or sole habitat type in the state.

The priority amphibians associated with mountain bogs are all salamanders, though there certainly are a much larger number of amphibians found in mountain bogs. These salamanders (Mole, Four-toed, Marbled, Three-lined, and Spotted Salamanders) for the most part require pools of water, preferably without fish, for breeding purposes. They are associated with mountain bogs, to the extent that mountain bogs (as defined here) often contain pools of water that are utilized as breeding habitat. Their association with mountain bogs is less related to the bog being spring fed, muddy, or with specific plant associations than many of the other priority mountain bog species. These species are more suited to treatment of their threats/problems within the depression community’s habitat type and surrounding upland and intact forest corridor habitat. Loss of wetland habitat in general is a significant problem for these species.

Beavers represent an additional unknown factor in mountain bogs and fens. Beaver impoundments may kill bog plants and flood habitats used by wildlife, including rare species. Situations such as Beaver control and fire suppression by humans may not have occurred at all mountain bog sites, but their indirect impact upon mountain bog habitats through facilitation of secondary succession certainly has occurred at some sites. However, some characteristic species, such as Bog Turtles, may have benefited from Beaver activity in the long run.

4.3.2.6 Recommendations

Bogs and fens occur as small, widely separated patches in certain landscapes and will not be able to migrate in response to climate change. They occur in specialized hydrological environments that are not driven primarily by climate. Much of their biota ranges far to the north and little, if at all, to the south. Because the composition and suite of rare species associated with each site varies dramatically, it is important to protect many examples, and to manage appropriately.

Protecting the remaining unprotected examples and conducting appropriate management in the protected examples are the most important actions for these communities. This includes determining the best vegetation management practices and understanding and correcting artificial alterations to hydrology.

Surveys

Priorities for conducting distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive communities (NCWRC 2005).

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• For many of the priority species associated with mountain bogs, we do not have a clear understanding of their current distribution within the state. Surveys need to gather baseline information on the distribution and status of most of these species.

Monitoring

Monitoring of taxa is critical to assessing species and ecosystem health and gauging the resilience of organisms to a changing climate. These monitoring efforts will inform future decisions on how to manage species. Long-term monitoring is needed to identify population trends and to assess performance of conservation actions. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Given the limited availability and number of threats facing mountain bog habitat, considerable effort needs to be expended to determine if populations are increasing, decreasing, or remaining stable.
• Monitor amphibian populations to detect incidence of fungal and viral infections (e.g., iridoviruses, chytridiomycosis).
• Monitor connectivity of populations separated by fragmentation.
• If Beaver activity is detected in nearby streams, monitor to detect problems from flooding or inundation.

Research

Most species and their interrelationship associated with this habitat are poorly understood. Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Research must also be conducted to determine vulnerability of priority species to specific threats and studies should provide recommendations for mitigation and restoration. Species propagation is an area of current and ongoing research. Developing techniques for propagation may become critical for preserving species and their genetic stock, particularly those that are rare, at high risk of extinction or extirpation, and difficult to propagate in a laboratory setting.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Genetic studies to determine degree of gene flow between populations and to assess overall population health for species restricted to this habitat given the isolated nature of mountain bogs.

  Bog Turtle

- Study amphibian movements to and from breeding habitats and examine upland habitat use.

  Ambystomatid salamanders | Junaluska Salamander | Mountain Chorus Frog

- Investigate minimum hydroperiods needed by priority amphibian species that utilize ephemeral pools and wetlands. Results can be used to determine when supplemental or interventive measures are needed to support breeding periods and metamorphosis during drought periods.

- Establish a captive breeding program for Bog Turtles and work with land conservation partners to identify sites for population augmentation.

  Bog Turtle

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Specific bog management needs to include the control of woody encroachment and succession, the maintenance (and where necessary, restoration) of natural surface water and groundwater hydrology (using ditch plugs, temporary dams, level spreaders, or other engineering devices), the restoration of herbaceous vegetation, and the prohibition of taking rare bog-related species.

  Bog Turtle

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Use clearing methods that create the least impacts; avoid use of chemicals. Where appropriate, use prescribed burning to control encroachment by hardwoods. If mowing, limit to once a year or less and set blade height between 1 and 2 feet to avoid destroying nesting bird and small mammal habitat. If using heavy equipment, disturb only one patch of the site at a time and minimize ruts and compaction of soils and vegetation to the extent possible (Somers et al. 2000).
• If livestock grazing is allowed limit number of animals to one per acre and allow light to moderate seasonal (winter only) grazing where possible (Somers et al. 2000).
• Provide native vegetation buffers around wetlands to filter pollutants and benefit wildlife (Somers et al. 2000).
• Limit application of fertilizers and lime to lawns and fields surrounding wetlands (Somers et al. 2000).

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the greatest extent possible to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Focus habitat protection measures on utilizing existing regulatory frameworks to protect both the habitat and these species (e.g., state and federal endangered species laws, wetland protection laws, etc.).
• Fully utilize government conservation programs and incentives (e.g., Farm Bill programs) and partnerships with private landowners to stem the conversion of suitable bogs to other uses.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Actively pursue conservation ownership through acquisition of mountain bogs in concert with state and federal agency partners (e.g., US Fish and Wildlife Service [USFWS], US Forest Service, National Parks Service, Natural Resources Conservation Service, NC Division of Parks and Recreation, NC Natural Heritage Program, local governments, etc.) as well as private conservation partners (e.g., The Nature Conservancy, land trusts).

4.3.3 Estuarine Wetland Communities

4.3.3.1 Ecosystem Description

Estuarine wetland communities are coastal landscapes affected by tidal waters in and along the sounds and drowned river mouths (see Section 4.2.14) and includes brackish marsh, salt marsh, salt flats, and salt shrub components. In addition to the components described here, sand flats, mud flats, and algal mats are part of the estuarine community. Estuarine wetland communities have high and low elevation zones.

Saltmarshes occur where tides regularly flood the area with undiluted sea water. This environment of repeated flooding and exposure and higher salinity levels limit the diversity of plant species that occur in salt marshes to only a few species. Much of the productivity in salt marshes is likely below ground in organic materials. Saltmarsh and Salt Meadow Cordgrasses dominate these communities, and only a few other vascular plants occur. Algae may also be an important part of plant productivity. The abundance of invertebrates such as mollusks and crustaceans indicate the transitional nature of these communities between terrestrial and marine systems.

Brackish marshes occur in areas where the tidal waters are partly diluted by fresh water. At low elevation zones they can be low in plant diversity, with Black Needlerush usually dominating vast areas. High elevation zones contain a significant component of Salt Meadow Cordgrass and Saltgrass.

Salt flats occur in fairly small areas of slight depression at the upper edge of salt or brackish marshes. Salty water floods these areas only occasionally. Once flooded, the water is trapped in the depression and evaporates, leaving salt concentrated in the soil. Vegetation is usually a sparse collection of extremely salt-tolerant plants such as Saltgrass and Glasswort. The center of the salt flat may be completely barren.

Salt shrub communities occur on the upper edge of salt and brackish marshes, where saltwater rarely reaches or where salt is diluted by freshwater seepage. They are dominated by salt-tolerant shrubs with marsh herbs often occurring in openings.

Estuarine islands are not considered a wetland community but they are particularly important for nesting terns, skimmers, pelicans, wading birds, and American Oystercatchers. Most have been created by deposition of dredged material but there are a few that are natural islands. Dredged material islands are usually devoid of mammalian predators and have the added advantage of being high enough in elevation that ground nesting birds do not lose their nests during normal high tides.

4.3.3.2 Location of Habitat

Lower river portions of aquatic communities in the Roanoke, Tar-Pamlico, Neuse, Cape Fear, White Oak, Chowan, and Pasquotank river basins are associated with estuarine wetland communities. The shorelines of the Albemarle-Pamlico estuary system and the sound-side of the Outer Banks barrier islands are also fringed by estuarine wetlands.

4.3.3.3 Problems Affecting Habitats

Chapter 5 Threats provides more information about 11 categories of threats most likely to impact North Carolina's wildlife and natural communities. The list of threats are based on definitions and classifications published by Salafsky et al. (2008, 2024). The following information focuses on current and anticipated threats for this habitat.

Dredging. Dredging and dredged material placement can affect these sites through draining of marshes or filling of wetlands. Dredged material placement has been used very effectively in some areas to create marsh or upland bird nesting areas within the estuaries. Competition with coastal towns that use dredged sand for nourishment projects along developed beachfronts and constraints to navigation channel dredging projects limits access to dredged material for bird nesting islands.

Land Use. Development has impacted much of this habitat type and armoring shorelines to prevent erosion is a growing problem. Predation by nonnative predators and disturbance by people and their pets on nesting birds and the lack of fire to maintain the vegetation structure in marsh sites is also of concern. Beach stabilization projects (e.g., inlet channel relocation and efforts to restrict channel movement) reduce availability of microhabitats such as mud and algal flats around inlets. Ditching can drain estuarine wetlands, disrupt normal hydrologic cycles, contribute to water quality problems by conducting point source discharges into nearby surface waters, and be a conduit for saltwater intrusion. Shoreline fortifications and other armoring structures (e.g., bulkheads, groins) have increased the incidence of erosion from waves and storm surge (NCCF 2024).

Water Quality. Water quality impacts from pesticide use (related to mosquito control), secondary impacts from development, and water flow impacts caused by ditching and canals have greatly affected this habitat. Failing septic systems, sewage treatment and marina cleanout effluents, stormwater runoff, industrial organic waste discharge, and agricultural fertilizers or animal wastes contribute excessive nutrients that can result in eutrophication and algal blooms. Mats of algae block sunlight from penetrating the water and will impact sea grasses. Low dissolved oxygen levels can result from algal die-off and decay and excessive algae growth can result in brown or red tides and harmful blooms, such as *Pfiesteria piscicida*, that have been associated with fish kills (USEPA 2012b). The presence of drainage ditches will facilitate saltwater intrusion into more inland freshwater natural communities and rapid decomposition of peat soils by sulfate-reducing bacteria (Hackney and Yelverton 1990).

Runoff. Coastal development is coupled with increases in impervious surfaces and infrastructure that contributes more stormwater that drains into estuarine systems (NCCF 2024). Stomwater carries pollutants such as sediment, nutrients from nitrogen and phosphorus, metals, pesticides, and hydrocarbons that contribute to eutrophication of salt marshes (NCCF 2024).

Climate Change. Climate change impacts, primarily sea level rise, will lead to shifts in plant composition and more open water habitats. An increase in the number of storm events and storm severity will result in more flooding and erosion of vegetation. Other problems will include subsidence and increased inundation of freshwater communities and release of previously sequestered carbon as carbon dioxide and methane (Hackney and Yelverton 1990). Coastal marshes in North Carolina are not gaining in elevation at a pace sufficient to keep up with sea level rise (Bost et al. 2024, North Carolina SET Community of Practice 2024). Further, eutrophication of salt marshes can increase above-ground biomass and decrease bank-stabilizing below-ground biomass, resulting in salt marsh collapse and conversion to unvegetated open water (NCCF 2024).

Saltwater intrusion has created "ghost" forests, acres of dead trees that were associated with freshwaters that have been infiltrated by higher salinity waters. Examples can be found on the Albemarle-Pamlico peninsula and the USFWS Alligator River National Wildlife Refuge (NCCF 2024).

4.3.3.4 Climate Change Compared to Other Threats

Climate change, particularly rising sea level and the potential erosion of barrier islands is the greatest threat to estuarine wetland communities. Table 4.3.3-1 summarizes the comparison of climate change with other existing threats.

Table 4.3.3-1. Comparison of climate change with other threats to estuarine wetland communities

Threat	Rank Order	Comments
Climate Change	1	Estuarine communities are extremely vulnerable to the effects of rising sea levels and the potential erosion and inundation of barrier islands. Loss of barrier islands would expose the mainland side of estuarine areas to open ocean, leading to changes in salinity, tides, and wave action that would likely cause major changes to the mainland coastline.
Development	2	Development near coastal communities has resulted in pollution and water quality declines that impact SAVs. Buildings along shoreline introduce night lighting and light pollution. Development on uplands will prevent inland migration of marshes. Increased movement of sediment and nutrients from inland areas by increasingly intense

Table 4.3.3-1. Comparison of climate change with other threats to estuarine wetland communities

Threat	Rank Order	Comments
		storms will worsen water quality problems in estuaries, though this effect may be less important than the effects of increased urban development in general. Encroachment on public lands and public trust waters creates impacts to hunting and fishing access.
Pollution	3	Water pollution from rivers and from nearby development has caused fish kills and shellfish closures in some estuaries.
Dredge and Fill Impacts	4	Dredging and dredge material placement can drain marshes or fill wetlands. Dredged material placement has been used very effectively in some areas to create marsh or upland bird nesting areas within the estuaries. However, there is limited funding for dredging projects and increased competition with coastal towns for sand placement for beach nourishment projects. Other beach stabilization projects (e.g. inlet channel relocation and efforts to restrict channel movement) reduce availability of microhabitats such as mud and algal flats around inlets.
Predation and Disturbance	4	Ground-nesting birds are impacted by human disturbance, pets (especially free roaming and feral cats), and wildlife predation by nonnative species.
Invasive Species	4	Nutria are considered a serious pest species in the United States because they eat a variety of wetland and agricultural plants and their burrowing damages streambanks, impoundments, and drainage systems. Herbivory and burrowing damage from Nutria impact estuarine communities. As plant roots are removed and substrates damaged from excavation, soil loss and land subsidence can occur from sea level rise, tidal flooding, and storm surge. *Phragmites* can colonize disturbed areas quickly and can dominate native species.
Alternative Energy Systems	5	Development of wind power turbines will impact birds and bats (major activity zones for both).

4.3.3.5 Impacts to Wildlife

Appendix 3 provides a list of SGCN and other priority species for which there are knowledge gaps and management concerns. Appendix 3-17 identifies SGCN that depend on or are associated with estuarine wetlands.

Many bird species associated with these community types have experienced significant declines according to inventory and survey data. Several priority bird species, such as the Seaside Sparrow, Black Rail, and Northern Harrier, are ground nesters in estuarine marsh habitats.

Most SGCN waterbirds rely on estuarine wetlands for nesting and the majority of their foraging. Coastal marsh habitat is not migrating inland at comparable rates to sea level rise and coastal marshes in North Carolina are already drowning and will continue to drown (Osland et al. 2024, Parkinson 2024). Waterbird species that are colonial nesters are vulnerable to loss of habitat because they have relatively few nesting locations. Beach-nesting birds, sea turtles, and terrapins are more likely to have their nests washed over as sea level rises.

Black Ducks also nest in brackish marshes. This species will lose nesting habitat as inundation drowns currently occupied marshes. Climate change will have a significant effect on brackish waterfowl impoundments, which provide high-quality habitats for breeding and wintering waterfowl and other shore- and long-legged wading birds. Many of these areas will be lost to sea level rise.

Losses, drastic alteration, or disturbance of estuarine communities (especially marsh habitats) could have serious consequences for nutrient cycling and for reproduction of marine and estuarine organisms (Schafale and Weakley 1990). Some reptile species, including sea turtles, terrapins, and American alligators, exhibit temperature-dependent sex determination. With predicted increases in overall temperatures associated with climate change, it is possible that offspring sex ratios of these species may be affected (Hawkes et al. 2009). It will be important to gather baseline information on sex ratios for species with temperature-dependent sex determination to characterize impacts from climate change.

Several rare, disjunct, or endemic species–Carolina Watersnake, Aaron’s Skipper, and several moths -- are associated with brackish marsh habitats in the sounds of the northern Coastal Plain. The drastic changes in salinity and wave action that are likely to occur if the Outer Banks are breached may drastically affect these species, possibly leading to their extirpation or extinction. If they survive the initial effects of the barrier island breach, however, they may be able to spread to new areas of brackish marsh that will form farther inland on the mainland side of the sounds.

Nutria are an introduced and invasive mammal in freshwater and coastal marshes and wetlands, inland freshwater streams and rivers, and surface water impoundments. As warming trends increase, the range of Nutria is likely to expand and populations currently limited by intolerance to cold winters will quickly expand. There is some anecdotal evidence that Nutria will take over and expand smaller next burrows of native wildlife such as Muskrats, thereby displacing native species. Nutria may also be a vector for diseases (tuberculosis and septicemia) or parasites (Giardia, Fasciola, Liver Flukes, and nematodes), with fecal contamination in water the likely pathway (Carr 2010).

4.3.3.6 Recommendations

Land acquisition will play a vital role in protection of the future shoreline. Because dramatic movement of these communities is probably inevitable as sea level rises, one of the most important things that can be done to help them adapt is to protect areas where they can migrate to. Protection of low-lying shoreline areas that would allow for inland migration is difficult but would provide important benefits.

Surveys

Priorities for conducting distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Identify and designate strategic habitat areas for marine and coastal fishery species (Cape Fear River Basin) (NCDEQ 2021).
• Update NC Division of Coastal Management’s NC Coastal Region Evaluation of Wetland Significance (NC CREWS) estuarine shoreline maps (NCDEQ 2021).
• Continue collecting, analyzing, comparing, and sharing baseline measurements for a variety of NC wetland types (NCDEQ 2021).

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Long-term monitoring is needed to identify population trends and to assess performance of conservation actions. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Monitor the effect of sea level rise on estuarine habitats, document changes in habitat characteristics, such as salinity; elevation; water levels; plant community composition, structure, and density; and monitor marsh die-back events.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Pursue a coordinated federal and state mapping effort to use existing information; identify and address gaps necessary to monitor salt marshes over time (Lee 2024).
• Determine status and trends in wetland acreage, condition, and functions (NCDEQ 2021).
• Continue participation in EPA's National Wetland Condition Assessment (NCDEQ 2021).

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Research must also be conducted to determine vulnerability of SGCN and other priority species to specific threats and studies should provide recommendations for mitigation and restoration.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Evaluate and prioritize restoration of coastal marshes and waterbird habitats to reduce sea level rise impacts to breeding habitats.
• Research on how to facilitate coastal marsh migration and the effects of prescribed fire in high marsh, to reduce the impact of rapid sea level rise on breeding habitat of marsh species (e.g., Black Rail).
• Study the response of priority bird species that depend on estuarine high marsh to prescribed fire.
• Study past and predicted changes in coastal bird habitats, especially relative to sea level rise and storm events, including natural barrier islands, marsh islands, and dredged-material islands. Use models to provide guidance for long-term habitat restoration and management for continued population viability.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Assess changes in the quantity and quality of coastal wetlands from sea level rise, wetland migration, and other impacts (NCDEQ 2021).
- Research successful shoreline stabilization alternatives, with an emphasis on living shorelines (NCDEQ 2021).

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Allow barrier islands to migrate, as it increases their chance of survival and reduces the chance of sudden and drastic changes in tidal regime in the estuaries.
- Where practical, restore marsh habitat by filling drainage ditches, install ditch plugs and water control structures. Ditches may accelerate erosion and the effects of rising sea level such as saltwater intrusion.
- For locations at risk of future shoreline hardening, protect suitable nesting habitat for sea turtles and beach-nesting birds to maintain robust populations as disturbance and sea level rise issues mount.
- Continue working with the US Army Corps of Engineers and others to direct dredged material or conduct other management actions to refurbish waterbird nesting islands.
- Continue implementation of Coastal Area Management Act (CAMA) regulations (NCDEQ 2021).

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Continue outreach and education to support use of living shorelines (NCDEQ 2021).
- Support and implement priorities for marsh conservation developed by collaborative partnerships such as the Currituck Sound Coalition's Marsh Conservation Plan (2021), North Carolina Salt Marsh Action Plan (NCCF 2024), NC Coastal Habitat Protection Plan (NCCHPP 2021), APNEP Comprehensive Conservation and Management Plan (APNEP 2022), and others.
- Protect tidal freshwater wetlands in rivers and upper sounds, some of which will become the extensive estuarine communities in the future. Salt and brackish marshes will benefit from this.
- Protect buffers and floodplain rivers, as this will benefit estuaries by reducing pollutant input and reducing drastic changes in freshwater input.
- Protect inland tidal freshwater wetlands, which will become extensive estuarine communities in the future, and allow the barrier islands to migrate and new inlets to form.
- Focus on land acquisition and protection for a number of heronries on the mainland side of Pamlico Sound where brackish marshes are in private ownership. Acquisition targets should include brackish marsh impoundments, which will then require continued management for maintenance.
- Protect habitats in large enough patches to sustain priority species, reconnect fragmented habitats, restore habitats that have been lost or converted, enhance the function and structure of habitats that have been degraded, and manage habitats for priority species (ACJV 2004).

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Work with partners (e.g., NC Coastal Federation, Audubon NC, TNC, Ducks Unlimited) to leverage funding programs that target conservation of coastal wetlands.

4.3.4 Floodplains - Blackwater Systems

4.3.4.1 Ecosystem Description

Floodplains are defined as "areas of low lying land that are subject to inundation by lateral overflow water from rivers or lakes with which they are associated" (Junk and Welcomme 1990; Tockner and Stanford 2002). Other terms frequently used to refer to floodplains include alluvial forests, bottomlands, fluvial systems, riverine forests, or stream or riparian zones. Floodplains can be comprised of more than one community type since the timing, depth, and duration of flooding are considered the primary influence on plant species composition (Wharton et al. 1982; Kellison et al. 1998; Mitsch and Gosselink 2000; Burke et al.2003). The floodplain community will also be influenced by variations in soils and microenvironments that occur in the landscape adjacent to the aquatic community. In its natural state, floodplains have high biodiversity and productivity as well as providing recreational and aesthetic values (Tockner and Stanford 2002).

Blackwater floodplains include the vegetated communities on the floodplains of blackwater rivers. Blackwater rivers are low-gradient rivers in small watersheds where hydroperiods are characterized by short duration floods that may be deep and widespread, followed by extensive periods of lower discharge (Burke et al. 2003). The flow often is not sustained, and extended droughts during the growing season can occur in these floodplains (Wharton et al. 1982; Burke et al. 2003).

Contrary to brownwater rivers, they carry little mineral sediments (e.g., clay and silt). Instead, the water chemistry in blackwater rivers is dominated by dissolved organic matter leached from decomposing vegetation and is generally low in pH and nutrients. The water is tea-colored but not cloudy. The soils of blackwater floodplains are usually sandy or mucky and are acidic and relatively infertile. Many floodplains, particularly the larger ones, have at least some development of depositional features such as natural levees, point bars, and ridge-and-swale systems, but these are not as large or prominent as on brownwater rivers. Many smaller blackwater floodplains are filled with muck and are flat and featureless.

Communities that occur in blackwater floodplains include: Coastal Plain levee forest and bottomland hardwoods on the larger floodplains, cypress-gum swamps in the wettest and forested parts of the floodplain, Coastal Plain small stream swamps, Coastal Plain semi-permanent impoundments (e.g., Beaver ponds, millponds), oxbow lakes along the large rivers in abandoned channel segments, and sand and mud bars along the rivers (Schafale and Weakley 1990).

4.3.4.2 Location of Habitat

Blackwater rivers originate in the Coastal Plain ecoregion and many are located in the lower portion of the river basins that drain to the Atlantic coast. Examples of blackwater streams and rivers include the South River, Black River, Waccamaw River, and the Northeast Cape Fear

River. The Lumber River mainstem is the only North Carolina blackwater river designated as a National Wild and Scenic River.

4.4.4.3 Problems Affecting Habitats

Chapter 5 Threats provides more information about 11 categories of threats most likely to impact North Carolina's wildlife and natural communities. The list of threats are based on definitions and classifications published by Salafsky et al. (2008, 2024). The following information focuses on current and anticipated threats for this habitat.

The floodplain forest systems of the Coastal Plain in the southeast are now only small fragments and sections of the original millions of acres present before European settlement that have been lost or altered by development, drainage, agriculture, and logging (Weller and Stegman 1977).

Climate Variability. Milder winters will result in potentially longer growing seasons and earlier bloom times for plants and earlier breeding periods for reptiles and amphibians. Most species in this habitat type have a southeastern distribution and are fairly well adapted to higher temperatures. Increased temperatures will likely result in decreased winter kills of nonnative species and will likely allow these species native to areas further south to survive and reproduce. Insect infestations may increase and negatively affect forest health. Drought conditions will allow invasion of upland species (e.g., Red Maples and beech). Some more southern species may migrate into these communities. Conversion of lower river areas to tidal marsh will allow the Common Reed to invade. Increased temperatures and decreased winter kills will allow southern species to move farther north (e.g., the Asian Dayflower, Japanese Climbing Fern, Chinese Tallow Tree).

Storms. Increased hurricane intensity will increase blow down, especially near the coast. Bottomland hardwoods are more likely to be affected by windthrow than other floodplain communities. Increased canopy gaps may result from increased storm wind damage and from flood scouring. Flooding could benefit canebrakes and their associated species, but both the magnitude and direction of the effects are uncertain. Species composition could change following storm damage, resulting in loss of mast-producing species. Increased severity of flooding may destabilize channels, alter sediment load and deposition, and increase erosion. Increased frequency may have beneficial effects but increased duration may kill species not adapted to long periods of inundation. More large floods might mean increased river areas with increased instability of bars. This would come at the expense of forests along the river banks, which are often the least altered forests in the floodplains. If flood frequency increases, it might also cause the boundaries between bottomland hardwoods and cypress-gum swamp to shift. Effects on species composition are unknown but changes to the overall community structure are likely, especially in lower reaches that may eventually convert to marsh.

Sea Level Rise. Saltwater intrusion associated with sea level rise is expected to have significant adverse effects on lower reaches of blackwater floodplains where it is likely to affect long-term survivability of canopy species. Saltwater intrusion will affect long-term survivability of canopy species in the lower floodplain reaches. Wetlands close to the Cape Fear River near Wilmington and the lower portion of the Scuppernong River near Columbia have already been impacted. No expansion of this community type is possible upstream and expansion into the Piedmont is not possible for this ecosystem. Consequently, the net effect from climate change will be an overall loss of acreage. Because there is not substantial potential for the floodplain systems to expand inland, there will be a net loss in area.

4.4.4.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. While climate change is not the most severe threat, a combination of synergistic effects with other existing conditions could stress these systems to the point where several species are unable to persist.

Changes in flood regimes and rising sea level are the most important climate effects. Most Coastal Plain wetland communities, including blackwater systems, may be moderately vulnerable to climate change, depending on importance of precipitation and riverine flooding for hydrologic inputs. Direct loss of wetlands due to sea level rise is expected to be the greatest threat in coastal landscapes (DeWan et al. 2010). However, these systems will remain common. Table 4.3.4-1 summarizes the comparison of climate change with other existing threats.

Table 4.3.4-1 Comparison of climate change with other threats to blackwater floodplains

Threat	Rank Order	Comments
Flood Regime Alteration	1	Effects of changed flooding regime are very uncertain. If floods become more extreme, channels may begin to migrate more. Levee communities, where present, are the forested floodplain community most likely to be affected by changes in flooding regime and channel stability. Increased canopy gaps may result from increased storm wind damage and from flood scouring.
Logging/Exploitation	1	Logging will remain a large source of altered canopy age and structure. This might benefit species that depend on canopy openings.
Pollution/siltation	2	In particular, nutrient loads have the potential to greatly increase with the construction of new poultry processing facilities in coastal counties. Untreated stormwater runoff from large cities and towns is a major problem that impacts both

Table 4.3.4-1 Comparison of climate change with other threats to blackwater floodplains

Threat	Rank Order	Comments
		aquatic life and terrestrial wildlife associated with floodplain forests. Increased frequency of intense rainfall and flood events will contribute to an increase in pollution and sedimentation.
Groundwater Depletion	2	Increased drought may lead to demand for more water withdrawal.
Invasive Species	2	Chinese Privet, Japanese Stiltgrass, Japanese Honeysuckle, and Asian Dayflower are already problems and are expected to increase with climate change. If not controlled, these species will greatly expand the acreage severely affected, regardless of climate. Canopy gaps could allow invasive species to become established, especially Japanese Stiltgrass.
Climate Change	3	The effects of rising sea level would be felt only in the lower reaches of the rivers. Large expanses in these areas would shift to tidal swamps. Saltwater intrusion could occur during floods or high storm surge.

4.3.4.5 Impacts to Wildlife

Appendix 3 provides a list of SGCN and other priority species for which there are knowledge gaps and management concerns. Appendix 3-17 identifies SGCN that depend on or are associated with this habitat type.

Loss of old growth characteristics (canopy gaps, vine tangles, hollow trees, dead and downed woody material) and fragmentation of stands is a major concern. A lack of standing dead or older trees has impacted the availability of quality bat and Chimney Swift roosting and breeding sites and nesting productivity for species such as Wood Duck and Hooded Merganser. Removing woody debris from streams after storms has influenced in-stream habitat structure and food webs. Lack of downed woody debris has impacted a variety of amphibians and reptiles.

Fragmentation of floodplain forest stands has contributed to the loss of intact large riparian corridors and the width of many riparian corridors has been greatly reduced. Breeding area-sensitive bottomland-hardwood birds have likely been impacted by the loss of intact woodland systems. Large patches of floodplain habitat are lacking in much of the Coastal Plain. High-grading logging practices have changed plant species diversity and stand vegetative structure. Logging has reduced colonial waterbird and Bald Eagle nesting areas.

Alteration of hydrology due to dam creation and the draining of wetlands are one of the primary problems affecting species in this habitat type. The impacts of development adjacent to rivers and streams includes potential problems associated with direct input of contaminants and sediment, alteration of hydrologic patterns and processes, temperature regimes, and loss of critical habitat adjacent to aquatic habitat that may be of equal importance to species that only spend a portion of their lives in the water, like some amphibians. Drainage of wetlands has exacerbated the problems in and adjacent to floodplain forest habitats. This habitat loss impacts all floodplain species, including furbearers, breeding amphibians, overwintering birds, and migrant species that use these areas as stopover sites. Water quality is also an issue in certain major river drainages that negatively affects many invertebrates, fish, amphibians, and reptiles.

This ecosystem contains some extremely rare disjunct and near endemic plant species. Their rarity makes them vulnerable to changes in habitat. Random events in specific locations can have major impacts on the expected viability of whole species. Two cane-feeding moths are endemic (or nearly so) to the North Carolina Coastal Plain. Habitat for these species is divided between blackwater and brownwater floodplains, as well as peatlands. All of these species, plus the larger guild of cane-feeding insects, is likely to benefit from increased canopy gaps and other disturbances associated with climate change.

Diversity of “native” species may potentially increase due to movement of more southerly species northward into this habitat type (e.g., Wood Storks, Swallowtail Kites, water elms, water locusts). In fact, the Wood Stork has expanded its breeding range in the state and is now nesting at several blackwater stream/river sites. More substantial changes may occur in floodplains north of North Carolina, beyond the current range of widespread southern floodplain species.

4.4.4.6 Recommendations

Surveys are needed to document the distribution, relative abundance, and status of many wildlife species associated with these habitats. Priorities for conducting surveys need to focus on species believed to be declining, at risk, or mainly dependent on these communities (like rails). Secondary priority for surveys should be for species for which current distribution information is already available or for species that are considered common. Many bird species associated with these community types are not sampled well or at all by the Breeding Bird Survey (BBS).

Surveys

Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Document Bald Eagle nesting sites.

  Bald Eagle

- Survey for poorly known or secretive semi-aquatic snakes.

  Rainbow Snake | Glossy Crayfish Snake | Black Swamp Snake

- Determine the breeding and roosting status and distribution of Chimney Swifts in natural conditions along major floodplains with appropriate habitat conditions (e.g. older, hollow trees).

  Chimney Swift

- Design specific surveys to determine status and distribution of birds not adequately picked up by the BBS in floodplain forests.

  Cerulean Warbler | Kentucky Warbler | Swainson's Warbler
  Hooded Warbler | Prothonotary Warbler | Worm-eating Warbler

- Survey for bat species that roost or forage in blackwater systems.

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Continue nest monitoring for colonial waterbirds, especially Wood Storks.

  Wood Stork

- Continue long-term monitoring of active Bald Eagle territories, successful breeding pairs, and fledged eagles.

  Bald Eagle

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Establish Monitoring Avian Productivity and Survivorship (MAPS) and migration banding stations, as well as specialized long-term monitoring for hard-to-sample species such as the Cerulean and Swainson's warbler (Graves 2001).

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Explore techniques for restoration of tidal swamp forest and wetlands.

- Investigate the past, current, and potential future impact of Nutria on both floral and faunal communities and individual species.
  Nutria

- Research the genetic makeup of the coastal population of the Black-throated Green Warbler.
  Black-throated Green Warbler

- Research the genetic relationships among floodplain salamanders.

- Determine the conservation and restoration efforts needed for priority species in this habitat.

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include

preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Wherever possible, maintain or restore floodplain forest connectivity, as floodplain forests are important distribution and dispersal corridors for many species (Bailey et al. 2004). This would benefit floodplain forest species.

Amphibians	Acadian Flycatcher	Swainson's Warbler
Timber Rattlesnakes	Northern Parula	Wood Thrush
Forest bats	Prothonotary Warbler	Yellow-Throated Warbler

- Ensure floodplain buffers of 300 to 600 feet in as many areas as possible. Where possible, forest patches should be connected along river systems to provide connectivity.

- Make an attempt to protect waterbird nesting colonies.

- Further expand the Forest Landbird Legacy Program (a cooperative effort between the Commission, the USFWS, and the Natural Resources Conservation Service) to influence habitat for birds and other wildlife in mature floodplain forests through canopy gap management and other options.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Initiate partnerships with the Natural Resources Conservation Service to begin cane restoration projects and research.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Continue cooperative efforts with colonial waterbird (wading bird) working groups and follow future management recommendations from the North American Waterbird Management Plan (Kushlan et al. 2002). Colonial Waterbirds
• Work to develop eight patches of forested wetlands at least 10,000 acres in size throughout the South Atlantic Coastal Plain, as called for in the South Atlantic Coastal Plain Partners in Flight Bird Conservation Plan (Hunter et al. 2001b).

4.3.5 Floodplains – Brownwater Systems

4.3.5.1 Ecosystem Description

This ecosystem group includes the vegetated communities that occur on brownwater floodplains. In contrast to blackwater rivers, they carry heavy loads of mineral sediment, particularly clay and silt. The water is generally near neutral pH and high in nutrients. The deposition of sediment in the floodplain provides a periodic nutrient input that keeps the soils rich. Depositional topographic features such as natural levees, point bars, ridge-and-swale systems, and sloughs are well developed, with their size depending on the size of the river.

There are seven communities that occur in Coastal Plain brownwater floodplains: Levee Forests, Bottomland Hardwoods, Small Stream Swamps, Cypress-Gum Swamps, Semipermanent Impoundments, Oxbow Lakes, and Sand and Mud Bars (Schafale and Weakley 1990).

4.3.5.2 Location of Habitat

Brownwater rivers originate in the Mountains or Piedmont and flow eastward into the Coastal Plain ecoregion. Though brownwater floodplain forests of various conditions and sizes can be found throughout the Coastal Plain ecoregion, the number of them is limited to the Roanoke, Tar/Pamlico, Neuse, and Cape Fear rivers. The condition of Coastal Plain floodplain forests of all types have been greatly reduced in recent years throughout North Carolina and the entire southeast (Weller and Stegman 1977; Schafale and Weakley 1990) by a variety of anthropogenic factors.

4.3.5.3 Problems Affecting Habitats

Chapter 5 Threats provides more information about 11 categories of threats most likely to impact North Carolina's wildlife and natural communities. The list of threats are based on definitions and classifications published by Salafsky et al. (2008, 2024). The following information focuses on current and anticipated threats for this habitat.

Flooding. Factors that impact these systems include flooding regime patterns that have been changed by dams and other development, habitat fragmentation, changes in water chemistry and organic matter loads, increased nitrogen from agricultural and development-related runoff, exotic species and high-grading of stands and logging that reduces wide buffers. All of these factors individually or interactively produce abrupt or gradual changes in floodplain plant and wildlife communities. In particular, the sediment load in many brownwater rivers is now a major problem in the Coastal Plain, and even many blackwater systems now have high sediment loads (Schafale and Weakley 1990).

Increased frequency and/or severity of flooding will likely have a mix of positive and negative influences. Changes in rainfall regime may also induce water management that produces more floods of unnatural, destructive long duration. If floods become more extreme, channels may begin to migrate more. Increased scouring by more severe floods would create more early successional bar communities at the expense of mature communities on the banks. Increased magnitude of floods could affect higher terraces that now see little flooding. Leigh (2008) and Leigh et al. (2004) suggest that Coastal Plain rivers may be near a threshold for switching to a braided channel morphology. More large floods might mean increased area but reduced stability of sand and mud bars. Given the water availability in floodplains, drought is unlikely to stress floodplain ecosystems. The effect will be mostly in the form of allowing upland species to invade.

Climate Variability. Inundation from sea level rise will create wholesale change to a tidal system in the downstream portions. Large expanses in these areas will shift to tidal swamps. Saltwater intrusion would likely affect long-term survivability of canopy species in the lower floodplain reaches. Saltwater intrusion could occur further upstream during floods or high storm surge.

Increased wind disturbance may cause some shifts in species composition, such as favoring sweetgum and loblolly pine over oaks in bottomland hardwoods. These will be relatively small compared to the past and ongoing similar effects of logging, but will exacerbate them. Increased wind damage would decrease average canopy age and increase the proportion of gaps. Increased tree growth rates may offset the structural effect to some degree. Bottomland hardwoods will likely be most affected by structural and compositional changes from increased wind storms.

No significant inland migration is possible for this community so there will be a net loss of acreage, mostly caused by inundation from rising sea level. Some Coastal Plain species may be able to expand into the Piedmont as the climate warms, but many of the differences between brownwater and inland floodplains are the result of geology rather than climate. There is an expectation that nonnative plants (e.g., Chinese Privet, Japanese Stiltgrass, Japanese Honeysuckle) will increase and there will likely be additional invasive species, such as the Chinese Tallow Tree.

4.3.5.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. While climate change is not the most severe threat, a combination of synergistic effects with other existing conditions could stress these systems to the point where several species are unable to persist. Other than rising sea level, the effects of climate change are particularly uncertain in these systems.

Changes in flood regimes and rising sea level are the most important climate effects. Climate change effects upstream of the tidal zone are likely to be limited and other existing threats are likely to be more significant. Table 4.3.5-1 summarizes the comparison of climate change with other existing threats.

Table 4.3.5-1 Comparison of climate change with other threats to brownwater floodplains

Threat	Rank Order	Comments
Logging/ Exploitation	1	This is the most destructive recent force and may get worse if drought allows more access to currently wetter areas.
Utility Corridors/ Fragmentation	1	Floodplains are highly susceptible to fragmentation by sewerlines, gaslines, powerlines, and highways that are constructed within them. Nonnative, exotic, and invasive species can gain a foothold in openings within these corridors.
Climate Change	2	Temperature and rainfall averages are expected to increase. More important will be changes in frequency and magnitude of extreme rainfall events, which will affect flood regimes. An increase in droughts is also expected.
Invasive Species	2	Temperature increases create potential for invasion by exotic species that are already problematic farther south, such as the Chinese Tallow Tree. Invasive exotic species already spreading in these systems, such as Tree-of-heaven, Asian Dayflower, and Japanese Stiltgrass, will continue to spread regardless of the climate, but any increased disturbance by flooding or wind storms may accelerate it.
Flood Regime Alteration	2	Alteration of hydrology due to dam creation and the draining of wetlands is one of the primary problems affecting this habitat type. Upstream dams are significant on some rivers but not others. Increased drought may lead to demand for more reservoirs upstream and to more water withdrawal and interbasin transfer in all large river systems.
Conversion to agriculture/ silviculture	3	Very significant in the past but most feasible conversion is already done.

4.3.5.5 Impacts to Wildlife

Appendix 3 provides a list of SGCN and other priority species for which there are knowledge gaps and management concerns. Appendix 3-17 provides a list of the SGCN that depend on or are associated with this habitat type.

The few brownwater floodplains generally occur far apart on the landscape, are not hydrologically connected, and few have north–south courses, making it difficult for plants and animals confined to brownwater floodplains to move northward as suitable conditions are lost.

Large patches of floodplain habitat are absent in much of the Coastal Plain. Fragmentation of stands has contributed to the loss of intact large riparian corridors and the width of many riparian corridors has been greatly reduced. Breeding area-sensitive bottomland-hardwood birds have likely been impacted by the loss of large patches of intact woodland systems. Swallow-tailed Kite is an area-sensitive species and is now known to breed within the state along the Cape Fear River. High-grading of stands has changed plant species diversity and stand vegetative structure. Forestry activities (e.g., logging) have reduced colonial waterbird and eagle nesting areas, but wading birds make more use of timber-cleared wetlands for foraging.

Two cane-feeding moths are endemic to the region but also occur in blackwater floodplains and non-riverine swamp forests. Another cane-feeding moth appears to be significantly disjunct within the lower Cape Fear floodplain. Two hawthorn-feeding moths also appear to have disjunct populations in the lower Roanoke floodplain, as does the Cerulean Warbler. None of these species appear likely to be affected by climate change-related impacts.

Drainage of wetlands has exacerbated the problems in and adjacent to floodplain forest habitats. This habitat loss impacts all floodplain species, including furbearers, breeding amphibians, overwintering birds, and migrant species that use these areas as stopover sites. Water quality is also an issue in certain major river drainages that negatively affects many invertebrates, fish, amphibians, and reptiles.

Long-duration flooding has had impacts on all ground-nesting bird species. Loss of old growth characteristics (canopy gaps, vine tangles, hollow trees, dead and downed woody material) and fragmentation of stands is a major concern. A lack of standing dead or older trees has impacted the availability of quality bat and Chimney Swift roosting and breeding sites and nesting productivity for species such as the Wood Duck and Hooded Merganser. Lack of downed woody debris has impacted a variety of amphibians and reptiles.

4.3.5.6 Summary and Recommendations

In general, protection and restoration of natural composition and function, and protection of surrounding natural areas are the best ways to improve the ability of these communities to adapt to climate change. Protection of a large and diverse pool of examples is the best way to ensure that many survive the future stresses.

Surveys

Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Conduct surveys to document the distribution, relative abundance, and status of wildlife species associated with brownwater floodplain forest habitats. Priorities include SGCN and species believed to be declining, at risk, or mainly dependent on floodplain forest communities. Cerulean Warbler, Wood Stork, Bats, Swallow-tailed Kite
• Give secondary priority to surveys of species for which current distribution information is already available or for species that are considered common.

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Expand and/or target monitoring systems to be able to assess current population status and trend information for all wildlife species associated with floodplain forest habitats.

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Ensure that research studies targeting birds are long-term, large-scale, replicated studies that have controlled experimental approaches and focus on population demographics and the response of species to habitat manipulations where appropriate (as outlined by the National Partners in Flight Research working group) (Donovan et al. 2002). Similar research priorities are needed for other floodplain forest taxa including bats, small mammals, amphibians, and reptiles.

Bats	Small mammals	Amphibians Reptiles

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Make efforts to retain old growth floodplain forest (for Chimney Swifts, bats, and herpetofauna).

Chimney Swift	Bats	Herps

- Ensure floodplain buffers of 300 to 600 feet in as many areas as possible. This would benefit floodplain forest species.

Acadian Flycatcher	Prothonotary Warbler	Timber Rattlesnakes
Cerulean Warbler	Swallowtailed Kite	Amphibians
Mississippi Kite	Swainson’s Warbler	Forest bats
Northern Parula	Wood Thrush	

- Restore natural hydrology where dams have altered hydrology, such as on the Roanoke River.

- Work with partners to institute more natural water release regimes from dams.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Pursue land acquisition and easements through cooperation with land trusts with an effort to increase the width of riparian buffers and create larger patches of connected habitat. Priority should be given to brownwater bottomlands, as these are the most species-rich and are more susceptible to clearcutting and other timber harvest than cypress-gum swamps (i.e., wetter sites).
• Wherever possible, maintenance or restoration of floodplain forest connectivity should be pursued; floodplain forest are important distribution and dispersal corridors for many species (Bailey et al. 2004).

4.3.6 Floodplains – Inland Systems

4.3.6.1 Ecosystem Description

For this natural community description, Inland Floodplains are forested communities associated with freshwater systems of various conditions and sizes and are located primarily in the Mountain, Piedmont, and Sandhills ecoregions. Depending on landscape position and soil moisture gradients, some of the wetland communities described in Section 4.3 may also be part of the inland floodplain community; however, in this description, floodplain forests are considered the dominant community type. For this natural community description, inland floodplains are forested communities associated with freshwater systems of various conditions and sizes and are located primarily in the Mountain, Piedmont, and Sandhills ecoregions.

Floodplain systems in the Coastal Plain ecoregion may be associated with blackwater rivers (originating in the Coastal Plain) or brownwater rivers (originating in the Piedmont or Mountains but flowing into the Coastal Plain). Floodplains in the Coastal Plain are typically characterized as broad alluvial features that may be inundated for prolonged periods every year with low gradient meandering streams that terminate in tidal estuaries (Hupp 2000). Separate community descriptions are provided for the blackwater and brownwater floodplains (see Sections 4.3.4 and 4.3.5, respectively) because of their unique characteristics.

In the Piedmont and Sandhills ecoregions, floodplain forests generally do not contain the significant recognizable elevation differences seen in the larger coastal floodplain systems. In these smaller floodplains, the relief and size of the fluvial landforms (levees, sloughs, and ridges) that differentiate the communities in large floodplains become smaller and harder to find (Schafale and Weakley 1990). In larger and more expansive examples of these floodplains, the forest canopy contains a good mixture of bottomland and mesophytic (moderately moisture tolerant) plant species.

Floodplain forests of the Mountain ecoregion are relatively narrow and do not contain well-developed levees, sloughs, and ridges. Smaller high gradient streams often do not have representative floodplains, but instead have riparian zones embedded within other habitat types such as isolated patches of various wetland communities (Schafale and Weakley 1990). Mountain floodplains are subject to sporadic high-intensity flood events of short duration.

4.4.6.2 Location of Habitat

Floodplain forests of some type are found beside most rivers and streams in the Piedmont and Sandhills ecoregions. They are of varying widths, depending on the topography of land adjacent to the river, and the transition between floodplain and upland forest is often gradual. Mountain floodplains are generally restricted to larger streams and rivers with relatively low gradients of the valley landscape.

4.4.6.3 Problems Affecting Habitats

Chapter 5 Threats provides more information about 11 categories of threats most likely to impact North Carolina's wildlife and natural communities. The list of threats are based on definitions and classifications published by Salafsky et al. (2008, 2024). The following information focuses on current and anticipated threats for this habitat.

Flooding. Natural floodplains are biologically productive and diverse ecosystems that are among the most threatened due to habitat alteration, flow and flood control, invasive species, and pollution (Tockner and Stanford 2002). The condition of floodplain forests of all types has been greatly reduced in recent years throughout North Carolina and the entire southeast (Weller and Stegman 1977; Schafale and Weakley 1990) by a variety of anthropogenic factors. Factors that impact these systems in North Carolina include flooding regime patterns that have been changed by dams and other development, habitat fragmentation, changes in water chemistry and organic matter loads, increased nitrogen from agricultural and development-related runoff, exotic species, and high-grading of stands and logging that reduces wide buffers. All of these factors individually or interactively produce abrupt or gradual changes in floodplain plant and wildlife communities.

Long-duration flooding has had impacts on all ground-nesting bird species. Loss of old growth characteristics (canopy gaps, vine tangles, hollow trees, dead and downed woody material) and fragmentation of stands is a major concern. A lack of standing dead or older trees has impacted the availability of quality bat and Chimney Swift roosting and breeding sites and nesting productivity for species such as Wood Duck and Hooded Merganser. Lack of downed woody debris has impacted a variety of amphibians and reptiles.

Land Use. Logging and clearing land for agriculture, development, recreational use, and reservoir construction all cause direct loss and alteration of floodplain forests. In the past half century, an estimated 52% of bottomland forests in the south have been cleared for agriculture or development (Smith et al. 2002). Land clearing activities conducted adjacent to, and up and downstream of floodplain forests can cause indirect impacts to the floodplains, particularly related to hydrology. Areas adjacent to floodplains are often prime targets for general development and subdivisions, and buffer size is often inadequate to provide any protection from a variety of anthropomorphic disturbances over time. For instance, flooding events may occur with greater frequency in some areas due to increased upstream impervious surfaces and clearing of vegetation near buffers.

Snags play a very important role in providing nesting, foraging, and roosting areas for many cavity-nesting birds, bats, arboreal mammals, reptiles, and amphibians. Lack of snags and den trees is often a limiting factor for several species of wildlife, especially secondary cavity users (McComb et al. 1986). Younger riparian forests can also lack dead wood on the ground, which is important for some songbirds (like the Kentucky Warbler), many reptiles, amphibians, and some small mammals.

Dams can alter the timing and duration of flood events. Alteration of hydrology due to dam creation and the draining of wetlands changes plant communities and also affects the availability of ephemeral wetlands for breeding amphibians. Building ditches and canals in floodplains dramatically alters hydrology and is often done to prepare a floodplain for agriculture, forestry, or development. Even in abandoned sites, ditches will continue to alter the hydrology for many decades. Habitat loss from wetland drainage impacts all floodplain species, including furbearers, breeding amphibians, overwintering birds, and migrant species that use these areas as stopover sites.

Fragmentation of forest stands has contributed to the loss of intact large riparian corridors and the width of many riparian corridors has been greatly reduced. Breeding area-sensitive bottomland-hardwood birds have likely been impacted by the loss of intact woodland systems. High-grading of stands has changed plant species diversity and stand vegetative structure. Forestry activities (e.g., logging) have reduced colonial waterbird and eagle nesting areas. Clearing of adjacent uplands can increase edge effects and limit the effective size of floodplain forest habitat.

Water Quality. Sewer lines have been constructed along many floodplain corridors, especially in urbanized areas. These corridors fragment floodplain forests and allow conditions for invasion of exotic plant species. Poor water quality due to nutrient inputs, reduced dissolved oxygen (DO) levels, sedimentation, and chemical contamination (among others) can have a strong impact on amphibians, turtles, and other animals associated with floodplain forests that forage or breed in aquatic areas, in addition to the direct impacts on fully aquatic species. Sediment pollution is a major problem in the Piedmont and Coastal Plain. Beaver activity and the creation of beaver ponds in floodplain forest can have substantial impacts on trapping sediment and associated pollutants.

Invasives. Increases in amounts of non-native plants (e.g., Chinese Privet, Japanese Stiltgrass, Japanese Honeysuckle) and the overall loss of large canebreaks are partly due to the lack of infrequent fire and also certain logging practices. Understory vegetative diversity has declined in many areas due to modified flooding regimes and increases in invasive nonnative plant species. The reduction in overall plant diversity is often extensive due to these invasive nonnative plants and may cause problems for native fauna, though the extent of wildlife impacts is largely unknown.

4.3.6.4 Climate Change Compared to Other Threats

While climate change may not be the most severe threat, a combination of synergistic effects with other existing conditions could stress these systems to the point where several species are unable to persist. The effect of a changed climate is likely to vary widely among examples of this community type, depending on topographic sheltering, configuration of soil type and depth, elevation of groundwater, and the timing and duration of precipitation. Table 4.3.6-1 summarizes the comparison of climate change with other existing threats.

Table 4.3.6-1 Comparison of climate change with other threats to inland floodplains

Threat	Rank Order	Comments
Logging/ Exploitation	1	This is the most destructive recent force and may get worse if drought allows more access to wetter areas.
Utility Corridors	1	Sewerlines and gaslines have already created much damage to inland floodplains. Transmission lines also fragment these floodplains. As human population increases, corridor impacts will continue to increase, as well.
Climate Change	2	Temperature and rainfall averages are expected to increase. More important will be changes in frequency and magnitude of extreme rainfall events, which will affect flood regimes. An increase in droughts is also expected.
Invasive Species	2	Temperature increases create potential for invasion by exotic species that are already problematic farther south, such as Chinese Tallow Tree. Invasive exotic species already spreading in these systems, such as privet, Japanese honeysuckle, and Japanese grass will continue to spread regardless of the climate, but any increased disturbance by flooding or wind storms may accelerate it.
Flood Regime Alteration	2	Alteration of hydrology due to dam creation and the draining of wetlands are one of the primary problems affecting this habitat type. Upstream dams are significant on some rivers but not others. Increased drought may lead to demand for more reservoirs upstream and to more water withdrawal and interbasin transfer in all large river systems.
Conversion to agriculture/ silviculture	3	Somewhat significant in the past but most feasible conversion is already done.

4.3.6.5 Impacts to Wildlife

Appendix 3 provides a list of SGCN and other priority species for which there are knowledge gaps and management concerns. Appendix 3-17 provides a list of the SGCN that depend on or are associated with this habitat type.

The vegetative cover of some floodplains was historically maintained in Switch Cane and herbaceous plants through fire and other periodic disturbance. Small remnants of “canebrake” communities still exist throughout the Piedmont, but management strategies to maintain this feature are almost nonexistent. Migratory landbirds that use switch cane areas for breeding include Hooded Warblers, Kentucky Warblers, and Swainson’s Warblers.

Floodplains are also important as movement corridors for mammals, reptiles, and amphibians. Birds use riparian corridors at all times of the year and these areas are especially important to neotropical migrants during the migration periods. Indeed, floodplain forests generally have the highest nesting bird concentrations in the state and they are arguably the most important habitats for birds. Floodplain pools that occur in small depressions and are flooded for a portion of the year generally have few or no trees and are especially important sites for breeding amphibians such as Spotted Salamanders, Marbled Salamanders, Four-toed Salamanders, and many frogs.

4.3.6.6 Recommendations

In general, protection and restoration of natural composition and function, and protection of surrounding natural areas are the best ways to improve the ability of these communities to adapt to climate change. Protection of a large and diverse pool of examples is the best way to ensure that many survive the future stresses.

Surveys

Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Design specific surveys to determine status and distribution of birds not adequately picked up by the Breeding Bird Survey in floodplain forests.

Cerulean Warbler	Kentucky Warbler	Swainson’s Warbler
Hooded Warbler	Prothonotary Warbler	Worm-eating Warbler

- Determine the status and distribution of Wayne’s Black-throated Green Warbler.

  Wayne’s Black-throated Green Warbler

- Determine the status and distribution of colonial nesting waterbirds and kites.

Anhinga	Swallow-tailed Kite
Mississippi Kite	Yellow-crowned Night Heron

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Determine the breeding and roosting status and distribution of the Chimney Swift in natural conditions along major floodplains with appropriate habitat conditions (e.g., older, hollow trees).

  Chimney Swift

- Determine the status and distribution of priority bat species.

  Little Brown Bat
  Northern Long-eared Bat
  Rafinesque's Big-eared Bat
  Northern Yellow Bat
  Seminole Bat
  Southeastern Bat
  Tricolored Bat

- Conduct small mammal surveys with a focus on circumneutral soils.

  Cotton Mouse
  Eastern Woodrat
  Southern Pygmy Shrew

- Determine the status and distribution of snakes using floodplain forest habitats (Taylor and Jones 2002).

- Document Bald Eagle nesting sites.

  Bald Eagle

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Continue long-term monitoring of active Bald Eagle territories, successful breeding pairs, and fledged eagles.

  Bald Eagle

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Develop monitoring for any North Carolina floodplain forest bird species that require specialized attention, since neither BBS nor standard point counts can adequately sample irregularly distributed or clumped species like Kentucky, Cerulean, and Swainson's warblers.

  Cerulean Warbler | Kentucky Warbler | Swainson's Warbler

- Develop or enhance long-term monitoring for amphibians and reptiles (Taylor and Jones 2002).

  Amphibians | Reptiles

- Develop or enhance long-term monitoring for most bat species (Ellis et al. 2002).

  Bats

- Conduct long-term monitoring for floodplain forest birds (breeding, migration, and winter periods) in forest patches of varying size (Robbins et al. 1989; Doherty, Jr. and Grubb, Jr. 2000).

- Establish long-term monitoring for herpetofauna using floodplain forest habitat (especially breeding salamanders and snakes).

  Amphibians | Snakes

- Examine demographics and habitat use of bats in floodplain forests; there is also a need to identify, monitor, and maintain (or recruit) key bat habitats and microhabitats in floodplain forests (Ellis et al. 2002).

  Bats

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Ensure that research studies targeting birds are long-term, large-scale, replicated studies that have controlled experimental approaches and focus on population demographics and the response of species to habitat manipulations where appropriate (as outlined by the National Partners in Flight Research working group) (Donovan et al. 2002).

- Similar research priorities are needed for other floodplain forest taxa including bats, small mammals, amphibians, and reptiles.

  Amphibians, Bats, Small mammals, Reptiles

- Research the genetic makeup of the coastal population of the Black-throated Green Warbler.

  Black-throated Green Warbler

- Research the genetic relationships among floodplain salamanders.

  Salamanders

- Examine the impacts of long-term flooding regimes on ground-nesting birds (Swift et al. 1984). Similar studies are also needed for salamanders.

  Swainson's Warbler, Salamanders

- Determine the conservation and restoration efforts needed for canebrake rattlesnakes in floodplain forests (Brantley and Platt 2001).

  Canebrake Rattlesnake

- Conduct bird productivity research (especially neotropical migrants) with a focus on nest searching studies to determine the predator community and bird nesting success in patches of different sizes and with various landscape contexts (Rodewald and Yahner 2001).

- Study the effects of riverine buffer width characteristics on bird species diversity, richness, survival, nest success, and productivity (Perkins et al. 2003). Similar studies are also needed for small mammals, bats, amphibians, and reptiles to determine long-term productivity in buffers of various widths.

  Amphibians, Bats, Birds, Small mammals, Reptiles

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Examine the demographics, habitat-use patterns, and impacts of feral hogs on ground-nesting birds, salamanders, and small mammals (Warren and Ford 1997).

- Study the impacts of beaver and beaver ponds on species composition (both flora and fauna) to determine negative or positive impacts of beaver or beaver control measures.

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Wherever possible, maintain or restore floodplain forest connectivity, as floodplain forests are important distribution and dispersal corridors for many species .

- Floodplain buffers of 300 to 600 feet provide the most benefit for species that use this habitat.

Acadian Flycatcher	Swainson’s Warbler	Amphibians
Northern Parula	Wood Thrush	Snakes
Prothonotary Warbler	Worm-eating Warbler	Forest bats
	Yellow-throated Warbler	

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
Make an attempt to protect waterbird nesting colonies. Continue cooperative efforts with colonial waterbird (wading bird) working groups and follow future management recommendations from the North American Waterbird Management Plan (Kushlan et al. 2002).

- Make efforts to retain old growth floodplain forest for chimney swifts, bats, and herpetofauna.

- Work to develop eight patches of forested wetlands at least 10,000 acres in size throughout the South Atlantic Coastal Plain, as called for in the South Atlantic Coastal Plain Partners in Flight Bird Conservation Plan (Hunter et al. 2000b).

- Initiate partnerships with the Natural Resources Conservation Service to begin cane restoration projects and research.

- Further expand the Forest Landbird Legacy Program (a cooperative effort between the Commission, the US Fish and Wildlife Service [USFWS], and the Natural Resources Conservation Service) to influence habitat for birds and other wildlife in mature floodplain forest through canopy gap management and other options.

- Concentrate conservation efforts on the Pee Dee and Dan River basins, as they contain some of the larger tracts of intact floodplain forest left in the Piedmont and offer some of the best opportunities for large-scale habitat conservation.

  Pee Dee River basin   Dan River basin

4.3.7 Freshwater Tidal Wetlands

4.3.7.1 Ecosystem Description

Freshwater tidal wetlands occur in sites where flooding occurs in response to lunar or wind tides, but where the water has less than the 0.5 parts per thousand (ppt) salt content used to define freshwater. Tidal freshwaters occur in rivers, where freshwater flow keeps out saltwater, and along the large sounds where distance from seawater inlets keeps the water fresh. Components of this habitat include tidal cypress-gum swamps and tidal freshwater marshes:

Tidal cypress-gum swamps occupy vast areas at the mouths of large rivers and also occur at the mouths of smaller creeks and occasionally along the sound shoreline. They are dominated by Swamp Black Gum, Water Tupelo, and Bald Cypress. Understory tree, shrub, and herb layers are generally sparse and low in diversity.

Tidal freshwater marshes occur in the lowermost parts of some tidal rivers and creeks and, more commonly, in large flats along the shorelines of freshwater sounds. The vegetation is generally strongly zoned and often very diverse in at least some zones. Two distinct variants are recognized, one with very slightly salty (oligohaline) water, the other completely fresh.

4.3.7.2 Location of Habitat

These habitats occur along rivers or coastal sounds in areas where flooding is influenced by lunar or wind tides. Fresh water input may heavily influence the salt content. Tidal cypress-gum swamps are extensive along shorelines and along drowned river valleys (e.g. Cape Fear, Neuse, and Chowan rivers). The most extensive examples can be found around Albemarle Sound areas, Alligator River, and at the mouths of the Cape Fear, Neuse, Tar, and Roanoke rivers. Tidal freshwater marshes are common around the margins of Currituck Sound, and occur in smaller areas, such as in the Cape Fear River just west of Wilmington.

4.3.7.3 Problems Affecting Habitats

Chapter 5 Threats provides more information about 11 categories of threats most likely to impact North Carolina's wildlife and natural communities. The list of threats is based on definitions and classifications published by Salafsky et al. (2008, 2024). The following information focuses on current and anticipated threats for this habitat.

Erosion. Erosion control measures may help protect these communities, but measures that alter the shoreline, whether sea walls, "soft" structures, or planting off-site species, are potentially destructive to these communities. Shoreline armoring and hardening to protect infrastructure will prevent ecosystems such as tidal marshes from migrating inland (DeWan et al. 2010). As development continues inland, water demands in the Piedmont will affect freshwater flows from the major rivers that feed this system through water removals.

Flooding. Alteration of flood regimes in rivers may affect these systems. Some areas are fresh largely, or at least partly, because of the dilution of sea water by river input. Increased water withdrawal or interbasin transfer may increase this problem in the future. The effects are local, affecting primarily the mouth of the altered rivers, but could be important cumulatively. Existing drainage ditches and canals bringing saltwater into wetlands is a serious threat. In fact, saltwater intrusion is already impacting former forests in Alligator River National Wildlife Refuge near the intersection of US 64 and US 264, and in the lowest portion of the Scuppernong River at Columbia. Tide gates or blocking ditches are needed to slow, if not eliminate, some saltwater intrusion. However, saltwater intrusion into Albemarle Sound and into the Scuppernong River cannot be controlled by tide gates or blocking ditches.

Plant communities in low-elevation marshes may tolerate infrequent flooding. An increase in frequency, duration and amplitude of flooding will increase stress beyond tolerances so that plants do not survive (Colombano 2021, Moorman et al. 2024). Eventually, more tolerant species will replace the plant community and ecosystem processes may not longer support the species that depend on freshwater marsh habitats.

Logging. This ecosystem group is likely to experience drastic changes in extent and significant movement of communities that are logged. Logging is a threat to some tidal cypress-gum swamps, while others are in protected status or are too wet for logging equipment. Drying may create opportunities for logging these wet areas.

Small plants of low interior marshes appear to need fire to maintain their habitat. Lack of fire allows unnatural vegetation succession in some freshwater marshes. Common Reed, Chinese Tallow Tree, Alligator Weed, and Nutria are primary invasive species concerns. The disruptions created by shifting communities and catastrophic events may increase the spread of Common Reed. Giant Salvinia could become a problem. Early control of species that have proven more invasive farther south will be less costly and less ecologically disruptive than allowing populations to become large.

4.3.7.4 Climate Change Compared to Other Threats

Changes caused by rising sea level are the greatest threat, but increased intensity of storms, both in rainfall and wind, are also important. Because these systems are so subject to sea level, tidal movement, water salinity, and storms, these effects of climate change are the greatest threats. Table 4.3.7-1 summarizes the comparison of climate change with other existing threats.

Table 4.3.7-1 Comparison of climate change with other threats to freshwater tidal wetlands

Threat	Rank Order	Comments
Climate Change	1	This ecosystem group is likely to experience drastic changes in extent and significant movement and composition of communities. Sea level rise, drought, increased storm activity, and saltwater intrusion are threats to freshwater tidal wetlands.
Invasive Species	2	Common Reed, Chinese Tallow Tree, Alligator Weed, and Nutria are primary concerns. The disruptions created by shifting communities and catastrophic events may increase the spread of Common Reed. Giant Salvinia could become a problem. Early control of species that have proven more invasive farther south will be less costly and less ecologically disruptive than allowing populations to become large.
Shoreline Hardening	2	Erosion control measures may help protect these communities, but measures that alter the shoreline, whether sea walls, “soft” structures, or planting off-site species, are potentially destructive to these communities. Shoreline armoring and hardening to protect infrastructure will prevent ecosystems such as tidal marshes from migrating inland (DeWan et al. 2010).
Logging/ Exploitation	3	Logging is a threat to some tidal cypress-gum swamps, while others are in protected status or are too wet for logging equipment. Drying may create opportunities for logging these wet areas.
Fire	3	Many herbaceous plants of tidal freshwater marshes appear to need fire to maintain their populations. Lack of fire allows unnatural vegetation succession, especially invasion by woody species, in some freshwater marshes.
Flooding Regime Alteration	4	Alteration of flood regimes in rivers may affect these systems. Some areas are fresh largely, or at least partly, because of the dilution of sea water by river input. Increased water withdrawal or interbasin transfer may increase this problem in the future. The effects are local, affecting primarily the mouth of the altered rivers, but could be important cumulatively. Existing drainage ditches and canals bringing saltwater into wetlands is a serious threat. Tide gates or blocking ditches are needed.
Freshwater Withdrawal	5	As development continues inland, water demands in the Piedmont will affect freshwater flows from the major rivers that feed this system through water removals.

4.3.7.5 Impacts to Wildlife

Appendix 3 provides a list of SGCN and other priority species for which there are knowledge gaps and management concerns. Appendix 3-17 provides a list of the SGCN that depend on or are associated with this habitat type.

No terrestrial animals are endemic to this ecosystem group within North Carolina. Manatees, Roseate Spoonbills, and possibly other species may be able to persist in North Carolina in the future climate with warmer weather. Coastal freshwater wetlands provide important habitats for bitterns, rails, and a variety of other long-legged wading and shorebirds. Conversion of other habitats, especially tidal forests, to tidal freshwater marsh will occur over time, which means availability of this habitat for nesting, cover, and forage may briefly increase; however, in the long term, location and amount of such marshes is uncertain (DeWan et al. 2010).

Tidal freshwater wetlands provide nursery habitat for aquatic species that live in saltwaters but rely on fresh and brackish waters for larval recruitment and development. Many of these species are economically or commercially important, such as crabs, shrimp, and flounder species (DeWan et al. 2010). Coastal freshwater wetlands are also important to furbearers, waterfowl, and other game species.

The Rare Skipper (*Problema bulenta*) occurs solely within tidal freshwater marshes throughout its range, from New Jersey to southern Georgia. Dukes' Skipper (*Euphyes dukesi*) is also restricted to these habitats along the Atlantic coastal portion of its range, although it also occurs inland in Florida, and in the Midwest region. Although the reasons for these restrictions are not clear, the larvae of both species feed on plants that occur well inland from the coast, even in North Carolina. Both of these species are potentially susceptible to extirpation from the state if they or their specialized habitats cannot keep pace with the effects of sea level rise and saltwater intrusion.

Nutria are considered a serious pest species in the United States because they eat a variety of wetland and agricultural plants and their burrowing damages streambanks, impoundments, and drainage systems. Nutria may also be a vector for diseases (tuberculosis and septicemia) or parasites (*Giardia, Fasciola*, Liver Flukes, and nematodes), with fecal contamination in water the likely pathway. As warming trends increase, the range of Nutria is likely to expand and populations currently limited by intolerance to cold winters will quickly expand (Carr 2010).

4.3.7.6 Recommendations

Priority to increase resilience in these systems should be placed on protecting areas that will be likely to persist or migrate, blocking ditches that are now allowing saltwater into freshwater wetlands, and controlling Common Reed in these areas. While many existing marshes are likely to be lost, there is a need to protect the examples that will be the seed sources for newly developing marshes. There is also a need to protect the areas that will become tidal freshwater marshes as sea level rises. Most of these are likely tidal cypress-gum swamps at present. Tidal cypress-gum swamps with mature cypress trees in them may lead to marshes with a tree component that will improve their resistance to erosion.

There is a corresponding need to protect sites that will become tidal cypress-gum swamps in the future. Because most of the dominant trees are the same and can persist in the transition to tidal conditions, protecting mature nonriverine swamp forest and brownwater or blackwater cypress-gum swamp areas will allow more rapid development of tidal cypress-gum swamps.

Surveys

Priorities for conducting distributional and status surveys need to focus on SGCN believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Collect baseline information on marsh elevations, flood frequency, and water salinities. This information is important for tracking changes to this wetland type, especially considering sea level rise and increased frequency of coastal inundation.

    Freshwater tidal marsh

Monitoring

Monitoring is critical to assessing species and ecosystem health and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Long-term monitoring is needed to identify population trends and to assess performance of conservation actions. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Begin long-term monitoring, following survey data, for all marsh birds, mammals, and reptiles in this habitat type.

    Marsh birds | Mammals | Reptiles

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Research must also be conducted to determine vulnerability of SGCN and other priority species to specific threats and studies should provide recommendations for mitigation and restoration.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Investigate how reduction in freshwater marsh and increases in higher salinity areas affect alligators. American Alligator
• Conduct research on fire management in marsh habitats to determine optimal frequency, timing, and firing techniques (e.g., flanking fire, back fire) to benefit priority birds.
• Investigate population densities, population growth rates, dispersal range, and extent of property damage from Nutria burrowing and herbivory.
• Determine what circumstances cause organic soils to rapidly decay in coastal wetlands.

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Explore techniques for restoring tidal swamp forest and wetlands.
• Consider planting bald cypress to create the next shoreline as sea level rises and blocking ditches to slow saltwater flow into the interior of freshwater tidal marsh as a measure to reduce erosion and buy time for habitat migration inland.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Use prescribed fire to burn portions of tidal freshwater marshes to eliminate or set-back competing woody species. Mechanical cutting of woody vegetation may be more feasible in wetter areas that cannot be reached by fire.
• The use of bulkheads should be discouraged when other possibilities are available.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience. Work with land trusts and The Nature Conservancy to identify priority sites needing protection.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Priorities for protection include colonial waterbird nesting sites, eagle nesting sites, Wood Stork foraging areas, and important Black Rail habitat once it is better identified. Adjacent nesting habitat for snakes and turtles should also be protected. Colonial waterbirds; Black Rail; Reptiles Bald Eagle; Wood Stork
• Acquisition of freshwater tidal marsh habitat in the Currituck Sound area is important.

4.3.8 Freshwater Herbaceous Marsh

4.3.8.1 Ecosystem Description

Freshwater herbaceous marsh communities are non-tidal or supratidal (above the spring high tide line) wetland systems dominated by a variety of grasses, sedges, rushes, cattails, cane, and forbs without woody shrubs or trees. They can be classified as peatland canebrakes, beaver marshes, impoundments and herbaceous marshes in the supratidal-zone that only receive tidal flooding during storm surge events. They occur along streams in poorly drained depressions and in the shallow water along the boundaries of lakes, ponds, and rivers and can be flooded for extended periods during the growing season.

In the coastal plain, they can also be delineated as supratidal high marsh located in slightly higher elevations transitional between brackish marsh and wetland forest or non-wetland upland communities. The examples of supratidal herbaceous marshes on the upland side near brackish marsh can be dominated by sawgrass (*Cladium spp.*).

Freshwater marshes are known by many names, including emergent wetlands, wet meadows, fens, and sloughs (FGDC 2013). Water levels in these systems can fluctuate from moist soil to a couple of inches depending on landscape location, hydrologic sources, and seasonal precipitation (USEPA 2024). Different SGCN can tolerate different water levels. For example, Black Rails require less than one inch of water during the breeding season, while other SGCN can tolerate deeper water depths.

As with other wetlands, they are able to mitigate flood damage and filter excess nutrients from surface runoff. They can have highly organic, mineral rich soils of sand, silt, and clay that sustain a vast array of plant communities that in turn provide considerable habitat value and support a wide variety of wildlife. For example, herbaceous communities provide excellent habitat for songbirds, waterbirds, and waterfowl such as Red-winged Blackbird, Black Rail, American Bittern, Black Duck, and Great Blue Herons as well as small mammals such as American Otters and Muskrats (USEPA 2024).

The freshwater marsh natural community is a new wetland description added to the WAP during the 2025 revision process.

4.3.8.2 Location of Habitat

These habitats occur in small pockets throughout the state. Today they are found mostly in the Coastal Plain, are mainly rain or freshwater fed and are located beyond normal tidal influences adjacent to and at slightly higher elevations than brackish and salt marshes. They occur in smaller occurrences statewide, primarily along slow-moving rivers and streams, in beaver dam marshes, old oxbows and overflow channels, in ditched areas, impoundments, around the edges of ponds and lakes, or in relatively flat areas or shallow depressions that intercept the groundwater table (NCDWR 2024, NatureServe 2024). These wetlands can be identified through GIS mapping, with locations mapped as palustrine emergent freshwater wetlands (PEM) as defined in the national classification of wetlands (FGDC 2013). However, aerial photos must be checked to identify that marshes are herbaceous and do not have a significant component of wood shrubs or trees. One of the few good examples of this habitat type exists along Bell Island Road in Swanquarter National Wildlife Refuge.

4.3.8.3 Problems Affecting Habitats

Fire Suppression. It is likely that freshwater herbaceous marshes existed in areas now covered by forest or that have a tree and shrub component that would not exist under a natural fire regime (Noss 2012). Historically there may have been more freshwater herbaceous marshes due to frequent fires that were able to reach intense heat conditions and knock back shrub and tree succession on hydric soils.

Land Use. Development of farming and agricultural activities, logging of nearby forests, conversion to pine plantation, and stormwater runoff contribute to losses. Some freshwater herbaceous wetlands have been degraded by excessive deposits of nutrients and sediment from construction and farming related erosion. Such environmental problems prove the vital roles these wetlands play (USEPA 2024).

Development Freshwater marshes have suffered major acreage losses to residential and commercial development. Additional threats associated with development include new roads and crossing structures, utilities and utility maintenance activities, and land use changes to surrounding landscapes.

Flooding. Coastal locations will be subject to flooding associated with storm surge which can introduce salt water to these freshwater systems. Freshwater marsh destruction and degradation in other locations statewide that are subject to flooding events can result in nutrient deposition to downstream waters. When it rains, water runs across hard surfaces like parking lots and roofs and flows into wetlands. This stormwater may carry pollutants (e.g., fertilizer, gasoline, oils, sediment, litter). Wetlands help filter this stormwater to keep our water clean, but too many pollutants in the stormwater may over-whelm wetlands (NCDWR 2024).

Drought. Low rain levels during extremely dry (drought) conditions can decrease, and sometimes completely remove, the amount of water on the surface and/or in the soils of wetlands. The lack of water can cause changes in soil chemistry and affect the plants and animals that live there. To conserve secretive marsh bird species such as the Black Rail it is necessary to create and restore moist soil or very shallow herbaceous freshwater marshes to move populations out of areas that will receive frequent tidal flooding.

Invasive Species. Invasive species are non-native species that grow aggressively and displace native species. Invasive plants decrease biodiversity and degrade habitat by outcompeting native plants that wetland animals rely on for food and shelter. Invasive animals, like nutria, alter the overall ecology of wetlands by reproducing quickly and eating anything in sight (NCDWR 2024).

4.3.8.4 Climate Change Compared to Other Threats

In coastal landscapes, changes caused by rising sea level are the greatest threat, but increased intensity of storms, both in rainfall and wind, are also important to other locations. Because these systems are so subject to sea level, tidal movement, water salinity, and storms, these effects of climate change are the greatest threats. Table 4.3.7-1 summarizes the comparison of climate change with other existing threats.

Table 4.3.7-1 Comparison of climate change with other threats to freshwater herbaceous wetlands

Threat	Rank Order	Comments
Climate Change	1	Freshwater herbaceous marsh is likely to experience drastic changes in extent and significant movement and composition of communities because of the various aspects of climate change. Sea level rise, drought, increased storm activity, and flooding are threats to all wetlands in the coastal plains. Statewide, they are at risk from flooding, erosion and sedimentation, and hydrological changes from drought.
Development	1	Wetland soil is unstable, so wetlands are often filled (i.e. depositing enough sediment in a wetland to raise the soil surface above water level) or drained (digging ditches for water to flow out of wetlands) prior to construction. Both can change plants and animals that are able to survive in the new conditions (NCDWR 2024).
Lack of Fire	1	Many herbaceous plants of freshwater marshes appear to need fire to maintain their populations. Lack of fire allows unnatural vegetation succession, especially invasion by woody species, in some freshwater marshes.
Conversion	1	Conversion to agricultural fields or pine plantations combined with the factors above have likely led to the current rarity of this habitat type.
Invasive Species	2	The disruptions created by shifting communities and catastrophic events may increase the spread of non-native and invasive species. Early control of species that have been proven more invasive, such as nutria and *Phragmites*, will be less costly and less ecologically disruptive than allowing populations to become large.

Table 4.3.7-1 Comparison of climate change with other threats to freshwater herbaceous wetlands

Threat	Rank Order	Comments
Flooding Regime Alteration	3	Alteration of flood regimes in rivers may affect these systems. Along the coast, some areas are fresh because of the dilution of sea water by river input. Increased water withdrawal or interbasin transfer may increase this problem in the future. The effects are local, affecting primarily the mouth of the altered rivers, but could be important cumulatively. Dams (beaver or man-made) can increase flooding in an area, which may cause some trees to die, changing a forested wetland into a marsh. Filling in or ditching around a wetland can decrease the amount of water available, changing the types of plants and animals that can live there as well.
Freshwater Withdrawal	4	As development continues inland, water demands in the Piedmont will affect freshwater flows from the major rivers that feed this system through water removals. A change in the amount of water in a wetland can alter the plant community.

4.3.8.5 Impacts to Wildlife

Appendix 3 contains list of SGCN and other priority species. Appendix 3-17 provides a list of the SGCN that depend on or are associated with this habitat type.

Secretive bird species such as Black Rail, King Rail, Virginia Rail, American Bittern, and Common Gallinule depend on the cover and forage provided by very dense cover of the tall grasses found in freshwater herbaceous marshes.

4.3.8.6 Recommendations

Current priority actions are to protect and restore fire to areas that will likely persist or migrate; blocking ditches that are now allowing saltwater into freshwater wetlands; and controlling the spread of non-native and invasive species. Many freshwater herbaceous marshes have already been lost, so there is also and equal priority to re-create this habitat through prescribed fire where ghost forests exist or where forests have succeeded due to lack of fire. There is also a need to protect the areas that will become tidal freshwater or brackish marshes as sea level rises.

Surveys

Priorities for conducting distributional and status surveys need to focus on SGCN believed to be declining or mainly dependent on this habitat type and on tidal freshwater wetlands, such as Black Rail and King Rail.

Monitoring

Monitoring is critical to assessing species and ecosystem health and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Long-term monitoring is needed to identify population trends and to assess performance of conservation actions. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Begin long-term monitoring, following survey data, for all populations of marsh birds, mammals, and reptiles that rely on this habitat type and that rely on tidal freshwater wetlands.

Research

Research topics that facilitate appropriate conservation actions include how to expand or re-create freshwater herbaceous marsh through restoration of natural hydrologic and fire regimes, how to facilitate the migration and re-creation of this habitat type given rapid sea level rise, habitat use and preferences, fecundity, population dynamics and genetics, and food web dynamics. Research must also be conducted to determine vulnerability of SGCN to specific threats, such as sea level rise. Studies should provide recommendations for mitigation and restoration.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Identify priority areas where hydrology and fire could be restored to enhance or re-create this habitat type to benefit secretive marsh birds and other species.

- Given appropriate hydrologic conditions, evaluate the effects of prescribed fire on this habitat type and on expanding this habitat type by burning adjacent shrub and forest. Study the effects of prescribed fire on the creation of this habitat type in the ecotone between brackish marsh and what is currently adjacent forest.

- Investigate how reduction in freshwater marsh and increases in higher salinity areas affect alligators.
  American Alligator

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Conduct research on fire management in marsh habitats to determine optimal frequency, timing, and firing techniques (e.g., flanking fire, backfire) to benefit priority birds.
• Investigate population densities, population growth rates, dispersal range, and extent of property damage from Nutria burrowing and herbivory. Nutria

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Use prescribed fire to burn portions of freshwater marshes to eliminate or set-back competing woody species. Mechanical cutting of woody vegetation may be more feasible in areas that cannot be burned.
• The use of shoreline hardening should be discouraged when other possibilities are available.
• Manage for moist soils, very shallow water levels (<1.5 in) and very dense herbaceous vegetation in appropriate impoundments, or old waterfowl impoundments near the coast, for Black Rail and other birds that rely on herbaceous freshwater marsh. Black Rail

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience. Work with land trusts, the Audubon Society, and The Nature Conservancy to identify priority sites needing protection.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Priorities for protection include Black Rail habitat once it is better identified and King Rail habitat. Black Rail King Rail
• Protect adjacent upland habitats that provide nesting areas for reptiles that use freshwater marsh habitats.
• Acquisition of agricultural or forested areas that could be restored to freshwater herbaceous marsh in the coastal plain is likely to be critical for the conservation of secretive marsh birds such as Black Rail and King Rail. Black Rail King Rail

4.3.9 Nonalluvial Mineral Wetlands

4.3.9.1 Ecosystem Description

Nonalluvial mineral wetlands occur on flat, poorly drained areas of the outer Coastal Plain and occasionally in shallow depressions such as Carolina bays. There may also be sites that fit this community description located in the Sandhills ecoregion. The soils in these sites are saturated in the wetter seasons, may have shallow standing water, and do not experience overflow flooding. The wetness comes from poor drainage and sheet flow from adjoining peatlands. The soils are less acidic and infertile than the peat soils of pocosins, but they do not have the regular nutrient input of river floodplains. Organic deposits are generally lacking, though occasional examples are found on organic soils where some other factor offsets the tendency of these soils to support pocosins.

In the wettest areas, bald cypress, swamp black gum, and red maple dominate. Where these areas transition to peatland, loblolly pine, pond pine, and Atlantic white cedar may also be present. In less saturated nonalluvial wetlands, trees characteristic of bottomland hardwood systems dominate: cherrybark oak, laurel oak, swamp chestnut oak, tulip poplar, sweetgum, American elm, and red maple. There are three community types that differ in wetness and the nature of the soil: non-riverine swamp forests, non-riverine wet hardwood forests, and wet marl forest.

- Non-riverine swamp forests occur in the wettest sites. They are dominated by trees tolerant of extreme wetness, such as bald cypress, swamp black gum, and red maple. A distinctive variant, transitional to peatland communities, has these species mixed with loblolly pine, pond pine, and Atlantic white cedar.

- Non-riverine wet hardwood forests occur in less wet areas. They are dominated by trees typically called “bottomland hardwoods”. The undergrowth is usually open beneath the closed canopy, but sometimes dense cane or shrubs occur.

- The wet marl forest type occurs where marl or limestone occurs near the surface and affects the soil. This extremely rare community is completely isolated, and is fragmented. Although they are wet, these soils are not acidic and are more fertile than most Coastal Plain soils. The vegetation is dominated by a diverse mixture of tree, shrub, and herb layers. Dwarf palmetto is an abundant and distinctive part of the shrub layer.

4.3.9.2 Location of Habitat

Examples of this habitat type can be found in the Alligator River, Swanquarter, and Great Dismal Swamp National Wildlife Refuges, Hofmann Forest, Rocky Point, and several swamps (Van and East Dismal) in Washington County.

4.3.9.3 Problems Affecting Habitats

The condition of nonalluvial mineral wetlands in the Coastal Plain is generally poor due to alteration of hydrology (primarily from draining for farmland and conversion to loblolly pine plantations) and is rather fragmented. Some of the best remaining examples are on public lands such as on Alligator River National Wildlife Refuge, Swanquarter National Wildlife Refuge, and the Great Dismal Swamp National Wildlife Refuge.

Nonalluvial mineral wetlands tend to be converted for forestry and agriculture more readily since mineral soils can support heavy equipment better than organic soils, and they are more fertile. Much of this type existed in Beaufort and Pamlico counties until recent years, relatively little remains. A higher percentage of this habitat type has probably been destroyed than any other type in the Coastal Plain, with the exception of dry longleaf pine.

Fire suppression has led to a decline in diversity of these habitats but the alteration of hydrology from ditches associated with farming and forestry practices is the biggest factor impacting this habitat type. Altered hydrology that drains these wetland types will decrease the ability to use prescribed fire as a management tool and increase the risk of catastrophic damage from wildfire. Non-native plant species (e.g., Chinese Privet, Japanese Stiltgrass) are also competing with native vegetation in many areas, especially those frequently disturbed. Although little of this quality habitat remains, it can be burned more safely than those sites with organic soils. Therefore, the potential still exists to re-establish some high-quality nonalluvial mineral wetlands on the Coastal Plain of North Carolina, where it has not already been converted to farmland or ditched for pine plantations.

4.3.9.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. While climate change is not the most severe threat, a combination of synergistic effects with other existing conditions could stress these systems to the point where several species are unable to persist.

Climate change is a significant threat primarily because of the likelihood of inundation from sea level rise. Rising sea level will be more of a concern in the larger riverine wetlands at lower elevations, such as those around the Alligator River, than wetlands further inland. However, other threats such as logging and the alteration of hydrology, in the form of ditches, pose equal threats to these systems.

Impacts to the non-riverine swamps and hardwood stands in the Albemarle-Pamlico Peninsula, which include the largest blocks of habitats of this ecosystem group in the state, are likely to be catastrophic. These stands are unlikely to be replaced by the development of new stands located farther inland.Table 4.3.8-1 summarizes the comparison of climate change with other existing threats.

Table 4.3.8-1 Comparison of climate change with other threats to nonalluvial mineral wetlands

Threat	Rank Order	Comments
Climate Change	1	Much of the protected acreage is in low elevation areas that are particularly threatened by rising sea level. Areas in Dare and Tyrrell Counties are already being converted to tidal communities and this effect is likely to accelerate.
Flood Regime Alteration	1	Hydrological alteration, in the form of ditches, increases the threat of rising sea level. Ditches bring tidal water into low-lying examples, causing it to penetrate inland into the nonalluvial wetlands.
Conversion to agriculture/silviculture	1	Nonalluvial mineral wetlands tend to be converted for forestry and agriculture more readily since the mineral soils can support heavy equipment better than organic soils, and they are more fertile. The condition of nonalluvial mineral wetlands is generally poor due to alternation of hydrology (primarily from draining for farmland and conversion to loblolly pine plantation) and is rather fragmented.
Invasive Species	2	Nonnative plant species (e.g., Chinese Privet, Japanese Stiltgrass) are also competing with native vegetation in many areas, especially those frequently disturbed. Several potential threats, including Chinese Tallow Tree and Gypsy Moth may become significant even if the climate does not change. Invasive species are currently a significant problem only in the rarer community types. Wet marl forest is highly threatened by invasive plants.

4.3.9.5 Impacts to Wildlife

Appendix 3 provides a list of SGCN and other priority species for which there are knowledge gaps and management concerns. Appendix 3-17 identifies SGCN that depend on or are associated with nonalluvial mineral wetlands.

These sites are important for a variety of neotropical migrants during the breeding season and migration periods (Hunter et al. 2000b; Johns 2004), and also several reptiles of conservation concern (NCWRC 2005). Wayne's Black-throated Green Warbler is nearly confined to non-riverine swamp forests throughout its narrow range from Virginia to South Carolina. This taxon is declining throughout its range, and loss of the population on the Albemarle-Pamlico Peninsula (believed to be the largest remaining) due to rising sea levels would significantly reduce the chances of its survival overall. Storm-related impacts to the Wayne's Black-throated Green Warbler could be particularly severe, since it is a canopy-dwelling species that is often found in the vicinity of tall conifers (likely nesting sites) that emerge above a canopy of hardwoods (Fussell et al. 1995). Likewise, the coastal population of the Worm-eating Warbler uses this habitat type heavily and is isolated from other populations that breed in the Mountains of North Carolina.

Even more likely to become extirpated is the sole population of Wood Frogs known to occur in the Coastal Plain of North Carolina. This population exists on the Albemarle-Pamlico Peninsula in the vicinity of hardwoods near Scranton and likely represents a relic from the Pleistocene epoch, as do several other animals and plants recorded in this area (e.g., cranberry, Sundew moth, undescribed shrew). The reasons for its restricted range in this area are unknown, but it may not be able to migrate inland to keep pace with sea level rise.

Nonriverine mineral wetlands are the primary habitat for the Red Wolf in the state, with most individuals being present at Alligator River and Pocosin Lakes refuges. Other large mammals also utilize these habitats, such as Black Bear, Bobcat, and White-tailed Deer.

Other terrestrial vertebrates and invertebrates associated with this ecosystem group occupy other types of habitat, including floodplain forests and peatlands, and are more likely to survive impacts associated with climate change. Two species of Canebrake Moths, however, are endemic to the North Carolina Coastal Plain and the portion of the Great Dismal Swamp in Virginia: *Lascopia roblei* and the still-undescribed *Apameine*, new genus 2, species 3. Some of their largest known populations are associated with non-riverine habitats, the loss of which would be significant, if not as damaging as for Wayne's Black-throated Green Warbler.

4.3.9.6 Recommendations

Recommendations are to restore or maintain hydrology, protect remaining Coastal Plain nonalluvial mineral wetlands, and control invasive species in these areas to intervene against climate change effects. The maintenance of contiguous gradients between wetland and adjacent upland sites is critical for seasonal migration and dispersal of herpetofauna. Site protection and protection of surrounding areas through land acquisition or easements and cooperation with land trusts are urgently needed, as large acreages (>500 acres) are frequently clearcut all at once for agriculture, pine conversion, or development.

Regional land trusts and The Nature Conservancy can be valuable partners in these efforts. Identified funding sources for acquisition include the Clean Water Management Trust Fund, Coastal Wetlands Grants, Natural Heritage Trust Fund, Forest Legacy Grants, and Recovery Land Acquisition Grants. Restoration efforts may be possible in some cases through partnerships with land trusts, the Nature Conservancy, and state and federal agencies.

The use of fire at the remaining unconverted nonalluvial mineral wetland sites is the single most important factor to restore these sites. Plowed firelines along transition zones between habitats should be rehabilitated (smoothed over) where possible. If feasible, fires should be allowed to sweep through the habitat or at least into the edges of the wetland from the adjacent upland sites. New firelines should be constructed when necessary. These areas should be maintained as a permanent narrow opening by discing with a tractor or by wetting with water or foam prior to a burn.

The maintenance of contiguous gradients between wetland and adjacent upland sites is critical for seasonal migration and dispersal of herpetofauna. Roads, agriculture, or forestry operations between complimentary sites may still render them ineffective at supporting amphibian and reptile populations. Where fire cannot be introduced back into the site for smoke management or other reasons, the use of a hydro-ax or other chipping machinery should be considered to control midstory (where funds allow).

Surveys

Priorities for conducting distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive communities:

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Determine the status of colonial nesting birds as well as neotropical migrants that are not well sampled by BBS and their use of this habitat.		
Yellow-crowned Night Heron	Wayne’s Black-throated Green Warbler	
• Document the status and distribution of priority bat species in this habitat.		
Rafinesque’s Big-eared Bat	Northern Yellow Bat Seminole Bat	Northern Long-eared Bat Southeastern Bat
• Conduct Eastern Woodrat surveys and subsequently establish standardized long-term monitoring of the species in this habitat.		
Eastern Woodrat		

Priority Conservation Action, Examples of Focal Species or Focal Habitats	
• Determine the status and distribution of rattlesnakes in this habitat.	
Timber (Canebrake) Rattlesnake	Pigmy Rattlesnake
• Survey for other SGCN and high priority species, especially herpetofauna.	
Lizards	Snakes
• Determine composition of vegetation and use this baseline data to monitor for changes to vegetation structure.	

Monitoring

Monitoring is critical to assessing species and ecosystem health and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Long-term monitoring is needed to identify population trends and to assess performance of conservation actions. Monitoring plans should be coordinated with other existing monitoring programs where feasible:

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Establish long-term monitoring for neotropical migrants that are not well tracked by BBS in this habitat type.
• Establish vegetation monitoring plots to detect phenological and plant structure changes.

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Research must also be conducted to determine vulnerability of SGCN and other priority species to specific threats and studies should provide recommendations for mitigation and restoration.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Conduct genetics research to determine if the Coastal Worm-eating Warbler is a separate sub-species.		
Worm-eating Warbler		
• Explore alternatives to using fire for the initial restoration of severely fire suppressed non-alluvial wetlands (e.g., mechanical treatments).		
• Determine why some priority species use this habitat on the coast, when the same species primarily is found in the Mountains using completely different habitats.		
Wood Frog	Wayne’s Black-throated Green Warbler	Worm-eating Warbler
• Conduct home-range and movement research on snakes of conservation concern.		
Timber (Canebrake) Rattlesnake	Pigmy Rattlesnake	

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Reintroduction of fire to unconverted nonalluvial mineral wetland sites is the single most important factor to restore these sites.
• Plowed fire lines along transition zones between habitats should be rehabilitated (smoothed over) where possible. New fire lines should be constructed when necessary. These areas should be maintained as permanent narrow openings by discing with a tractor or by wetting with water or foam prior to a burn.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Control tide water penetration and saltwater intrusion with tide gates where feasible.
• Where fire cannot be introduced back into the site for smoke management or other reasons, the use of a hydro-ax or other chipping machinery should be considered to control midstory.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Site protection and protection of surrounding areas through land acquisition or easements and cooperation with land trusts are urgently needed, as large acreages (>500 acres) are frequently clearcut all at once for agriculture, pine conversion, or development.
• Restoration efforts may be possible in some cases through partnerships with land trusts, the Nature Conservancy, and state and federal agencies.

4.3.10 Pocosins

4.3.10.1 Ecosystem Description

Pocosin habitats are those parts of eastern North Carolina characterized by flooded, acidic, anaerobic soils with limited decomposition and accumulating biomass. Peat deposits develop where the soil is saturated for long enough periods that organic matter cannot completely decompose. Once peat has developed, it holds water, raising water levels in the soil and making the site wetter. The shallow water tables and patterns of normal flooding result in anaerobic soil conditions that slow decomposition of biomass. Soils are acidic and nearly sterile, with available nutrients provided from periodic surface flooding of adjoining landscapes and from precipitation. The soils of streamhead pocosin habitats are flooded, acidic, and infertile.

Peatland pocosins occur on nearly flat, poorly drained areas of the outer Coastal Plain and in large shallow depressions such as Carolina bays. Streamhead pocosin habitats are patchy and limited to ravines that are permanently flooded by acidic seepage and run-off from adjacent hills. Fire history, hydrology, and drainage influence the composition of the community type, with some unfragmented examples occupying many thousands of acres.

Natural community types are determined by variation in wetness, depth of peat, and fire dynamics and include: streamhead pocosin, low pocosin, high pocosin, Pond Pine woodland, peatland and streamhead Atlantic White Cedar forest, and bay forest. The distinction between these community types may seem clear, but there are significant overlaps in the characteristics of the soils, wildlife, and plant species that occur across them.

- Streamhead pocosin plant community compositions can range from dense shrub thickets to treeless canebrakes. The natural fire cycle results in open canopy pond pine forests. However, fire suppression leads to pond pine forests with a dense shrub understory. The understory is dominated by a dense evergreen shrub layer including several members of the laurel and holly families and is frequently tangled with Laurel-leaf Greenbrier. Herbs are nearly absent except in the edge (ecotone) with neighboring sandhill communities. These ecotones often support a high diversity of herb and shrub species including many rare ones.

- Low pocosins occur on the deepest peats, in the interior of large domed peatlands, and in the largest peat-filled Carolina bays. They are the wettest, most nutrient-poor sites and support only low shrubs and scattered stunted pond pine trees. Often beds of pitcher plants and sphagnum moss cover large areas and bog species such as cranberries occasionally occur.

- High pocosins occur in somewhat less deep peats. The shrubs, up to six or eight feet tall and impenetrably dense, are generally laced together with greenbriers and punctuated with sparse stunted pond pines.

- Pond Pine woodlands occur on shallow organic deposits on the edge of peatlands and in shallow swales and bays, where tree roots can grow through the thin organic layer to reach mineral soil below. Pond Pines are tall and often fairly dense and the shrub layer is tall and usually very thick. In some pond pine woodlands the dense shrub layer is replaced by canebrakes.

- Peatland Atlantic White Cedar forests occur in sites similar to pond pine woodland or high pocosin but are dominated by Atlantic White Cedar instead of pond pine. In the few remaining places where fire is frequent, streamhead Atlantic White Cedar forests are dominated by Atlantic White Cedar, though any of the species of the streamhead pocosin type also may be present in small numbers. The canopy is often dense enough that the shrub layer is fairly open. Atlantic White Cedars are sensitive to fire, but depend on fire to prepare a seedbed for regeneration. These communities probably can persist only where fire is infrequent; however, fire suppression for many decades can lead to the cedars being overtaken by widespread hardwood species such as Red Maple or Sweetgum.

- Bay forests may occur in similar sites, but they are usually more associated with creeks draining out of peatland pocosins. They have a canopy dominated by evergreen hardwood Loblolly Bay, Redbay, and/or Sweetbay.

4.3.10.2 Location of Habitat

Extensive examples of pond pine woodlands exist in the Green Swamp, at Alligator River National Wildlife Refuge, Pocosin Lakes National Wildlife Refuges, Holly Shelter Game Land, and in Dare County at the Dare Bombing Range. Atlantic White Cedar-dominated communities still exist at Alligator River and Pocosin Lakes National Wildlife Refuges, and in the Great Dismal Swamp. There is a significant sized stand of Atlantic White Cedar in the Buckridge Preserve (Tyrell County), the only inland site that is part of the NC Coastal Reserve.

Examples of fire-managed streamhead pocosin can be found on Sandhills Game Land, Fort Bragg, Croatan National Forest, and Camp Lejeune Marine Corps Base. The Croatan National Forest, Dare Bombing Range, Camp Lejeune, and Holly Shelter Game Land do conduct some pocosin burns, but all other fire introduced into pocosin habitats tends to be on small acreages (less than 100 acres).

4.3.10.3 Problems Affecting Habitats

Peatland pocosin is a large, dominant habitat in the eastern part of the state and once occupied nearly 3 million acres from Virginia to Florida, with about 70% occurring in North Carolina. Only about 750,000 acres remain, with most of the area lost used for agriculture, forestry, and peat mining.

Land Use. Logging, particularly of Atlantic white cedar and pond pine stands, altered flood regime through ditching, constructing impoundments to store water, fire suppression, and conversion to agriculture or silviculture that fragment communities can significantly impact pocosin ecosystems. The hydrologic changes resulting from ditches and canals developed to drain peatland pocosins for agriculture and forestry reduce the water holding capacity of the ecosystem and can alter the chemistry of nearby estuaries. The ditches and canals result in the rapid drainage of rainwater into estuaries that become loaded with sediment and nutrients. The deluge of freshwater into estuaries causes salinity values to plummet while the nutrients cause eutrophication and oxygen depletion. The result is severe alteration of habitat needed for wildlife in river mouths and estuaries near shore.

Fire Suppression. Fire return intervals vary widely depending on vegetation, hydrology, and extent of organic soils. Fire suppression takes the peatland pocosin out of the normal 25- to 50-year burn cycle and allows the build up of fuel, because the acidic habitat has slow decomposition and rates of soil formation. The build-up of fuel increases vulnerability to fires during dry summers. Impacts of fire suppression lead to larger, hotter fires in the vegetation and can cause ignition of peat fires that are difficult to extinguish. Similarly, the streamhead Atlantic White Cedar forest composition is affected by the fire cycle: fire suppression leads to accumulating fuel loads and a layer of thick, understory shrubs, and hardwood saplings.

4.3.10.4 Climate Change Compared to Other Threats

Overall, climate change is not the most significant threat to peatland pocosins. The most pressing climate change impacts on peatland pocosins will be from intense precipitation events and intense fire events. Other important climate change events will be from wind damage to tree species that do not regenerate and saltwater intrusion from storm surge and sea level rise. Tropical storms are predicted to become more frequent, larger, and more intense with rainfall larger than in the past. Larger rainfalls connected with violent storms will add to drainage problems in estuaries.

Pocosins play an important role in climate change by acting as a carbon sink, thereby mitigating CO_2 emissions from human activities. The carbon gained by pocosin ecosystems through photosynthesis is taken from the atmosphere and stored in biomass that does not decompose. The primary productivity of pocosins offsets CO_2 emissions produced through use of fossil fuels and land use activities.

Pocosin communities can also be large carbon sources, adding CO_2 to the atmosphere. For example, if vegetation burns, CO_2 is released into the atmosphere adding to the greenhouse gas effect driving climate change. If peat burns, the CO_2 release will be much larger than from just the vegetation alone.

Predicted warmer temperatures and longer summer droughts will lead to increased fires. Burning vegetation and peat will generate large amounts of greenhouse gases. The change in landscape from large fires fed by climate change factors and fire suppression will burn hotter, longer, and cover more area than occurred in the natural fire cycle. The new burning cycle will compromise the quality of the habitat needed by wildlife. Table 4.3.9-1 summarizes the comparison of climate change with other existing threats.

Table 4.3.9-1 Comparison of climate change with other threats to pocosins

Threat	Rank Order	Comments
Logging/ Exploitation	1	Unprotected white cedar and pond pine stands continue to be logged and often do not regenerate.
Flood Regime Alteration	2	Ditching for drainage and for road construction alters communities, increases wildfire damage, and likely exacerbates effects of droughts. Ditches will bring tidal water into peatlands and will hasten their destruction. Impounding effects of roads also alter hydrology in some peatlands, and may have increasing impact if rainfall events become more extreme.
Fire	3	Loss of natural fire has altered communities and ecosystem processes. Deep peat fires in artificially drained areas cause lasting damage to communities. Increased wildfire or increased temperature may actually be ecologically beneficial in some areas, but could be detrimental in others that have been ditched and could cause excessive peat consumption. Extreme wildfires in deep peat can result in depressions several feet deep. These areas could fill with water in wet years and create freshwater marsh type conditions.
Conversion to agriculture/ silviculture	3	Pocosins on private land have largely been ditched and converted to loblolly pine plantations by the forest products industry. While deeper peats resist conversion, pine plantations continue to replace pond pine woodland and peatland Atlantic white cedar forest.
Climate Change	4	Areas that occur in the lowest elevations may be lost to sea level rise due to saltwater intrusion and inundation. Loss of significant minority acreage is a likely threat. Other threats are very uncertain.

4.3.10.5 Impacts to Wildlife

Appendix 3 provides a list of SGCN and other priority species for which there are knowledge gaps and management concerns. Appendix 3-17 identifies SGCN that depend on or are associated with this habitat type.

In general, little detailed information exists for many wildlife species that use pocosin habitats because of the impenetrable nature of these communities. Few surveys have been done on a long-term basis, which makes land management decisions difficult. We also lack detailed information about populations of small mammals, bats, reptiles, and amphibians in pocosin habitats (Mitchell 1994). Black Bears are dependent on the large undisturbed areas that pocosins offer in the east. Further reduction in this habitat type could impact bear populations.

The remoteness and thickness of the vegetation in the peatland pocosin makes it the ideal habitat for resident and migratory species and protects them from human disturbance. Pocosins are particularly important for wintering birds because of the high amount of soft mast available. Greenbrier, Red Bay, Sweet Bay, and many ericaceous shrubs produce large quantities of berries that are persistent through much of the winter. In more extensive pocosins, such as the Alligator River refuge, Prairie Warblers and Prothonotary Warblers are quite common in the breeding season, and Gray Catbirds are numerous as well.

A study by NCWRC in the Sandhills demonstrated a high territory density of shrub nesting birds in fire-managed streamhead pocosin, including Common Yellowthroat, Indigo Bunting, Eastern Towhee, and Yellow-breasted Chat. This same study found a relatively high density of cavity nesters such as Brown-headed Nuthatch, Red-headed Woodpecker and Carolina Wren. Fire-suppressed streamhead pocosins supported significantly lower densities of nine bird species but had higher numbers of Carolina Chickadee, Hooded Warbler, and Red-eyed Vireo.

Pocosin habitats are important for a variety of shrub-scrub birds, though we lack status and distribution data (Karriker 1993). Red-cockaded Woodpeckers exist in some of these pond pine-dominated sites where suitable habitat also occurs in the uplands. However, loss of this fire maintained habitat has caused fragmentation of Red-cockaded Woodpecker habitat across the landscape.

There is a significant lack of information about populations of small mammals, bats, reptiles and amphibians in pocosin habitats (Mitchell 1994). Sandhills Salamander (*Eurycea* n. sp. 9) is endemic to this habitat (in streamhead pocosins) and is the species most at risk to alterations of hydrology and fire frequency due to climate change. Other species associated with this ecosystem include Pine Barrens Treefrog, a species with strong associations to Sandhill streamheads. These species occur in other types of habitat and are not as confined to the Sandhills ecoregion.

4.3.10.6 Recommendations

Though extensive amounts of pocosin land are already protected, some specialized types require more protection, such as Carolina bays (Bladen Lakes area) and white cedar stands. Land managers and planners need to address management issues related to pocosin habitats in their conservation and land-use planning efforts. They should also work to understand what the public wants and is willing to accept regarding the management of pocosin habitats and the wildlife associated with these habitats (Thompson and DeGraaf 2001 in NCWRC 2005). Protecting additional inland examples will help mitigate the loss of those that lie near sea level.

The most important management needed for these systems is restoration of fire, which will over time reverse the alteration in natural composition and structure. While of general ecological benefit, burning will also reduce the risk of uncontrollable or damaging wildfires during droughts caused by climate change, and the more robust natural vegetation will be better able to withstand all kinds of climate-related stress.

Surveys

Priorities for conducting distributional and status surveys need to focus on species believed to be declining, at risk, or mainly dependent on pocosin communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Determine status and distribution for neotropical migratory birds that use this habitat.

Black-billed Cuckoo	Swainson's Warbler	Wayne's Black-throated Green Warbler
	Worm-eating warbler	

Monitoring

Monitoring is critical to assessing species and ecosystem health and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Long-term monitoring is needed to identify population trends and to assess performance of conservation actions. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Develop or enhance long-term monitoring for breeding and wintering birds, amphibians and reptiles, and mammal populations (including bats) that use this habitat (Ellis et al. 2002; Taylor II and Jones 2002).

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Research must also be conducted to determine vulnerability of SGCN and other priority species to specific threats and studies should provide recommendations for mitigation and restoration.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Examine the relationship between habitat patch size and nesting success of shrubland birds and habitat use by small mammals.

  Shrubland birds   Small mammals

- Determine the best ways to burn these sites or develop alternative management strategies and methods that will mimic the effects of fire at sites where birds, mammals, reptiles, and amphibians are being monitored.

- Determine how the use of chipping (using a hydro-ax or other heavy chipping machinery) midstory and understory vegetation affects the plant and animal communities. This practice is becoming more common, particularly in areas where Red-cockaded Woodpeckers are present.

- Conduct studies to obtain basic demographic information on priority birds, small mammals, amphibians, and reptiles.

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Restore hydrology by reversing the effects of artificial drainage, as this is probably the most important action to protect pocosins.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Institute a prescribed fire regime, especially on conserved lands. Burning can often be accomplished on uplands without the use of fire-lines in transition zones between upland sites and pocosin habitats (especially in winter). This promotes a healthy transition zone between the two habitats that is critical for many plant species and allows for nutrient flow to some pocosin habitats.

Conservation Practices and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Focus land acquisition on consolidating these areas into larger holdings so that they may be managed through fire.
• Discern and offer increased protection to specialized pocosin types. Though extensive amounts of pocosin lands are already protected, some require more protection, such as Carolina bays (Bladen Lakes area) and white cedar stands. Carolina bays

4.3.11 Upland Pools and Depressions

4.3.11.1 Ecosystem Description

Small, isolated wetlands, such as upland pools and depressions, are important areas of diversity for plants and animals, especially specialized amphibians that require these habitats for breeding. Upland pools and depression communities occur in all regions of North Carolina. Typically, they include shallow depressions which hold water in wetter parts of the year. Many are ephemeral, drying during some part of the year (often in summer), but are flooded long enough into the growing season to contain wetland vegetation that contrasts with the surrounding uplands. Water levels usually fluctuate over the course of a season, and also from year to year.

Communities differ in overall hydroperiod, in soil, in slope, and in depth. Hydroperiod is the length of time that there is standing water at a particular location; it can also be defined as the number of days per year that an area of land is dry (Gaff et al. 2000). Some ephemeral (temporary) pools are wet enough to accumulate muck on the bottom, while others remain sandy.

Upland pools and depressions can be categorized into one of several types, including the following:

- Upland pools that occur in sites where the water is deep enough or long-standing enough to prevent development of a closed tree canopy. The vegetation varies widely, and it is likely that this type could be split into several community types. Trees of the Upland Depression Swamp Forest community type may occur around the edges.

- Upland depression swamp forests that occur in shallower depressions than upland pools, and are flooded for shorter periods. They usually occur on broad upland flats but occasionally on high ridge tops. They have a closed canopy of wetland trees. Understory, shrubs, and ground cover are usually sparse.

- Ephemeral (temporary) pools that are small, seasonally flooded depressions with gently sloping sides and are usually found in sandy uplands.

- Seeps that occur along slopes where groundwater trickles out of the surface and collects in small pools and will often trickle into streams.

- Clay-based upland depressions that typically occur as oval or round depressions with a clay base that allows them to hold water for at least a portion of the year. In the Sandhills and Coastal Plain, these depressions historically have had a longleaf pine upland where hot season fires burned regularly, creating an open-canopy, grassy wetland system with long hydroperiods.

In the Coastal Plain and Sandhills ecoregions, pond basins may also be limesink depressions, Carolina Bays, or swales between recent or older sand dunes.

- Limestone sinks occur over limestone formations. Scattered trees (Pond Cypress and Swamp Blackgum) may be present in both deep and shallow water zones and most ponds are surrounded by a dense shrub layer. These shrubby zones provide breeding habitat for shrub-scrub-nesting birds (Hunter et al. 2001a; Johns 2004) and these sites are used by wading birds for foraging/nesting and amphibians for breeding.

- Swale wetlands occur on barrier islands, such as in the Outer Banks, in areas where the freshwater aquifer saturates the soil and collects on the surface between sand dunes. These ponds will also have dense maritime shrublands in areas where water is shallow, in deeper water they are characterized by emergent and submerged aquatic vegetation.

- Carolina bays with organic/ peat substrates are relatively deep closed basins associated with pocosins, depression swamps, Pond Pine woodlands, bay forests, or Atlantic White Cedar forests. Occasionally they occur in shallow depressions associated with nonriverine communities such as swamp forests, wet hardwood forests, and wet marl forests with nonalluvial mineral soils (NCNHP 2010).

All of these natural community types often have abundant amphibian species. Those that dry annually or semi-annually benefit amphibians the most, due to the absence of fish, which would typically eat amphibian eggs and larvae. During heavy storm events, however, fish can be swept in by overbank flooding, reducing the suitability of these pools for amphibian breeding until they dry out again.

4.3.11.2 Location of Habitat

Upland depression communities occur throughout NC but are often overlooked features on the landscape mainly because they are difficult to discern on aerial photographs unless they are quite large. In the Piedmont and in the Mountains, these small wetland communities can be found on broad upland flats and occasionally on high ridge tops. Ephemeral (temporary) pools are usually found in sandy uplands. Those that occur in the Piedmont are associated with mafic rocks or shale. Those in the Mountains occur on quartzite. Examples include Frogsboro Upland Depression Forest in Caswell Game Land; Badin Upland Depression Swamps in the Uwharrie National Forest; Meadow Flats in Duke Forest; and Bog Hole (Seventeen Frog Pond, Grassy Pond) in Sandhills Game Land in Scotland County (an unusually wet example, transitional to Small Depression Pond).

Carolina bays and limestone sinks are probably the best known examples of isolated wetlands in NC because they are easy to view on aerial or infrared photos of the region and they are generally obvious on the landscape. Carolina bays and clay-based upland depressions occur throughout the Coastal Plain, whereas limestone sinks tend to occur in clusters in areas along the lower Coastal Plain – numerous limestone sinks are visible around the Boiling Springs Lakes area in Brunswick County, NC.

4.3.11.3 Problems Affecting Habitats

Isolated, ephemeral wetlands are regarded as one of the most endangered, and simultaneously one of the most biologically productive habitats in North America. Wetlands of this type are characterized by unique assemblages of flora and fauna that are not associated with permanent-water wetlands. In the southeast, they serve as critical breeding habitat for several endangered species of amphibians. Many declining species of plants and animals depend on, or use, isolated, temporary wetlands.

Land Use. Across the Southeast, most of these systems have been lost to draining for agriculture, commercial silviculture, and development. Others have been altered to retain the permanent water necessary to support fish populations. Further, many of the temporary wetlands that remain on the southeastern landscape have been greatly affected by lack of fire that would have naturally maintained them in an early successional condition. The resulting colonization by large overstory trees significantly alters these wetland systems such that they no longer support many of the rare species that depend on them.

The vegetation of upland ephemeral pools varies widely because of natural and human-induced differences among ponds. Factors related to human-induced changes such as ditching and lowering of water tables through agricultural and urban uses have caused some pools to completely dry or revert to forested wetlands. Some upland ephemeral pools are maintained as open-canopy emergent wetlands because of naturally long hydroperiods that prevent the colonization of trees and shrubs (e.g., limestone sinks with a groundwater connection).

Prescribed Suppression. However, many upland, isolated wetlands would have historically been maintained as open, “grassy” ponds through a combination of hydroperiod and fire regime processes (DeSteven and Toner 2004). In these situations, summer fires would occasionally burn through the dry basins, limiting the establishment and growth of fire-intolerant woody species and controlling the buildup of excessive amounts of peat (Florida Natural Areas Inventory 1990). Specifically, vegetation of clay-based depressions has been altered by fire suppression or exclusion in adjacent uplands, ditching of wetlands, or by intentional fire exclusion by maintaining fire lines around wetland habitats. Even where fire has been re-introduced into the longleaf pine ecosystem in the Southeast, most managers use winter or spring burning instead of hot, summer fires that would have naturally occurred in the past. Winter or spring fires usually do not burn through wetlands because water is often present in the pond basin at that time of year. Indeed, fire suppression or exclusion has been linked to the encroachment of trees into historically treeless ponds in the Southeast (Kushlan 1990; Kirkman et al. 1990; De Steven and Toner 2004).

Hydrologic Changes. The reduction of open-canopy, ephemeral ponds is a major reason for the loss of populations of some southeastern amphibian species (e.g., Gopher Frog) that depend on them exclusively for breeding (LaClaire 2001). Additionally, the encroachment of trees into temporary wetlands can have multiple adverse effects on the larvae of many amphibian species (Schiesari 2006;Thurgate and Pechmann 2007; Werner and Glennemeier 1999). The most obvious effect is increased evapotranspiration in the pond resulting in a shorter hydroperiod (Sun et al. 2001). Shorter hydroperiods may not allow larval amphibians enough time to reach metamorphosis (Skelly 2004).

Vegetation Changes. Shading of ponds can also lower the pond’s water temperature, slowing the growth and development of larval amphibians (Blaustein et al. 1999; Skelly et al. 2002). Ponds with significant canopy cover may also suffer from lowered oxygen availability (Skelly et al. 2002) and reduced algal communities (Skelly and Golon 2003), both of which have detrimental effects on larval amphibian growth and survival. Further, increases in leaf litter associated with the establishment of overstory trees can substantially lower the pH in these degraded wetlands. Evidence exists that breeding habitats can indeed become too acidic for the successful hatching and rearing of some southeastern amphibian larvae (Braswell 1993 and references therein).

4.3.11.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. In this comparison, the greatest threat to depression communities is likely to be habitat conversion. Habitat conversion occurs for various reasons, including suppression of natural fire regimes, development, and land use changes. Drier basins are destroyed by development or conversion to pine plantations, while wetter ones are degraded by these activities on the surrounding uplands. In protected examples, alteration of hydrology and effects of fire suppression are usually the most serious threats.

Climate change is likely to exacerbate existing effects, increasing the number and severity of droughts and increasing the amount of evaporation even in years of normal rainfall. If increased drought and severe weather reduces the ability to conduct prescribed burning, this may reduce fire even in the few examples that are getting burned. With respect to climate change, however, upland pools and their associated species are likely to respond differently from the surrounding forests. Table 4.3.10-1 summarizes the comparison of climate change with other existing threats.

Table 4.3.10-1 Comparison of climate change with other threats to upland pools and depressions

Threat	Rank Order	Comments
Logging/ Exploitation	1	Shallower examples may be destroyed by development or heavily altered by logging. Logging when the ground is wet creates permanent ruts as well as altering canopy structure and composition. Clearcutting near ephemeral wetlands causes higher solar radiation and an increase in the probability of wetlands drying out; also, timber harvest may introduce weedy plant invasions of wetlands.
Development	1	Piedmont wetland habitats are heavily impacted by, and have been greatly reduced by, development, roads, and drainage throughout the region. Wetter examples are degraded by development of surrounding areas.
Climate Change	2	Some models predict that rainfall will be concentrated during the fall and that there will be increased droughts in the spring and summer. This may reflect an expectation of increased hurricane activity rather than well-distributed rainfall. There is also a general expectation that both droughts and extreme rainfall events will become more common.
Flood Regime Alteration	3	Drainage ditches have affected some examples, and alteration of drainage by roads has altered some other examples. Includes artificial drainage and Beaver impoundment effects. Beaver ponds can be a nuisance to landowners when they flood farm fields or commercial timber. Pools located in floodplain terraces that now rarely flood may experience greater flooding in the future due to more frequent severe storms.
Invasive Species	3	Invasive species are not a significant problem in these systems at present. Increased canopy opening and shortened hydroperiod will make them more susceptible to invasion by Japanese Honeysuckle, Japanese Stiltgrass, and possibly Asian Dayflower. Fire Ants, which are not abundant in the Piedmont at present, are likely to increase with warmer temperatures. They represent a threat to these communities, and may represent an additional indirect threat if they harm amphibians in the uplands. The introduction of fish, bullfrogs, and other predatory species can devastate the breeding effort of amphibians in small wetlands.

4.3.11.5 Impacts to Wildlife

Appendix 3 contains a list of SGCN and other priority species for which there are knowledge gaps and management concerns. Appendix 3-17 identifies SGCN and other priority species that depend on or are associated with this habitat type.

Members of this community all make use of upland pools for breeding, but make use of floodplain pools as well, at least where they are fairly well isolated from frequent overbank flooding. Windthrow pits may also be used and Four-Toed Salamanders, in particular, make frequent use of seepage habitats. All Piedmont wetland habitats are especially important as breeding sites for amphibian species. Small wetlands can also be important breeding habitat for crayfishes. Wading birds, waterfowl, and songbirds may also use small wetland communities for nesting and feeding areas.

While often small in size, cumulatively these habitats provide critical breeding habitat for many amphibian species. Ephemeral and isolated wetlands are very valuable to amphibians because they typically do not support fish and other predators of amphibian eggs. The loss of ephemeral wetland communities in the Piedmont has strong ramifications for future amphibian populations. Amphibians in these communities depend on the surrounding uplands, and populations are lost or much reduced if the surrounding habitat is destroyed or altered. Pool-breeding amphibians that make use of these pools may potentially be as adversely affected by these changes as those associated with upland pools are by increased frequency of drought.

Increased road densities are correlated with declines in amphibian diversity and abundance (Vos and Chardon 1998; Findlay et al. 2001; Fahrig et al. 1995). Roads can cause heavy mortality for reptiles and amphibians and can effectively isolate breeding populations, or separate wetland habitats from upland habitats that are used during non-breeding portions of amphibian and reptile life cycles. The increase in impervious surfaces from the proliferation of roads causes excess stormwater runoff and pollution from point and nonpoint sources, which degrades water quality. Most amphibians are highly sensitive to changes in water quality.

All are likely to be strongly affected, particularly upland populations, by increases in prolonged droughts associated with climate change. Increased drawdown of groundwater levels, also the result of prolonged drought as well as increased human utilization, particularly in times of surface water scarcity, is another major threat for populations associated with floodplain pools or seeps. Floodplain pool populations are additionally likely to be adversely affected by increases in overbank floods that carry fish into their breeding sites. These impacts may be offset to some extent, however, by increases in the number of windthrow pits resulting from heavier storm damage.

4.3.11.6 Recommendations

These communities are isolated and contrast strongly with the surrounding uplands. They will be unable to migrate. The most important actions needed for these communities are to protect unprotected examples and to protect or restore the surrounding uplands for as many of these wetland communities as possible. As more examples are lost, the remaining ones will become increasingly important for the survival of amphibian populations.

Seasonal wetlands must have sufficient surrounding habitat to support the life history requirements of amphibian and reptile populations. It is particularly important to protect the larger and wetter examples, which are more likely to persist in drier conditions. With more extreme weather, species populations in individual basins may become less stable and more dependent on metapopulation dynamics for their long-term survival. Where they can be protected or established, connections between examples will become even more important than at present.

Surveys

Priorities for conducting distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Investigate the status and distribution of species associated with Piedmont wetland habitats.

  Common Ribbonsnake   Three-lined Salamander

- Survey for all amphibian species associated with small wetland communities.

Monitoring

Monitoring is critical to assessing species and ecosystem health and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Long-term monitoring is needed to identify population trends and to assess performance of conservation actions. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Determine population trends and persistence of small wetland breeding amphibian populations.

  Dwarf Salamander   Eastern Tiger Salamander   Mole Salamander

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
	Four-toed Salamander	
• Monitor amphibian populations to detect incidence of fungal and viral infections.		
Bsal	Iridoviruses	Chytridiomycosis

Research
Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Research must also be conducted to determine vulnerability of SGCN and other priority species to specific threats and studies should provide recommendations for mitigation and restoration.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Determine minimum upland buffers required to sustain at-risk amphibian populations.
• Explore management strategies to eradicate undesirable species, such as bullfrogs, from wetlands.
• Study the efficacy and practicality of “toad tunnels” and other wildlife crossings that allow passage under roadways and help maintain connectivity between wetland metapopulations.
• Investigate minimum hydroperiods needed by priority amphibian species that utilize ephemeral pools and wetlands. Results can be used to determine when supplemental measures or intervention is needed to support breeding periods and metamorphosis during drought periods.

Management Practices
Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Employ hydrological restoration methods such as plugging ditches where ditches are affecting the hydrology of the pools.
• Promote the adoption of agricultural and forestry best management practices (BMPs) that reduce run-off, erosion, and pollution. The federal Farm Bill and other cost share programs provide incentives for land stewards to adopt these practices.
• Growing season prescribed fire when the wetlands are dry is preferred. Where growing season burns cannot be administered, winter burns can be constructive. Burning should be accomplished without placing fire lines in transition zones from uplands to wetlands and with the fire allowed to burn through transition zones. If this cannot be done initially, consider returning to burn the wetland once it is dry to prevent overgrowth within the basin.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the greatest extent possible to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but overall it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Make every effort to maintain continuous gradients between wetland and upland sites; roads, agriculture, or forestry operations between complimentary sites may render them ineffective at supporting amphibian and reptile populations (Bailey et al. 2004).
• Provide for habitat connectivity between nearby upland pools and other wetlands or surface waters.
• Place high priority on protecting wetlands and adjacent uplands through acquisition or easement.

4.3.12 Upland Seepages and Spray Cliffs

4.3.12.1 Ecosystem Description

The communities included in upland seepages and spray cliffs are wetlands that occur on sloping uplands and can be found across the state. The soils are generally saturated permanently or for long periods. They are generally fairly small and contrast sharply with adjacent communities, though boundaries may be gradational. There are four communities in this ecosystem group: spray cliffs, hillside seepage bogs, low elevation seeps, and high-elevation seeps. Spray cliffs are areas kept wet by spray from waterfalls. The other three community types are fed by groundwater seepage and their soils are saturated for much or all of the year, but they are seldom, if ever, flooded.

- Most spray cliff areas are vertical cliffs, but gentle slopes, talus, and soil at the base of cliffs are also included. Vegetation is very patchy, reflecting the patchiness of soil accumulations. The microclimate is generally moderated by the flowing water and sheltered position of the cliffs. Though water flow may vary with rainfall, these are probably among the most stable environments in North Carolina. Trees rooted in crevices and between rocks often grow to large size and may shade the entire area. The bare wet rocks generally have a great diversity of mosses and liverworts. Herbs in small soil pockets include a wide variety of forbs, ferns, and sedges.

- The rarest type is the hillside seepage bog. These communities are wet enough to have boggy vegetation. The vegetation is generally a patchy mix of shrubs and herbs with an open tree canopy. Many species characteristic of the Coastal Plain occur in these communities. Fire may have played a role in keeping hillside seepage bogs open enough to allow persistence of light-requiring bog species.

- Low elevation seeps, occurring in uplands or edges of floodplain throughout much of the state, are also very wet but differ in vegetation. The factors which cause these differences are poorly known. Trees such as red maple may be present, or the seep may be shaded by canopy species from adjacent forests.

- High-elevation seeps occur in the higher Mountains, where they are surrounded by Spruce–Fir forests, northern hardwood forests, or grass and heath bald communities. High-elevation seeps are quite variable in vegetation and setting. Some are open and somewhat boggy, with peat moss, sundews, and even cranberries present. Others are shaded by canopy and more closely resemble a rich northern hardwood forest.

4.3.12.2 Location of Habitat

This group of communities covers a wide geographic range in the Mountains and Piedmont ecoregions. High-elevation mountain seepage communities are usually surrounded by Spruce–-Fir forests, northern hardwood forests, or grass and heath bald communities. Low elevation seeps tend to occur at the bases of slopes in the Piedmont and lower Mountains, just above a floodplain. Spray cliffs are more likely to occur in gorges and riverine areas. Examples of spray cliffs can be found in the Nantahala National Forest, Bonas Defeat Gorge on the Tuckasegee River in Jackson County, Reid Branch waterfalls in Transylvania County, Phillips Branch waterfalls in Caldwell County, and the Dismal Creek waterfalls in Transylvania County (Stevenson 2015).

4.3.12.3 Problems Affecting Habitats

Threats to individual seepages and spray cliffs are extremely variable and include invasive plants; death of Canada hemlock trees due to the Hemlock Woolly Adelgid; development on or adjacent to the community; recreational trampling; stream flooding and scouring or downcutting; depletion of ground water pools that supply seepage; ditching or drainage; increased temperatures in sheltered refugia; and vegetational succession in the absence of fire or other natural disturbance. This ecosystem is highly threatened overall, with or without climate change.

The communities located at high elevations are the most likely to be affected by increased temperatures. Some distinctive high-elevation species may be lost, while some lower elevation species may be able to migrate into them. Warmer temperatures may allow exotic species to invade. Some seeps have increased in tree cover due to fire suppression or other alterations, and loss of tree cover may be positive in some examples.

4.3.12.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. While climate change is not the most severe threat, a combination of synergistic effects with other existing conditions could stress these systems to the point where several species are unable to persist.

The effect of a changed climate is likely to vary widely among examples of these communities, depending on topographic sheltering, configuration of rocks, soil depth, size of groundwater pools, and amount of overland runoff. These systems are tied to specialized small environments and will be unable to migrate as the climate changes. Many may change very little, while a few will shrink, be disturbed by wind or flood, or change substantially because of temperature changes or drought. A small net loss of acreage may occur, but more seeps may be temporarily affected by drought. Table 4.3.11-1 summarizes the comparison of climate change with other existing threats.

Table 4.3.11-1 Comparison of climate change with other threats to upland seepages and spray cliffs

Threat	Rank Order	Comments
Groundwater Depletion	1	Droughts may cause seeps supplied by shallow ground water to dry up. If drought increases wildfire, it might be of benefit to some examples, but fires are generally easy to control in the uplands around seeps.
Flood Regime Alteration	1	Spray cliffs may be subject to scouring if intensity of floods increases. Some low elevation seeps are on the edge of floodplains, and increased intensity of rainfall events might increase flooding of them.
Development	1	Development may not have direct impact, but may increase access (and therefore trampling) or lead to utility easements (e.g., sewer lines) that cross seepage habitats.
Climate Change	1	Climate change may pose a significant threat, but no more than these other problems.
Invasive Species	1	These communities are susceptible to invasive species, which may be exacerbated by climate change.

4.3.12.5 Impacts to Wildlife

Appendix 3 provides a list of the SGCN and other priority species for which there are knowledge gap and management concerns. Appendix 3-17 identifies SGCN associated with this habitat type.

Seepage communities have very limited distribution and availability across the landscape and are one of the most significant habitat types of the state for rare plants and animals (TNC and SAFC 2000). Several animal species that are state-listed or rare are associated with seepage habitats, including the Bog Turtle, Mole Salamander, Four-toed Salamander, Long-tailed Salamander, Seepage Salamander, and Alder Flycatcher.

The priority amphibian associated with mountain bogs are all salamander species, though there certainly are a much larger number of amphibians found in mountain bogs. These salamanders (e.g., Mole, Four-toed, Marbled, Three-lined, and Spotted Salamanders) for the most part require pools of water (preferably fishless) for breeding purposes. The community association is less related to the system being spring fed, muddy, or with specific plant associations than for many of the other priority species associated with the seepage habitats.

Some of these communities serve as refugia for species for which the current climate is not suitable. They are likely to continue to do so but warming temperature and changed moisture regimes may make some of them less hospitable to some of these species. At the same time, these communities may become refugia for additional species that are currently common, if the regional climate becomes unsuitable for them. They may be crucial for the survival of some species in the state.

While moisture levels are probably the most important factor in these communities, some species may be directly affected by increased average or extreme temperatures. Warmer temperatures may cause some species to be lost at certain sites, and this may include some of the most unusual and rarest species in these communities. Warmer temperatures may also allow some more southern species to enter these communities, but the small and isolated nature of these distinctive environments will limit movement of species. The species that depend on cool, moist conditions are more likely to be extirpated if warmer temperatures (especially combined with drought) reduce the suitable habitat and/or allow other species to invade the habitat.

4.3.12.6 Recommendations

In general, protection and restoration of natural composition and function, and protection of surrounding natural areas, under current conditions are the best way to improve the ability of these communities to adapt to climate change. Protection of a large and diverse pool of examples is the best way to ensure that many survive the future stresses.

Surveys

Priorities for conducting distributional and status surveys need to focus on SGCN species and those believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Monitoring

Monitoring is critical to assessing species and ecosystem health and for gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Long-term monitoring is needed to identify population trends and to assess performance of conservation actions. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Research must also be conducted to determine vulnerability of SGCN and other priority species to specific threats and studies should provide recommendations for mitigation and restoration.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Perform genetic studies to determine the degree of gene flow or degree of isolation between populations and to assess overall population health for species restricted to this habitat.
• Document how priority species are utilizing the habitat and whether specific hydrological and biological requirements are being met under current management regimes.

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Specific management needs include the control of woody encroachment and succession, the maintenance (and where necessary, restoration) of natural surface water and groundwater hydrology (using ditch plugs, temporary dams, level spreaders, or other engineering devices), the restoration of herbaceous vegetation, and the prohibition of take of rare bog-related species (e.g., Bog Turtle). Bog Turtle

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Actively pursue acquisition of conservation ownership of mountain bogs in concert with state and federal agency partners as well as private conservation partners.

4.3.13 Wet Pine Savannas

4.3.13.1 Ecosystem Description

The communities in wet pine savannas are Coastal Plain mineral soil wetlands that under natural conditions were frequently burned. With frequent fire, they have an open canopy dominated by longleaf or pond pine over a grassy herb layer. Shrubs are short and sparse with frequent fire but become dense if fire is suppressed for more than a couple of years. There are three community types in this ecosystem group: pine savanna, sandhill seeps, and wet pine flatwoods.

- The pine savanna type occurs in flat areas that are saturated or even slightly flooded during the wetter parts of the year. The herb layer is dominated by grasses and sedges and a variety of low shrubs may be present but are low and open if the savanna is frequently burned. The herb layer usually contains many showy composites, orchids, and insectivorous plants. One of the most notable features of pine savanna communities is their tremendous plant diversity at small scales.

- Sandhill seeps occur on sloping seepage areas, where the wettest parts are essentially permanently saturated. They share many species with the pine savanna type but are more heterogeneous and more bog-like in character. In frequently burned seeps, grassy and sedgy areas can have a high diversity of plants, rivaling the pine savannas in species richness at small scales.

- Wet pine flatwoods communities usually occur in flat areas, though sloping areas are possible. They resemble pine savannas in general structure, with an open pine canopy over a grassy ground cover with low shrubs. Wiregrass is always the dominant herb. Shrubs become dense if fire is excluded. Unlike pine savannas, the herb diversity is low: in many cases, only one to five species may be present in a square meter.

4.3.13.2 Location of Habitat

The Green Swamp, Holly Shelter, and Sandhills Game Lands and the Croatan National Forest contain good examples of this habitat.

4.3.13.3 Problems Affecting Habitats

Timber Operations. Intensively managed pine plantations, urban development, a lack of fire, and subsequent habitat fragmentation continue to threaten these communities. Climate change may exacerbate some of these problems. New alternative energy development in the region, such as solar farms, natural gas fracking, and biofuel harvesting, may be an emerging threat but it is uncertain what direct effect these will have on wildlife. Anticipated indirect impacts will include displacement from loss of habitat and loss of connectivity due to habitat fragmentation. Table 4.3.12-1 identifies the most important threats and summarizes the anticipated impacts.

Invasives. Although no invasive exotic plants are a serious problem in these systems now, early detection and control of invasive exotic species (such as Cogon Grass) will reduce the ecological damage caused by invasives and the cost of controlling them. Preventative measures such as forbidding sales and transport of invasive species will help reduce the risks and cost. Fire Ants are already serious cause for concern for many of the animal species that inhabit savannas.

Climate Change. These systems occur mostly in low-lying areas that are unlikely to become extremely dry even in droughts. Sandhill seeps are probably more vulnerable than other community types in this group because they depend on movement of shallow ground water. Droughts would dry them up, perhaps enough for plants to experience water stress. Many species excluded from them at present by wetness may be able to invade with drought.

Increased drought conditions and increased thunderstorm intensity may lead to more wildfires. These systems depend on fire and are often degraded by lack of fire. An increase in wildfires may allow some occurrences to burn in a way that is ecologically beneficial. However, wildfires in drought may be more likely to be too intense or extensive and to harm some species.

If droughts are frequent enough, species of drier communities that are currently excluded by wet periods may be able to establish in them. While species of dry Longleaf Pine communities are presumably excluded from wet pine savannas by moisture, most other species are excluded more by frequent fire. Composition is unlikely to change much for sites that can be burned.

Longleaf Pines are among the least susceptible trees to wind destruction, and it is unclear how significant increases in windstorms will affect them. Pines with nest cavities of the threatened Red-cockaded Woodpecker frequently snap at the cavity site because much of the internal wood has been removed by the birds. General forecasts suggest an increase in severe storms may cause more wind damage to canopy trees, especially to those with woodpecker nest cavities.

Flammability of pocosins varies with season and a change in seasonal phenology that makes them flammable earlier in the season would limit prescribed burning in savannas. Changes in phenology can disrupt pollinator and predator–prey relationships. Warmer temperatures may allow an increase in abundance or rate of spread of Fire Ants and other invasive species. Mild winters, with decreased cold damage, may allow species from the south to move into North Carolina.

These systems range well to the south of North Carolina. They and their component species are well adapted to warm temperatures. Increased temperatures might increase the range of these systems in the northern Coastal Plain and in Virginia. Most plants in these systems have limited dispersal ability even locally, so any influx of native species from the south is likely to be slow. The widespread conversion of potential sites in this region, the fragmented distribution of examples, and their dependence on fire make natural expansion difficult.

4.3.13.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. While climate change is not the most severe threat, a combination of synergistic effects with other existing conditions could stress these systems to the point where several species are unable to persist.

The effect of a changed climate is likely to vary widely among examples of these communities, depending on topographic sheltering, configuration of rocks, soil depth, size of groundwater pools, and amount of overland runoff. These systems are tied to specialized small environments and will be unable to migrate as the climate changes. Many may change very little, while a few will shrink, will be disturbed by wind or flood, or will change substantially because of temperature changes or drought. A small net loss of acreage may occur, but more seeps may be temporarily affected by drought. Table 4.3.13-1 summarizes the comparison of climate change with other existing threats.

Table 4.3.13-1 Comparison of climate change with other threats to wet pine savannas

Threat	Rank Order	Comments
Development	1	Conversion for subdivisions, businesses, and golf courses permanently reduces available habitat and increases stormwater runoff.
Conversion to agriculture/ silviculture	2	The threat of agricultural conversion has reduced in recent years (having greatly reduced habitat historically), but conversion to pine plantation continues.
Logging/ Exploitation	2	Many of the drier areas have been cleared for agriculture, or converted to intensive forestry operations or development. Increased habitat fragmentation can create islands that become population sinks. Conversion of pine production to biofuel production will increase rotation periods and remove slash debris.
Fire	3	In the current settled landscape, these systems depend on prescribed burning for the fire they need. Inadequate fire is the greatest threat to protected examples. Severe wildfires in droughts, burning in excessive fuel loads, may cause ecological damage. Because many examples are now fragmented and isolated, uncontrolled fire that burns whole patches is a significant threat to many insect populations. Prescribed burning is crucial for retaining these systems

Table 4.3.13-1 Comparison of climate change with other threats to wet pine savannas

Threat	Rank Order	Comments
		in both the present and the expected future climate. Smoke management becomes an issue along with wildfires that result from unsafe landowners burning debris. Firefighting methods can damage the habitats through use of heavy equipment and fire suppression chemicals.
Climate Change	4	Wet pine savannas are likely to be resilient to climate change effects. With drought, fuel loads could increase and contribute to catastrophic fire events. Increased high wind storm events causes wind throws that damage tree stands, especially Red-cockaded Woodpecker cavity trees.

4.3.13.5 Impacts to Wildlife

Appendix 3 provides a list of SGCN and other priority species for which there are knowledge gaps and management concerns. Appendices 3-17 (wildlife) and 3-18 (plants) identifies SGCN that depend on or are associated with wet pine savannas.

These habitats are particularly important for reptiles and amphibians where ponds are embedded in savannas or flatwoods; such species include Carolina Gopher Frog, Ornate Chorus Frog, and Southern Chorus Frog. Several reptile species, such as Pigmy and Timber (Canebrake) rattlesnakes and Mimic Glass Lizard, are found in savannas and pine flatwoods away from pools and ponds. Many of the bird species of highest conservation concern inhabit these communities and depend on frequent fire to create suitable habitat conditions (e.g., the Red-cockaded Woodpecker, Bachman’s Sparrow, Henslow’s Sparrow, Brown-headed Nuthatch, American Kestrel, Prairie Warbler) (Hunter et al. 2001b; Johns 2004). Game species such as the White-tailed Deer, Northern Bobwhite Quail, Eastern Wild Turkey, Eastern Cottontail Rabbit, Gray Squirrel, and Eastern Fox Squirrel also utilize this habitat for forage and cover.

Red-cockaded Woodpeckers use these habitats, because they typically have a sparse overstory and open midstory that is preferred by the woodpeckers. Increased windstorm damage could affect canopy structure and topple some nesting cavity trees. Because of the slow reproductive rate and long life span of longleaf pine, increased wind mortality would reduce average age and might reduce natural canopy density. This would be detrimental to Red-cockaded Woodpeckers and other species that depend on older longleaf pine trees.

Three species of insects are endemics or near-endemics to wet pine savanna habitats in North Carolina. Five others are major disjuncts, with their next nearest populations in New Jersey, Florida, or in the case of Rattlesnake-Master Borer moth, the tallgrass prairies of the Midwest. The Coastal Plain Apamea moth appears to have a highly disjunct population in the coastal savannas but also occurs in the Southern Appalachians.

Fire suppression and a lack of growing season prescribed burning causes a thick shrubby understory to develop which shades out grasses and herbaceous ground vegetation and greatly reduces overall plant and animal diversity. Microhabitats and ecotones can be impacted by fire line construction, and a lack of woody debris particularly impacts reptiles, amphibians, and small mammals.

While all of these species are associated with fire-maintained habitats, the majority depend on having a metapopulation structure to cope with fire, as well as other environmental perturbations. Five of these species have substantially lost their metapopulation structure and have become highly vulnerable to the effects of single catastrophic events, including wildfires. Because many examples of this habitat are now fragmented and isolated, uncontrolled fire that burns whole patches is a significant threat to many insect populations. In summer 2009 a backfire to control a wildfire in Croatan National Forest burned the entire known habitat of the Arogos Skipper; this butterfly has not been seen there or anywhere else in the state since that fire.

4.3.13.6 Recommendations

Protection of remaining examples and restoration of degraded examples would help the Coastal Plain landscape adapt to future climates, as well as provide benefits under the current climate. Keeping or restoring fire to these systems, through prescribed burning, is crucial to their long-term survival in both the present and any future climate.

Most of their component species range well to the south of North Carolina. They are tolerant of drought, fire, and wind. Many have broad tolerance of varying moisture and nutrient conditions. However, they have been drastically reduced by conversion to other uses and degraded by lack of fire. This makes them more vulnerable to loss of species and degradation both by climate change and by other threats.

Surveys

Priorities for conducting distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive communities.

Monitoring

Monitoring is critical to assessing species and ecosystem health and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Long-term monitoring is needed to identify population trends and to assess performance of conservation actions. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Initiate long-term monitoring once baseline surveys have been conducted. Focus should begin with herpetofauna and bird species in decline, or for which little is known about the population fluctuations and demographics.

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Research must also be conducted to determine vulnerability of SGCN and other priority species to specific threats and studies should provide recommendations for mitigation and restoration.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Determine better ways to construct fire lines and better ways to burn around populated areas where smoke would otherwise be a concern when burning.

- Determine how to effectively restore altered portions of this habitat type and develop methods to manage them without fire.

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Establish examples of well-maintained and burned savannas as demonstration sites for landowners to emulate. Burning should be accomplished without placing fire lines in transition zones from uplands to wetlands and with the fire allowed to burn through transition zones.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• to develop and maintain the herbaceous layer and open pine stands. Where growing season burns cannot be administered, winter burns can be constructive. Burning should be accomplished without placing fire lines in transition zones from uplands to wetlands and with the fire allowed to burn through transition zones. Whenever possible, burn wetlands/pools when they are dry. If this cannot be done initially, consider returning to burn wetland once it is dry to prevent overgrowth within the basin.
• Habitat restoration should primarily occur through growing season prescribed burning,
• Snags should be retained during logging operations to increase the numbers available for cavity-using wildlife species.
• Maintain sufficient levels of woody debris in stands for reptiles, amphibians, and small mammals.
• Create borrow sites or ponds for breeding use by amphibians. Otherwise, amphibians are scarce in most flatwoods and savannas devoid of pools or open water.
• Watch for arrival of Cogon Grass and other new invaders and control promptly.

Conservation Programs and Partnerships
Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience. Land acquisition and easements should be promoted through cooperation with local conservation organizations and state and federal agencies.

4.4 Terrestrial Communities

4.4.1 Introduction

Terrestrial and aquatic systems are highly connected to the extent that upland land clearing activities can result in increased erosion and sedimentation in adjacent riparian communities. Water quality impacts can reduce aquatic species population sizes, leading to food limitations for terrestrial species with an aquatic food base. Unfortunately, the Southeast contains some of the most endangered ecosystems in the country: southern Appalachian Spruce-Fir, longleaf pine forest and savanna, eastern grasslands, coastal communities, and forested wetlands (Noss et al. 1995).

Threats to habitats across the region include fragmentation, conversion to other habitat types, suppression of fire, and outright loss due to development (Noss et al. 1995, Ricketts et al. 1999). There are numerous other threats that can affect a broad range of terrestrial or upland communities and the natural community descriptions provided in this section include information about the problems that affect specific community types. Additional information about threats most likely to impact fish and wildlife and their habitats is provided in Chapter 5.

The natural communities described in this section are primarily based on descriptions published by the NC Natural Heritage Program (Schafale and Weakley 1990, NCNHP 2010, Schafale2012). A recent update to the classification themes was published in 2024, the Classification of the Natural Communities of North Carolina, 4th Approximation (Schafale 2024). Where relevant the associated subtypes associated with each natural community have been updated with the 4th Approximation themes. See Classification of the Natural Communities of North Carolina, 4th Approximation for complete descriptions and lists of plants associated with each subtype (Schafale 2024).

The recommendations provided within each of the natural community descriptions represent priorities specific to the habitats and wildlife species associated with them. Numerous state, regional, and national-scale efforts have been used as a resource on which to build the conservation priorities addressed in this chapter. To the greatest extent possible and where applicable, the guidance provided by these important efforts has been incorporated into this Plan.

There are numerous threats that can affect a broad range of terrestrial or upland communities and some of the most common and widely occurring are described in this section. The natural community descriptions provided in this chapter provide information about the problems that affect specific community types. Additional information about threats likely to impact wildlife and habitats is provided in Chapter 5.

The natural community descriptions in Sections 4.4.3 through 4.4.20 are generally arranged in elevational order as they occur on the landscape, beginning in the western Mountains and proceeding eastward toward the coast. Those that are found statewide are provided at the end of this section. Common names are used throughout this document for species discussions except those animals for which there is taxonomic uncertainty or they are invertebrates that are not Species of Greatest Conservation Need (SGCN); in those few instances the scientific name is provided in the text for the species.

Appendix 3 contains lists of common and scientific names for invasive, exotic, and nonnative species and the common and scientific names of the native plants identified in the community descriptions. Appendix 3 also provides a list of SGCN and priority species for which there are knowledge gaps or management concerns. Appendix 3-17 identifies SGCN and the habitats they are associated with.

4.4.1 Caves and Mines

4.4.1.1 Ecosystem Description

The majority of documented caves in North Carolina occur in the Mountain ecoregion, though there are some caves present in all regions of the state, including the Coastal Plain. There are several different types of natural caves; however, the most common types are solution caves, fissure caves, and rock shelter/boulder caves. These types differ primarily in the way they are formed. Our definition of the caves and mines habitat type is intended to include only mines which include subterranean excavations with conditions inside the mine shafts and tunnels that resemble conditions in natural caves. That being said, the range of variability of those conditions is extensive.

- Solution caves are created by the action of water dissolving the underlying rock to form tunnels. Over time, solution caves get larger and larger and are generally the most extensive (size and length of passage). There are a few areas of North Carolina with underlying limestone geology which lend themselves to solution cave formations. Most notably the Nantahala Gorge and North Fork Catawba River/Linville Mountain area of western North Carolina and parts of the Coastal Plain are underlain with limestone (marble, dolomite, and marl respectively).

- Fissure caves are formed by movement of the earth's surface, which results in cracks in the rock layers. Depending on the actual events which spawn the development, fissure caves have varying sizes and configuration. Fissure caves occur in many places in North Carolina, though one of the most well-known and largest fissure cave systems in the world occurs in Hickory Nut Gorge in Rutherford County.

- Rock shelter/boulder caves are formed by erosive forces, weather events, earth surface movements, and other factors which essentially leave spaces underneath/behind surface rock. The vast majority of caves in North Carolina are rock shelter/boulder caves. Owing to their diversity of formation, geology, and range in the state, caves in North Carolina are quite variable in terms of both the plant and animal communities adapted to and found in them (also see Sections 4.4.9 Mesic Forests and 4.4.10 Piedmont and Mountain Dry Coniferous Woodlands in this chapter).

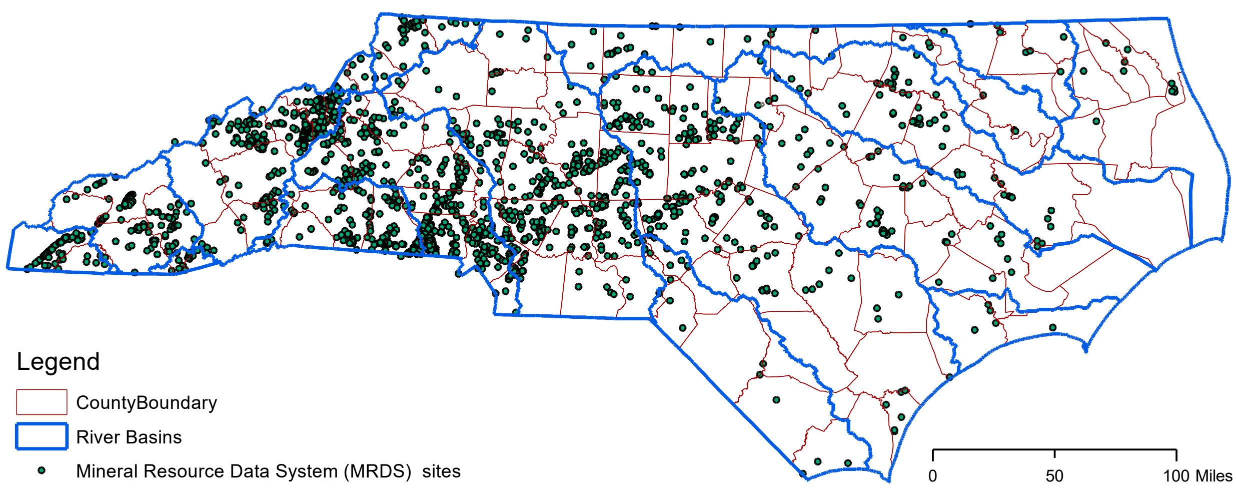
- In addition, an extensive mining history in North Carolina has provided numerous subterranean excavations which can and do mimic the environmental conditions of natural caves. Like caves, mines come in many shapes and forms, depending upon numerous factors. There are many mines which do not provide conditions similar to those found in caves, such as open pit mines, strip mines, and quarries.

4.4.1.2 Location of Habitat

According to Christman and Culver (2001) caves are common in the United States. Details about cave locations in North Carolina are not provided in this document in order to protect them from vandalism and degradation that can occur when used by casual or recreational visitors. Old mines that may pose a geologic hazard (pre—North Carolina Mining Act) and have subsurface workings have been documented in a database previously maintained in the Mineral Resource Data System (MRDS) of USGS and the Mineral Availability System/Mineral Industry Locator System (MAS/MILS) in the US Bureau of Mines (USBM), which is now part of USGS.

Figure 4.4.3-1 represents generalized location information of this dataset (McFaul et al. 2000); however, we have made no attempt to verify the type of subsurface feature or location represented by the data. While this data set was developed by USBM/USGS to portray the distribution of old mine workings in North Carolina and contains non-confidential data, it should be recognized that these sites are located on privately owned land in most cases.

Figure 4.4.3-1 Statewide location of subsurface mines (McFaul et al. 2000)**.**



4.4.1.3 Problems Affecting Habitats

Given the variability in cave types, mine types, and a host of different substrates, orientations, positions on the landscape, etc., the condition of caves and mines in North Carolina is quite variable.

Human Intrusion. Caves and mines occur across all land ownership types. Several of the most significant sites have received attention in the past to protect resources (wildlife or geological in most cases). Bat-friendly gates have been installed in some locations to prohibit or regulate human entry and subsequent impacts upon cave resources. However, modifications at cave entrances and gate design and placement may impede air exchange, ultimately exerting influence on the ambient and substrate temperatures inside caves which in turn will influence body temperature and metabolic rates of hibernating bats (McNab 1974; Humphrey 1978; Martin et al. 2006).

Human activities alter the microclimate, biogeochemistry, and balance of organic matter in caves, which also impacts microbial communities (Saiz-Jimenez 2012). Several research articles have reported on declines of cave-obligate bats caused by human disturbance at caves (in Martin et al. 2006). In many states, and throughout the world, many caves have been developed into tourist attractions, often with lighting, tours, gates, etc. All of these activities have resulted in degraded habitat conditions for cave-dwelling animals as well as disrupted normal behavior patterns, effectively eliminating habitat for many cave animals. The Southern Blue Ridge Ecoregional Conservation Plan noted recreation, including developed tourist caves and recreational caving/exploration, to be the greatest threat to cave and cave species conservation (TNC and SAFC 2000).

Climate Change. Seasonal variations in surface climate, entrance characteristics (Tuttle and Stevenson 1978) and physical structure of the cave itself (Twente 1955; Raesly and Gates 1987) are thought to have the greatest impact on climate of cave interiors (Martin et al. 2006). Changes in precipitation may contribute to variation in moisture and temperature but may not be drastic. Drought conditions cause moisture gradients in caves and mines to change, especially those with groundwater seepage contributing to the humidity level. Warmer temperatures in caves and mines will change the suitability of this habitat for species adapted to historic microclimate conditions.

4.4.1.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. While climate change is not the most severe threat, a combination of synergistic effects with other existing conditions could stress these systems to the point where several species are unable to persist. The Southern Blue Ridge Ecoregional Conservation Plan identifies recreation as the greatest threat to cave and cave species conservation (TNC and SAFC 2000). Communities and species associated with cave and mine habitats are likely to be affected by changes in temperature and mild winters associated with climate change. Table 4.4.3-1 summarizes the comparison of climate change with other existing threats.

Table 4.4.3-1 Comparison of climate change with other threats to caves and mines

Threat	Rank Order	Comments
Pathogens/Disease	1	White-nose syndrome (WNS) has devastated bat populations roosting in caves in the northeastern states, including North Carolina, over the past 5-10 years. Several bat species have declined in the state by over 95% due to the death caused by this fungus.
Recreation	2	Disturbance from human intrusions can disrupt normal animal activities (hibernation, roosting) and introduce contamination from other sites (fungal spores, disease). Most accessible caves or mines experience some level of human visitation by caving and rock climbing enthusiasts.
Development	2	Caves are at risk of being developed into tourist attractions, often with lighting, tours, gates, etc. These activities result in detrimental impacts to habitat conditions for cave-dwelling animals, as well as disrupted normal behavior patterns, effectively eliminating habitat for many cave animals. Linville Caverns is the only cave complex that has been commercially developed as a recreational destination in the state.
Climate Change	3	Caves and mines provide unique microclimates that some species require during key phases of their life history (e.g., bat hibernation). Even slight increases in temperature can change the humidity in these environments and increase the potential for fungal and bacterial growth. Evidence of temperature variability is the increased occurrence of WNS in winter hibernating bats.

4.4.1.5 Impacts to Wildlife

Appendix 3 provides a list of the SGCN and other priority species for which there are knowledge gaps and management concerns. Appendices 3-17 (wildlife) and 3-19 (plants) identify SGCN that depend on or are associated with this habitat type. Subterranean aquatic communities are described in Section 4.2.6.

We have some accurate assessment of the wildlife habitat potential of abandoned mines in North Carolina, and since the first SWAP published in 2005 we certainly have a better idea as to their individual suitability for use by cave-dwelling animals or plants (NCWRC unpublished data). Some portions of abandoned subsurface mines function similarly to caves in providing the range of microhabitat conditions which cave-obligate species need, especially larger mine excavations that can provide the volume and air flow needed by cave-dwelling species (particularly bats of various species). Smaller mines may support use by small numbers of individuals. Other human infrastructures, such as bridges, culverts, and buildings, can also serve as a roost, hibernaculum, or other habitat elements naturally found in caves.

White-nose syndrome (WNS), a fungal disease that affects hibernating bats, is reported to be caused by *Pseudogymnoascus destructans* (Blehert et al. 2009; Frick et al. 2015), formerly *Geomyces destructans* (Lorch et al. 2011; Hayes 2012). The first evidence of the disease was documented in 2006 and since then there has been widespread evidence of its impact on bats. WNS has already decimated populations of most cave-dwelling species of bats in the state, especially Tricolored bat, Northern Long-eared Bat and Little Brown Bat. Chapter 5 provides additional information on disease and pathogens affecting wildlife, including WNS.

Nearly a thousand species and subspecies known from caves and associated subterranean habitats in the United States have been described (Culver et al. 2000; Christman and Culver 2001). Various surveys and investigations have been conducted in many caves and mines in attempts to document significant wildlife or geological resources in North Carolina. However, no comprehensive evaluation has ever occurred in the state other than for bats in caves. Caves also provide important habitat for cavespiders (*Nesticus* spp.), millipedes, crustaceans, pseudoscorpions, and crickets (TNC and SAFC 2000). Not only is the condition of caves and mines quite variable in North Carolina, but our state of knowledge about the use of caves and mines by plants and animals is extremely variable. Habitat specialists and species with restricted ranges will likely be some of the greatest affected by the combined effects of habitat loss and climate change.

Troglobites are cave-dwelling organisms that have adapted to darkness, have no skin pigment, and are blind because they spend their entire lives underground. Troglobites include fish, salamanders, crayfish, insects, and spiders. They cannot live outside a cave and their survival may be threatened if the cave environment is damaged or altered. The National Speleological Society (NSS) notes that water pollution, visitor traffic, trash, flooding, and a change in air patterns and temperature contribute to disturbing a cave’s fragile food web and ecosystem.

One cave complex has been developed as a recreational destination in North Carolina and many other cave or mine systems have experienced some level of human visitation. Many of the wildlife species that use caves, if not the caves themselves, have been impacted by human activities, including both direct impacts (e.g., repeated disturbance during bat hibernation) and indirect impacts (e.g., habitat changes that make microhabitat conditions inside the cave or mine unsuitable). Human use of caves can cause alteration of the physical structure of the caves themselves, changes in the water chemistry or hydrology within the cave, or destruction of cave structures and cave-dwelling organisms (Fleury 2009). Dripwater flows are critical both to cave biota and to the microclimates of the caves themselves, and if those flows carry surface-level contaminants, the entire cave environment is affected (Fleury 2009).

It is believed many smaller caves and mines have been impacted by nearby development, though there is little to no documentation of the occurrences. Careless disposal of wastes or excessive fertilization in agricultural areas can have devastating impacts on cave life by altering the water chemistry (Watson et al. 1997; Gillieson 1996). Though it rarely happens, caves can also be destroyed by aquifer drawdown, as sinkholes can form on the surface and collapse so they fill in the cave. It is usually not possible to restore a cave to its original condition after it has been degraded by human activity; for that reason, conservation is a preferred strategy (Elliott 2004).

4.4.1.6 Recommendations

Caves and mines occur across all types of land ownership types. Several of the most significant sites have been identified as conservation priorities. The North Carolina Cave Survey has documented over 1,300 caves in the state (NCWRC 2005). We have little accurate assessment of the availability of abandoned mines in North Carolina, nor do we possess much information on their individual suitability for use by cave-dwelling animals or plants.

Surveys

Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Create a comprehensive, prioritized list of significant caves, including the factors which add significance (e.g., roost of endangered bats, rare geologic formations, other rare plants or animal use).

  Bats Plants

- Inventory salamander communities associated with cave habitat (particularly in the twilight zone of caves).

  Salamanders

- Conduct bat surveys in caves and mines that have not been previously evaluated.

  Bats

- Conduct surveys for Cave Salamanders (*Eurycea lucifuga*) in areas along the Tennessee/North Carolina border.

  Cave Salamanders

Monitoring

Long-term monitoring of caves and mines is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Continue long term monitoring protocol to document bat use of significant cave/mine roosts, especially in those caves and mines that are affected by WNS. Bats
• Develop protocols and procedures for long-term bat capture study and data storage throughout the state. Bats
• Establish protocol for periodic monitoring and assessment of Allegheny woodrat populations. Allegheny Woodrat
• Develop and implement systematic, long-term population monitoring protocols for cave-dwelling salamanders. Salamanders

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- In some areas of its range, the Longtail Salamander is associated with caves or portions of caves. Investigate its habitat use in North Carolina in conjunction with more generalized research on this species' distribution, status, and habitat in the state.

  Longtail Salamander

- Conduct studies to document maternity sites used by bats from specific hibernacula (e.g., find maternity colonies utilizing radio telemetry of individual Virginia Big-eared Bats that hibernate in known caves/mines, or track any Indiana or Gray Bats captured to their maternity sites or hibernacula).

  Virginia Big-eared Bat Gray Bat

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Where feasible and cost effective, install gates to limit access (similar to protective measures used at Cranberry Mine). Inspection and monitoring may be needed to detect vandalism and illegal entry.

  Cranberry Mine

- Identify ways to address the effects of WNS where it occurs in the state.

  Bats

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Acquire cave habitat through purchase, conservation easement, or other perpetual management agreements (potential for partnerships with NC Natural Heritage Program, The Nature Conservancy).

- Develop plans to protect caves where roosting bats or other cave resources are at risk from human intrusion, including the use of the Wildlife Conservation Lands Program.

4.4.2 Spruce–Fir Forests

4.4.2.1 Ecosystem Description

Classification of the Natural Communities of North Carolina, 4th Approximation (Schafale 2024) includes this natural community as Spruce-Fir Forests Theme with two community subtypes: Fraser Fir Forest Herb Subtype and Rhododendron Subtype. Both communities tend to have dense canopies under natural conditions. A variety of distinctive shrubs and herbs, many of them more common in the northern United States, but some endemic to the southern Appalachians, occur beneath the canopy. Lush beds of moss and ferns cover the rocky soil and abundant fallen logs in some areas.

These forests are dominated by Red Spruce and Fraser Fir and occur on the high mountain tops in western North Carolina, generally over 5,500 feet in elevation. The cold climate of the high elevations is equivalent in some ways to the boreal forests of Canada. However, the climate differs from the north in that it is less continuously cold and much wetter, with both rain and fog tending to concentrate on the mountain tops (NCNHP 2024).

Estimates of the amount of Spruce-Fir habitat are quite variable depending upon a number of factors including the estimation methods and habitat definition. The Partners in Flight Bird Conservation Plan for the Southern Blue Ridge (Hunter et al. 1999) identifies over 66,000 acres of Spruce−Fir forest in the southern Blue Ridge ecoregion and the Southern Appalachian Assessment (SAMAB 1996) identifies over 75,000 acres in North Carolina and Tennessee. The vast majority of these areas occur in North Carolina.

A large suite of rare plant and animal species also occur primarily in Spruce–Fir Forests (Schafale 2024); Appendices 3-17 (wildlife) and 3-19 (plants) provides an association between species and this habitat type.

4.4.2.2 Location of Habitat

Fraser Fir forests occur on the highest mountain tops, where the Fraser Fir is the only tree species able to survive the cold, wind, ice, and storms in large numbers. Red Spruce−Fraser Fir forests occur in slightly less hostile environments where Red Spruce and Yellow Birch can also persist in large numbers.

Forests dominated by Red Spruce and Fraser Fir occur on the high mountain tops generally over 5,500 feet in elevation. Spruce−Fir habitats are now found within a narrow range of suitable conditions, isolated from each other and the rest of their range. There are currently six significant areas of Spruce−Fir habitats in western North Carolina, including portions of Grandfather Mountain, Roan Mountain, the Black/Craggy Mountains, the Great Balsam Mountains, the Plott Balsam Mountains, and the Great Smoky Mountains.

Most of the Spruce−Fir habitat in North Carolina is located on public land, or private lands with permanent conservation easements, with estimates of 90 to 95 % in conservation ownership in the southern Blue Ridge physiographic province including North Carolina, Tennessee, and Virginia (Hunter et al. 1999; SAMAB 1996). However, significant private ownership of Spruce−Fir habitat occurs in the Plott Balsams and Black/Craggy Mountains, and to lesser extents in several other ranges.

Red Spruce habitats of lesser size or with somewhat different ecological community associates occur in a few other locations, including Long Hope Valley, Beech Mountain, Unaka Mountain, and Alarka Laurel. Recent restoration efforts have replanted Red Spruce and fir as a conservation measure in the Unicoi Mountains (Graham County) for Carolina Northern Flying Squirrel.

4.4.2.3 Problems Affecting Habitats

Red Spruce−Fraser Fir forests are considered an endangered community in North Carolina and are ranked the second most endangered ecosystem in the United States (White et al. 2012; Noss et al. 1995, Christensen NL et al. 1996; Rentch et al. 2007). There is no potential for latitudinal migration of these systems. No high elevation areas exist for a considerable distance north of their current range. All patches are isolated by low elevation areas that are already unsuitable in today's climate (NCNHP 2024). Many of the former fir forests and logged or grazed areas are regenerating into northern hardwood stands without a conifer component (spruce or fir).

Climate Change. Climate change is associated with increased intensity and severity of storms. Recent extreme weather events have caused blowdowns and landslides in the spruce zone. Wildfires have carried through the otherwise mesic spruce zone during periods of extreme drought. This ecosystem is among the most vulnerable to the effects of climate change of any in the state. Given the high number of endemic and disjunct species, it is also the ecosystem where threats to biodiversity are the greatest. Several of the species face outright extinction and others, if lost, are unlikely to ever recover within the region (NCNHP 2024).

Land Use. Given the high number of endemic and disjunct species that use spruce−fir habitat, it is the one community where threats to biodiversity are the greatest. Much of the spruce−fir habitat in North Carolina and throughout the southern Appalachians has been significantly altered due to a number of factors including historic logging, fire, exotic insects, historic grazing, and recreational development. Much of the spruce was logged in the early 20th century and in some areas (notably the Great Balsams) slash fires burned not only the coarse woody debris, but also the organic soil, which has subsequently inhibited the redevelopment of spruce and fir forests over large areas (Schafale and Weakley 1990). In former Spruce-Fir forest that was logged and burned, hardwoods now dominate the canopy.

The removal of mature Fraser Fir from the canopy has profound implications for the Spruce-Fir ecosystem and the continued existence of several unique plants and animals (Nicholas et al. 1999). Following extensive logging during the last century, it is estimated that as much as 50% of all Appalachian spruce−fir forests were replaced through successional growth of hardwood species (White et al. 2012; Pyle 1984). Several of the species face outright extinction and others, if lost, are unlikely to ever recover within the region.

Transportation. The Blue Ridge Parkway was completed through western North Carolina during the latter part of the 20th century. The Parkway traverses most of the high-elevation islands of Spruce−Fir habitat. The Parkway and its associated development (the motor road, vistas, and visitor facilities) have contributed to fragmentation and had a significant impact on the amount of Spruce−Fir habitat available.

Invasives. In the latter part of the 20th century, the Balsam Wooly Adelgid (*Adelges piceae*) began to have severe negative impacts on Fraser Firs throughout the region, resulting in the death of most of the mature fir of the high-elevation forests (White et al. 2012). Recent negative impacts include insect outbreaks in several areas including Roan Mountain, the Black Mountains, and the Great Balsam Mountains. Milder winters presumably will lead to invasion by species from lower elevation. This will eventually lead to competitive exclusion of distinctive Spruce-Fir species from the lower parts of their elevational range (NCNHP 2024).

Pollution. Some research has shown that recent increases in acid precipitation in the Mountains of western North Carolina may have impacts on forest health and productivity, particularly in the high Mountains (Schafale and Weakley 1990;; Hunter et al. 1999). While some Fraser firs remain in certain locations, the majority of late successional fir has been killed and often replaced by young fir, mixed northern hardwoods, and open, herbaceous habitats.

Wildfire. Because the current distribution of Spruce-Fir forest is limited and many patches cover small areas, some are likely already close to minimum viable population size. Wildfire would likely be catastrophic because Spruce-Fir forests are not adapted to fire. Forests that burned would likely lose most species and never recover. Forests that burned during the industrial logging era have not recovered after more than 100 years, even in the past climate conditions (NCNHP 2024).

4.4.2.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short-and long-term conservation actions and recommendations. Many species are currently excluded from these high-elevation communities because of the extreme climate, with winter cold the most likely cause.

Mild winters presumably will lead to invasion by species from lower elevations. For example, in January 2023, NCWRC biologists captured a Southern Flying Squirrel (*Glaucomys volans*) for the first time in 20 years of monitoring a nest box line located at elevations above 5,000 feet in the Black Mountains. This will eventually lead to competitive exclusion of distinctive Spruce−Fir species from the lower parts of their elevational range (DeWan et al. 2010) or hybridization in the case of flying squirrels (Garroway et al. 2010).

The fact that these habitats are so small and isolated from each other could have a negative impact upon genetic health of individual populations, as well as demographic effects upon populations. Table 4.4.2-1 summarizes the comparison of climate change with other existing threats.

Table 4.4.2-1. Comparison of climate change with other threats to spruce−fir forests

Threat	Rank Order	Comments
Climate Change	1	This ecosystem is among the most vulnerable to the effects of climate change of any in the state. Warmer winters will result in reduced snow fall and less snow pack, which in turn affects soil moisture gradients. Extreme storms have already caused blowdowns and landslides. During periods of extreme drought, the spruce zone, which is normally too moist to carry fire, has burned.
Invasive Species	1	The Balsam Woolly Adelgid is the most severe threat to Fraser fir forests. Insect outbreaks have occurred in several areas, including Roan Mountain, the Black Mountains, and the Great Balsam Mountains (NCWRC 2005). Changes in seasonal temperatures may allow pest species to survive during warmer winters and thus exacerbate the threat of insect outbreaks (Logan et al. 2003).
Air Pollution	1	Air pollution (including acid rain, ozone, and lead deposition) generated in other areas is carried by prevailing winds and deposited through precipitation. Acid rain kills or stunts new growth and contributes to heavy metal toxicity in soils.
Wildfire	2	The natural vegetation virtually never burns under the current climate, and the biota are not adapted to fire. Spruce−fir habitats in North Carolina are now found within a narrow range of suitable conditions, isolated from each other and the rest of their range. This condition alone makes them more susceptible to perturbation and catastrophic events.
Development	3	The Parkway and its associated developments (the motor road, vistas, and visitor facilities) have had a significant impact on the amount of spruce−fir habitats available (NCWRC 2005). Residential development (e.g., second homes) continues in parts of the Spruce-Fir zone, particularly in the Plott Balsams, Great Balsams, and Black Mountains. While wind turbine farms are unlikely to be built where stands of spruce−fir forests are still present, there is some potential for them to be sited on ridge-tops where spruce−fir once occurred and could be potentially restored.
Logging/ Exploitation	4	Much of the spruce was logged in the early 20th century and in some areas (notably the Great Balsams), slash fires burned not only the coarse woody debris,

Table 4.4.2-1. Comparison of climate change with other threats to spruce−fir forests

Threat	Rank Order	Comments
		but also the organic soil, which has subsequently inhibited the redevelopment of spruce−fir forests over large areas (Schafale and Weakley 1990).

The future climate is expected to include warmer temperatures, longer growing season, likely more hot spells and drought, and more severe storms. The North Carolina Climate Science Report projects it is very likely that temperatures in the state will increase substantially in all seasons.

- Annual average temperatures are projected to increase at least 2 to 4°F by 2050 (Kunkel et al 2020).
- By the end of the century (2100), annual average temperatures are projected to increase 5 to 10°F under a higher emissions scenario and increase 2 to 6°F under a lower emissions scenario.
- It is very likely that the annual coldest temperature will increase by 7 to 12°F under the higher emissions scenario and increase 0 to 8°F under the lower emissions scenario.
- The Mt. Mitchell National Weather Service Cooperative Observer Network site measured 140 inches of precipitation in 2018, setting a new state record for the most precipitation at a single state weather station in a year. It is likely that annual total precipitation for North Carolina will increase and that extreme precipitation frequency and intensity will increase due to increases in atmospheric water vapor content (NCNHP 2024).

4.4.2.5 Impacts to Wildlife

Appendix 3 provides a list of SGCN and other priority species for which there are knowledge gaps and management concerns. Appendix 3-17 (wildlife) and Appendix 3-19 (plants) identifies SGCN that depends on or are associated with this habitat type.

Spruce−Fir provides critical habitat for numerous plant and animal species found nowhere else in North Carolina. Twenty species or subspecies of invertebrates are endemic to spruce−fir forests in the Southern Appalachians. Another nine are highly disjunct within this region, with their next nearest populations located in New England or Canada (some may turn out to be distinct species once genetic studies are done). Still more such species exist within other insect orders and in other invertebrate taxa such as myriapods, Tardigrades, and land snails. For terrestrial animals, this level of endemism/disjunction is unmatched by any other habitat group in the state.

Carolina Northern Flying Squirrel, a federal listed endangered subspecies, forages on conifers and fungi found in high-elevation spruce−fir and hardwood forests. The moist, boreal conditions support the mycorrhizal fungi that grow in association with the tree roots. Habitat destruction and fragmentation from development, as well as alteration from logging, mineral extraction, pollution, and pest species, has reduced available habitat for the Carolina Northern Flying Squirrel. The highest quality habitat for the squirrel is the transition zone between spruce–fir forest and the northern hardwood forest, a mix of Red Spruce, Fraser Fir, Yellow Birch, Buckeye, Sugar Maple and even some beech at elevations above 4,000 feet (SHR 2013). Information about Carolina Northern Flying Squirrel can be found in Chapter 3, Section3.7 of this document.

Spruce–fir communities provide critical breeding habitat for many landbirds of conservation concern according to Partners in Flight (Brown Creeper, Northern Saw-whet Owl, Black-capped Chickadee that are likely endemic to these high peaks (Pashley et al. 2000;; Rich et al. 2004;; Johns 2004). Local relative abundance of many birds and mammals (e.g., the Red Crossbill, Brown Creeper, Pine Siskin, Black-capped Chickadee, Northern Saw-whet Owl, Northern Flying Squirrel) has decreased as the availability of Spruce-Fir habitats has declined. The fact that these habitats are so small and isolated from each other could have a negative impact upon genetic health of individual populations, as well as demographic effects upon populations.

Many species using Spruce–Fir forests are flightless, including salamanders and eight species of ground beetles (*Trechus* sp.). Weller's Salamander is at the highest risk of being pushed off the top of the mountain because of climate change. As is generally true for "sky island" species, even those capable of flight (or ballooning in the possible case of the Spruce-Fir Moss Spider), they rarely disperse out of their habitat, if at all. Even a flighted species, the Black-capped Chickadee, has not recolonized some massifs following turn of the century logging, even as the forest has slowly recovered.

All of these species depend on cool, moist microclimates, but the Spruce–Fir Moss Spider, ground beetles, and salamanders are particularly susceptible to desiccation and are among the species most likely to be affected by climate change of any in the state.

4.4.2.6 Recommendations

Most of the Spruce–Fir habitat in North Carolina is located on public land, or private lands with permanent conservation easements, with estimates of 90%–95% in conservation ownership in the southern Blue Ridge physiographic province (North Carolina, Tennessee, and Virginia) (Hunter et al. 1999;; SAMAB 1996).

Surveys

Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Determine the distribution, relative abundance, and status of all wildlife species associated with Spruce–Fir forests.

Carolina Mountain Dusky Salamander	Bobolink	Small mammals
Imitator Salamander	Brown Creeper	Eastern Milk Snake
Jordan's Salamander	Golden Eagle	Engraved Covert
	Bats	Fragile Glyph

- Focus survey priorities on species believed to be declining, at risk, or exclusively dependent on Spruce–Fir forest communities.

Black-capped Chickadee	Rock Shrew	Southern Pigmy Salamanders
Red Crossbill	Rock Vole	Weller's Salamander
Carolina Northern Flying Squirrel	Northern Pigmy Salamanders	

- Focus secondary survey priorities on species for which current distribution information is more available or for species associated with additional, more extensive habitats to collect distribution and abundance data.

Canada Warbler	Sharp-shinned Hawk	Northern Slimy Salamander
Hairy Woodpecker	Masked Shrew	
Northern Saw-whet Owl	Smoky Shrew	

- Collect baseline microhabitat and microclimate characteristics in spruce–fir salamander communities.

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Expand and/or target monitoring systems to assess current population status and trend information for priority wildlife species associated with spruce–fir forests.
• Establish mechanisms for monitoring the distribution and condition of spruce–fir habitats over time, including examples of restored forest.
• Monitor phenology of priority species and spruce–fir communities in relation to climate change.
• Monitor microhabitat and microclimate characteristics in spruce–fir salamander communities in relation to climate change.

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Conduct studies to explore the degree of endemism of Southern Appalachian populations. Black-capped Chickadee, Red Crossbill, Northern Saw-whet Owl, Pine Siskin
• Conduct studies to explore the degree of genetic isolation of species restricted to high elevations. Weller's Salamander, Carolina Northern Flying Squirrel, Rock Shrew, Northern Saw-whet Owl, Rock Vole

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Conduct studies to explore the degree of hybridization between Carolina Northern Flying Squirrel and Southern Flying Squirrel. Carolina Northern Flying Squirrel; Southern Flying Squirrel
• Conduct research on population demographics including trends, population structure, survivorship, reproduction, and population viability for all spruce–fir associated species/groups.
• Species phenology needs to be investigated, especially where there are endemic populations.

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Develop and/or implement techniques for managing pure spruce stands to include habitat components of the entire spruce–fir/northern hardwood community (i.e., thinning or canopy gaps).
• Restore spruce to natural abundance in ecologically appropriate locations where canopy density has been reduced (SASRI 2015).
• Develop capacity to store seed and grow genetically appropriate spruce seedlings to support resilient restoration projects in the face of climate change (SASRI 2015).
• Test silvicultural techniques to reintroduce spruce into formerly disturbed areas that have regenerated in northern hardwood communities (i.e., release treatments and underplanting).
• Protect Spruce–Fir communities from wildfire, as this is an important action that can be taken to save the remnants of these communities.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

The Southern Appalachian Spruce Restoration Initiative (SASRI; https://southernspruce.org) is a partnership of diverse interests with a common goal of restoring spruce ecosystems across the high elevation landscapes of the Southern Blue Ridge. It is comprised of private, state, federal, and non-governmental organizations which recognize the importance of this ecosystem for its ecological, aesthetic, recreational, economic, and cultural values.

The Red Spruce Technical Advisory Board (RSTAB) was convened and facilitated by The Nature Conservancy in 2023 for the purpose of providing expert opinion and science-informed technical recommendations on red spruce ecosystem restoration methods and potential impacts to US Forest Service. RSTAB's Red Spruce Restoration Recommendations document describes desired outcomes from restoration activities, provides principles and criteria for prioritizing restoration locations, details vegetation management methods for different site conditions, and discusses potential impacts of restoration activities (TNC 2024). In addition to recommendations from SASRI and RSTAB, efforts are needed to:

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Eliminate or minimize negative effects of future development in state and federal government holdings (state and federal parks, US Forest Service recreation developments).
• Acquire additional acreage of Spruce–Fir habitat through purchase, conservation easement, or other perpetual management agreements (particularly in the Plott Balsams and Black/Craggy Mountains).

4.4.3 Northern Hardwood Forests

4.4.3.1 Ecosystem Description

Classification of the Natural Communities of North Carolina, 4th Approximation (Schafale 2024) includes this natural community as Northern Hardwood Forests Theme. Northern hardwood forests are found on high mountain slopes with a cool climate and high levels of rainfall in western North Carolina and are concentrated in many of the same high-elevation areas as Spruce–Fir forests.

The name refers to the resemblance of these forests to those in the northeastern United States, which have similar canopies, but the presence of southern Appalachian endemic species makes the community types in North Carolina different from those in the north. High-elevation climate, slope, aspect, and past disturbance are critical ecological determinants of the distribution of northern hardwood forests today. In general, they are widespread throughout the region owing to their lower elevation range.

Northern hardwood forests are dominated by combinations of moist-site hardwoods such as Yellow Birch, American Beech, Yellow Buckeye, and Sugar Maple. The herb layer is often lush and may range from low to fairly high diversity. These forests are subject to periodically widespread disturbances, such as ice storms or severe winds, which provide canopy openings, but probably seldom or never remove the whole canopy at once.

There are four recognized subtypes in this community theme, determined primarily by topography and soil chemistry (Schafale 2024).

- Northern Hardwood Forest (Typic Subtype, Rich Subtype, Beech Gap Subtype)
- High Elevation Birch Boulderfield Forest

The typic subtype varies in composition and diversity. Some have a lawn-like ground cover of just a few species of sedges and grasses, while others have a lush and diverse herb layer. The rich subtype is found at higher elevations, occurring on exposed or somewhat sheltered sites. It encompasses the rare examples on mafic or calcareous rock substrates, which contain flora of rich soils, including many species shared with Rich Cove Forest. The beech gap subtype occurs in high-elevation gaps and peaks, where beech trees stunted by the wind predominate. In the most extreme cases, the tree canopy may be reduced to shrub size. The trees may be quite old, although small, as growth and reproduction are relatively slow.

In the boulderfield forest, Ice Age freeze–thaw processes have left the ground completely covered with large boulders with very little soil. These areas are found above 4,000 feet elevations and are dominated by yellow birch with a distinctive undergrowth of gooseberries and moss on the rocks.

While the northern hardwood habitat can be defined in general terms, ecologically, it should be considered in association with Spruce–Fir forest for the purposes of maintaining ecological relationships and sustainability. Often components of Spruce–Fir habitats are present in sub-dominant numbers within northern hardwood communities and increase in dominance along the elevation gradient to a point where spruce–fir becomes the dominant community.

4.4.3.2 Location of Habitat

Northern hardwood forests are found throughout western North Carolina on high-elevation sites with abundant rainfall and a cool climate. They occur on ridges, open slopes, and upper coves with most examples above 3,600 feet elevation, and they range up to 5,500 feet or higher, the highest elevations of any hardwood forests (NCNHP 2024).

The majority of northern hardwood forests are on public lands and many are in protected status. Significant amounts of northern hardwood forest occur on federally owned lands including US Forest Service (Pisgah and Nantahala National Forests) and National Park Service (Blue Ridge Parkway and Great Smoky Mountains National Park), in the Great Smoky Mountains, Great Balsams, Plott Balsams, Black/Craggy Mountains, Unaka Mountain, Unicoi Mountains, and in the vicinities of Roan Mountain and Grandfather Mountain.

While most of the available northern hardwood forest is associated with these high-elevation mountain ranges, significant amounts are present in other areas of suitable elevation throughout the region, such as in the Amphibolite Mountains in Ashe and Watauga counties. A small percentage does occur on state-owned lands, and other conservation ownerships (e.g., The Nature Conservancy, local land trusts, etc.).

4.4.3.3 Problems Affecting Habitats

Development. Development on private lands, and logging on private and some public lands remain threats and are likely the most immediate and greatest threats to a significant number of good examples. Development pressure includes threats from a large increase in second homes and recreation facilities. The isolated nature of several populations of wildlife, such as the Carolina Northern Flying Squirrel, Northern Saw-whet Owl, Black-capped Chickadee and Weller’s Salamander, is likely detrimental to the genetic flow and overall long-range health of the species.

Climate Change. Expected climate changes include warmer average temperatures, longer growing season, probably more hot spells, more drought, and more intense storms (NCNHP 2024). Climate change, particularly drought and wildfire, is the greatest threat to protected examples. Drought may lead to increased potential for wildfire. While northern hardwood forests are not very flammable under the current climate, they could become so in more severe droughts.

However, the threat of climate change is less severe than in Spruce–Fir forests and the threat of logging and development are relatively greater.

Land Use. The aging of many northern hardwood stands has resulted in closed canopy conditions and decreasing habitat for bird species that rely on diverse understory development, such as the Canada Warbler. Lack of disturbance has reduced available habitat for disturbance-dependent species such as the Golden-winged Warbler and Yellow-bellied Sapsucker (Hunter et al. 2001a). In turn, the impacts to other wildlife from stand level disturbance will need to be examined. For example, small mammals in family Soricidae, such as Masked and Smoky shrews, can respond favorably to forest disturbance in northern hardwoods (Ford et al. 2002), but this may not be true for other small mammals or salamanders.

Pathogens. Beech bark disease is a newly emerged threat to the Beech Gap Subtype and to other Northern Hardwood Forest communities that contain appreciable beech. Many nonnative pathogens are a potential problem for several tree species in this ecosystem, including the Hemlock Woolly Adelgid, Balsam Woolly Adelgid, gypsy moth, Emerald Ash Borer, and beech scale.

4.4.3.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. The effect of a changed climate is likely to vary widely among examples of these communities, depending on topographic sheltering, configuration of rocks, soil depth, size of groundwater pools, and amount of overland runoff.

These systems are tied to specialized small environments and will be unable to migrate as the climate changes. Many may change very little, while a few will shrink, will be disturbed by wind or flood, or will change substantially because of temperature changes or drought. A small net loss of acreage may occur, but more seeps may be temporarily affected by drought. Table 4.4.3-1 summarizes the comparison of climate change with other existing threats.

Table 4.4.3-1 Comparison of climate change with other threats

Threat	Rank Order	Comments
Climate Change	1	Expected climate changes include warmer average temperatures, longer growing season, probably more hot spells, more drought, and more intense storms. We do not know the effect on rainfall and fog. Much of the climate in this zone is orographically determined and may not follow the same patterns as the general regional climate.

Table 4.4.3-1 Comparison of climate change with other threats

Threat	Rank Order	Comments
Development	2	Fragmentation and increased edge areas can increase predation on forest interior species and increase competition from more common species. Warmer winters and more hot spells may fuel increasing desire for housing development at the higher elevations where these communities occur.
Logging/ Exploitation	2	Logging alters forest structure and composition by removing mature canopy trees and can cause fragmentation in larger stands. Clearcutting negatively affects the availability of mycorrhizal fungi and lichens that are a major part of the Carolina Northern Flying Squirrel diet (as reviewed in Loeb et al. 2000). However, cleared areas may provide increased flowering plant food and nesting resources for native bee species (Romey et al. 2007). In one study, significant increases in native bee species diversity, richness, and abundance were a direct response to logging (Romey et al. 2007).
Invasive Species/ Pathogens	3	Gypsy Moth, Emerald Ash Borer, and other invasive species can lead to local destruction of habitat, which may contribute to changes in animal community composition.

4.4.3.5 Impacts to Wildlife

Appendix 3 provides a list of SGCN and other priority species for which there are knowledge gaps and management concerns. Appendix 3-17 (wildlife) and Appendix 3-19 (plants) identifies SGCN that depends on or are associated with this habitat type.

Northern hardwood forests provide habitat for numerous wildlife species that also rely heavily on spruce–fir forests. Because of the spatial relationship between them, and the fact that they share many ecological components and plant species, northern hardwood forests are critical to maintaining many species of birds and mammals dependent upon spruce–fir habitats. In addition, northern hardwood plant species may be critical components of spruce–fir habitats even in their sub-dominant role. Consider, for example, the fact that many spruce–fir dependent wildlife species are cavity nesters. Yellow birch, beech, sugar maple, and buckeye often provide more natural cavities and decaying wood than spruce or fir for species such as Northern Flying Squirrels, Yellow-bellied Sapsuckers, Black-capped Chickadees, Northern Saw-whet Owls, and other wildlife.

There is a major concern about salamanders, as this is a key ecosystem group for rare and southern Appalachian endemic species. On the other hand, the bird species are all more common and widespread farther northward, though a few species may become rare in the state. The aging of many northern hardwood stands has resulted in closed canopy conditions and decreasing habitat for bird species that rely on diverse understory development, such as the Canada Warbler.

At least six taxa are endemic to northern hardwood forests in the southern Appalachians; three others may also fall in this category but have not yet been formally described as separate subspecies. Additionally, one moth appears to be a major disjunct from the northern Appalachians and several others are likely to have a similar distribution but are presently too poorly known. All species listed for this ecosystem group are likely to be strongly affected by climate change, as well as the effects of increased fragmentation.

4.4.3.6 Recommendations

Although occupying a larger area and probably somewhat more resilient than spruce–fir forests, this habitat group contains a similar high proportion of endemics and major disjuncts, the loss of which cannot be replaced. Along with the spruce–fir forests, northern hardwood forests should be considered as one of the most threatened by climate change and should receive a high priority for intervention. Like the spruce–fir forests, a substantial amount of the acreage of this group is located on public lands or on other conservation lands. Consequently, intervention should be easier to implement for northern hardwood forests than for many others.

Surveys

Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Fill in distribution gaps for Carolina Northern Flying Squirrel. Continue survey work on distributions within and between known populations. Carolina Northern Flying Squirrel
• Obtain baseline data on SGCN and priority species, especially species that depend on high-elevation forests. Fill in distribution gaps for Northern Saw-whet Owl which is known to use high elevation hardwood stands. Northern Saw-whet Owl
• Conduct shrew surveys to determine the distribution of Long-tailed, Pygmy, and Water shrews and surveys to document the response of shrews to disturbance/management.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
Long-tailed Shrew	Pygmy Shrew	Water shrew

- Conduct surveys for rare salamanders as well as more common species to determine their actual distribution and better define their habitat associations.

Northern Pygmy Salamander	Seepage Salamander	Ravine Salamander
Southern Pygmy Salamander	Tellico Salamander	
	Weller's Salamander	

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Establish monitoring systems and protocols and implement programs to monitor population trends for all high-elevation species.

- Establish monitoring systems and protocols and implement programs to monitor population trends for all high-elevation species.

- Establish monitoring systems and protocols and implement programs to monitor population trends for all high-elevation species.

- Develop and implement monitoring systems and protocols for population trends for all high-elevation species, including those associated with northern hardwood forest, with top priority toward rare species and secondary priority toward all species occurring in this relatively rare community of the North Carolina landscape.

- Establish more Monitoring Avian Productivity and Survivorship (MAPS) stations, point counts, and migration banding stations; montane birds are not adequately picked up in BBS routes.

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Conduct genetic studies across taxonomic groups to assess degree of population isolation/gene flow and determine taxonomic status (primarily bird taxa thought to be southern Appalachian endemics).
• Initiate habitat use studies for many species to assess use of microhabitats, forest age classes, and habitat spatial relationships.
• Conduct research on habitat management techniques to successfully establish mixed spruce-northern hardwood stands in non-forested areas or appropriate pure/young northern hardwood stands.
• Research phenological relationships of priority species to better understand how changing climate conditions will affect seasonal availability of food resources.
• Conduct research on impacts of Beech scale on forest regeneration and wildlife.

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Consider and implement silvicultural management at appropriate locations to enhance understory development, provide regeneration and habitat for disturbance dependent species or early successional species and enhance mature forest conditions in young to middle-aged pure stands.

  Golden-winged Warbler

- Expand management of existing northern hardwood forests and adjacent habitats (particularly spruce–fir forests) to ensure the complete mix of age class, composition, and conditions necessary to sustain populations of a wide range of species that utilize this community.

- Consider management needs in areas impacted by Beech scale.

- Protect from wildfire, as drought conditions persist the potential for severe fires that would cause catastrophic loss are increased.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Make particular effort to protect examples at the higher elevations, where the community is likely to persist and where the seed source for migration to higher elevations will primarily come from.

- Protect the current habitat and connectivity of isolated patches through conservation ownership acquisition or easement.

- Increase connectivity among habitat patches, both through acquisition or management of adjacent stands. Preservation of large tracts of minimally disturbed older forests may be key to maintaining forest litter amphibian populations.

4.4.4 Cove Forests

4.4.4.1 Ecosystem Description

Classification of the Natural Communities of North Carolina, 4th Approximation (Schafale 2024) defines this natural community as Mountain Cove Forests Theme. Cove forests are some of the most well-known and recognized community types in the Mountains, occurring on sheltered, moist, low to moderate elevation sites. They are characterized by a dense forest canopy of moisture-loving trees. There are several subtypes in this ecosystem.

- Rich Cove Forest (Montane Intermediate, Montane Rich, Foothills Intermediate, Foothills Rich, Red Oak, Boulderfield subtypes).
- Acidic Cove Forest (Typic, High Elevation, Silverbell subtypes).
- Canada Hemlock Forest (Typic and White Pine subtypes).

The rich cove forest type, occurring in the most fertile sites, has a lush herb layer and relatively few shrubs. The high diversity in all vegetation layers makes this forest of great interest to botanists and ecologists.

The acidic cove forest type, which occurs in less fertile but otherwise similar sites to those occupied by rich cove forests, is dominated by the more acid tolerant species, and has undergrowth dominated by ericaceous shrubs such as rhododendron, rather than by herbs. Canada hemlock forests have similarly dense shrub layers and relatively few herbs.

The Canada Hemlock Forest is a mountain and foothill forest naturally dominated by Canada Hemlock with acid-tolerant undergrowth and low species richness. They occur in sheltered, mesic, low- to mid-elevation sites, primarily in narrow rocky gorges, steep ravines, and low gentle ridges within coves. Local slopes may be concave or convex landscapes.

4.4.4.2 Location of Habitat

Cove hardwood habitat is well represented in the Mountain ecoregion of western North Carolina, including in the Pisgah and Nantahala National Forests. According to the most recent Southeast Gap Analysis Project (GAP), cove forests comprise a little over 558 thousand acres (nearly 226 thousand hectares) of land cover in North Carolina (SEGAP 2007; NatureServe 2007). This represents slightly more than 1.6 % of all land cover in the state.

Cove Forests occur in sheltered mesic sites such as valley bottoms, ravines, lower slopes, and concave slopes found from 2,000 to 5,000 feet elevation. Sites are well drained but mesic due to topographic sheltering and low slope position (Schafale 2024).

4.4.4.3 Problems Affecting Habitats

Invasives. The most pressing problem affecting the cove hardwood habitat is the advent of several exotic pest species which could have a significant impact upon the health of the forest, including the Hemlock Wooly Adelgid, Gypsy Moth, and beech scale, as well as several nonnative plants. Evans and Gregoire (2007) that aldelgid infestation can move across the landscape at about 9 miles (15 km) per year or faster and can kill trees in two to three years (Trotter III and Shields 2009). In fact, the adelgid has already devastated most of the Canada hemlock stands in the state, such that former mixed hemlock-hardwood stands are now mostly hardwoods, with much lessened evergreen cover available for wildlife during the cooler months.

Development. Though estimates of the amount of cove hardwood lost to development are unavailable, the most significant problem affecting this community type is its conversion to other uses. Residential development in mountain coves often differs from development in other habitats of the region because the homes and associated open spaces are often interspersed within the forest. The result may be that direct habitat loss as a result of the houses and associated structures may be more limited than other types of development.

Land Use. Timber harvesting and conversion to other forest types (white pine) or other uses on private lands in certain areas can also decrease the availability of this habitat in the future. The reduction in quality of the habitat through fragmentation by roads and driveways and human intrusion can have significant impact upon the wildlife species of the forest (Rosenberg et al. 2003).

4.4.4.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. The effect of a changed climate is likely to vary widely among examples of these communities, depending on topographic sheltering, configuration of rocks, soil depth, and amount of overland runoff. Unprotected examples of these forests are most threatened by development and logging. Table 4.4.4-1 summarizes the comparison of climate change with other existing threats.

Table 4.4.4-1 Comparison of climate change with other threats to cove forests

Threat	Rank Order	Comments
Invasive Species	1	Exotic species represent a growing threat, including the hemlock wooly adelgid, gypsy moth, and beech scale, as well as several nonnative plants. The Hemlock Wooly Adelgid has already caused widespread devastation in hemlock forests. Emerald Ash Borer and several other destructive insects represent large potential threats. Invasive plants are a serious and growing problem in lower elevation examples, particularly

Table 4.4.4-1 Comparison of climate change with other threats to cove forests

Threat	Rank Order	Comments
		in those that are disturbed by logging or that occur near developed areas. Invasive plants, such as Garlic Mustard and Oriental Bittersweet, are likely to increase regardless of climate change. Oriental Bittersweet is already a significant problem in some cove forests in the Mountains and has greatly altered vegetation composition and structure.
Logging/ Exploitation	2	Logging causes more drastic alterations to structure and composition than expected from climate change. Timber harvesting and conversion to other forest types (white pine) or other uses on private lands in certain areas can also decrease the availability of this habitat in the future.
Development	2	Development can cause indirect effects as well as outright destruction of these communities, creating an edge effect and developing seed sources for invasive species. Residential development in mountain coves often differs from development in other habitats of the region, in that homes and associated spaces are often interspersed within the forest. The result may be that direct habitat loss as a result of the houses and associated structures may be more limited than other types of development. However, the reduction in quality of the habitat by virtue of being bisected by roads and driveways, other infrastructure, and domesticated plants and animals can certainly have significant impact upon the wildlife species of the forest (Rosenberg et al. 2003)
Climate Change	3	Climate change poses several threats, including loss of area in more marginal sites, alteration by increased wind, flood, and fire disturbance, and increased problems with invasive plants. For some protected examples, this is the most severe threat.

4.4.4.5 Impacts to Wildlife

Appendix 3 provides a list of SGCN and other priority species for which there are knowledge gaps and management concerns. Appendix 3-17 (wildlife) and Appendix 3-19 (plants) identifies SGCN that depends on or are associated with this habitat type.

Appalachian cove hardwood forests represent some of the most diverse ecosystems in the world outside of tropical zones (Hunter et al. 1999). An amazing assortment of trees and herbaceous vegetation, coupled with topographic, microclimatic, and soil characteristics combine to provide an extremely productive habitat for numerous mammals, amphibians, and birds. High numbers of endemic salamanders are present (Petranka 1998), and population densities of these animal groups in cove hardwood forests make these extremely important habitats.

Problems of individual species associated with cove hardwood forests include isolation or extremely limited ranges of populations (e.g., Cerulean Warblers, Crevice Salamanders, Green Salamander). That could lead to increasing chances of genetic depression or stochastic events having negative consequences for the sustainability of populations. Some bird species which require a diverse understory may be impacted by the aging of stands, which can result in decreased plant diversity until the stand reaches age classes sufficient to produce canopy gaps (Hunter et al. 2001a).

Junaluska and Tellico salamanders are highly restricted to habitats within this ecosystem group. Both occupy extremely small global ranges and are likely to be strongly affected by increased drought-, fire-, or storm-created openings in the canopy. Several other salamanders with extremely limited global ranges also have significant amounts of habitat within this community and are also likely to be threatened by the same set of climate change factors. The same is true for several species of Lepidoptera (such as the Dusky Azure) that are associated with mesic habitats and occur in the Southern Appalachians as major disjuncts from the north.

Some high-elevation cove forests now serve as refugia for species for which the current climate in lower areas in North Carolina is not suitable. They are likely to continue to do so but warming temperature and changed moisture regimes may make some of them less hospitable to some of these species. At the same time, these communities may become refugia for additional species that are currently common, if the regional climate becomes unsuitable for them. They may be crucial for the survival of some species in the state.

4.4.4.6 Recommendations

Rich cove forests host a great diversity of trees and herbs and provide habitat for a large number of rare plant species in North Carolina. Climate change is not expected to be a major threat to these species overall. While many examples of cove forests are protected from development and logging, protecting more examples would help these communities weather climate change. It would reduce the loss of acreage as protected examples shrink, and would allow larger, more robust populations of their species to survive. Landscape connectivity will become more important as individual patches become smaller.

Surveys

Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Direct initial efforts toward surveys to determine current baseline distribution and status of species associated with cove hardwood forest for which that information is lacking.
• Focus initial survey efforts on state-listed species and others that may be declining. Black-billed Cuckoo, Brown Creeper, Cerulean Warbler, Cooper's Hawk, Sharp-shinned Hawk, Yellow-bellied Sapsucker, Green Salamander, Pigmy Salamanders, Seepage Salamander, Southern Zigzag Salamander, Tellico Salamander
• Conduct surveys to understand current status of species believed to be more common, from which we can measure future population changes Marbled Salamander, Ravine Salamander, Spotted Salamander, Eastern Box Turtle, Eastern Hognose Snake, Eastern Mole, Eastern Smooth Earth Snake, Longtailed Weasel, Masked Shrew, Silver-haired Bat, Smoky Shrew, Swainson's Warbler, Woodland Jumping Mouse

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible. Protocols and procedures developed during surveys for these various taxa should subsequently provide a means to convert from a baseline survey mode to a long-term population trend monitoring mode at all times of the year.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• The health of Canada hemlocks needs to be monitored, and efforts to halt the spread of the Hemlock Woolly Adelgid needs to be pursued.
• An integrated pest management strategy is needed; detection and monitoring of plant pest infestations needs to be an integral part of the strategy.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Investigate treatment options (e.g., foliar sprays, systemic soil treatments, aerial fungal pathogens, biological controls) and monitor applications to determine best method for stand-level treatments (Onken and Reardon 2005; MDA 2010).

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Conduct studies of bird, amphibian, reptile, and vegetation responses to gap management or specific timber harvest regimes

Plethodontid salamanders	Cerulean Warbler	Yellow-bellied Sapsucker
Reptiles	Swainson's Warbler	

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- With the vast majority of cove hardwood habitat in mid-successional stages, efforts should be directed toward increasing older age classes by both lengthening harvest rotation recommendations for timberland owners and exploring whether old growth gap dynamic conditions can be mimicked through selective harvesting techniques in mid- to late-successional cove hardwood stands.

- Protect riparian areas and control impervious surfaces and stormwater runoff to reduce flood damage to cove forests in altered watersheds, as well as protect the aquatic systems.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Protect cove forests from severe wildfire during drought periods to prevent catastrophic disturbance. In more favorable periods, prescribed burning of surrounding landscapes would help reduce the risk of controllable wildfire, as well as benefiting the upland communities.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Add to our base of conservation ownership for future generations of the wildlife species associated with the habitat, as well as the use and enjoyment of them by future generations of North Carolinians.

- Protect examples in the most sheltered sites, and those that serve as landscape connections to other patches.

4.4.5 Mafic Glades and Barrens

4.4.5.1 Ecosystem Description

Classification of the Natural Communities of North Carolina, 4th Approximation (Schafale 2024) includes this natural community as Piedmont and Mountain Glades and Barrens Theme. They occupy a wide variety of sites that have in common that they limit tree cover without being predominantly bare rock. There are numerous subtypes of glades and barrens in the Mountain and Piedmont ecoregions.

- High Elevation Acidic Glade
- Low Elevation Acidic Glade (Grass, Biltmore Sedge subtypes)
- Low Elevation Basic Glade (Montane, Brushy Mountains subtypes)
- Montane Red Cedar-Hardwood Woodland
- Granitic Dome Basic Woodland
- Ultramafic Outcrop Barren (Pitch Pine, White Oak, Virginia Pine, Piedmont subtypes)
- Acidic Shale Slope Woodland
- Calcareous Shale Slope Woodland
- Piedmont Acidic Glade
- Piedmont Basic Glade (Typic, Falls Dam Slope subtypes)
- Diabase Glade
- Xeric Hardpan Forest (Basic Hardpan, Northern Prairie Barren, Southern Prairie Barren, Acidic Hardpan, Basic Rocky subtypes)
- Xeric Piedmont Slope Woodland

Glades are communities where bedrock is near the surface, so that shallow soil limits tree cover. Those located in the Mountain ecoregion are adapted to a cooler, moister climate and may be more drought tolerant than locations in the Piedmont ecoregion. However, mountain locations may be more susceptible to alteration than Piedmont glades because of residential development.

Diabase glades occur in the Piedmont over outcrops of diabase and potentially over other mafic rocks. As with other glade communities, the soil and vegetation are patchy and range from nearly bare rock to patches deep enough to support trees. The vegetation includes many species shared with other high pH soil communities and some species found on granitic flatrocks.

High elevation mafic glade communities are an extremely rare community type, with only three examples known globally. A single known location in North Carolina occurs on a flat exposure of amphibolite in Ashe County. Lichens, including a species found nowhere else (*Cladonia psoromica*), dominate much of the area. Herbs on thin soil mats and in crevices include both lowland species and northern disjunct species. Woody species occur in deeper soils and crevices.

Barrens are woodland or savanna communities that have soils that are deep but that have physical or chemical properties that are extreme and limit tree cover (Schafale 2024). Ultramafic outcrop barrens occur on dunite, peridotite, or serpentinite. These rocks are associated with unusual vegetation and endemic species throughout the world because of their unusual chemistry. North Carolina's only well-developed ultramafic outcrop barren is tied to specialized soils and is an open savanna-like community with a scattered pitch pine canopy and grassy ground cover

4.4.5.2 Location of Habitat

This natural community has locations in both the Piedmont and Mountain ecoregions. Piedmont examples are less rare, but a couple of the community types occur only in the Mountains. According to the most recent Southeast GAP analysis, glades and barrens comprise approximately 11 acres (about 5 hectares) of land cover in North Carolina (SEGAP 2007; NatureServe 2007).

4.4.5.3 Problems Affecting Habitats

These communities have been substantially altered by fire suppression, and some of these changes may shift them toward more natural composition. Fire is believed to be a natural part of these communities. Low intensity fires may benefit these communities, but climate change may bring higher potential for wildfires to be severe.

Species adapted to mafic glade habitats are tolerant of drought and heat. Higher average temperatures, coupled with drought conditions, will likely increase occurrence of fire. Drought appears to be an important factor in keeping these communities from becoming dense forests. While these are among the driest sites in the Piedmont region, if droughts become much more extreme, they may be beyond the tolerance of some of the species. Drought may also allow this community type to expand into adjacent forests, though this expansion is likely to be limited by soil conditions. An increase in hurricanes or other severe storms may increase the wind damage in forests that create canopy openings which often favors herbaceous growth. Some of the changes associated with climate change may shift them more toward more natural composition and may even allow these communities to expand into adjacent forests.

4.4.5.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. Climate change is not expected to be a major threat for these communities. Development, logging, habitat fragmentation, and changes caused by fire suppression are the most severe threats. In some areas, excessive deer browse is also a major threat. Climate change appears less of a threat. Table 4.4.5-1 summarizes the comparison of climate change with other existing threats.

Table 4.4.5-1. Comparison of climate change with other threats to mafic glades and barrens

Threat	Rank Order	Comments
Development	1	Warmer winters and more hot spells may fuel increasing desire for housing development at the higher elevations where these communities occur. Development may not directly impact these communities, but may increase access and therefore trampling. Development of adjacent landscapes is likely to introduce pollution and sediment through stormwater runoff. There may also be increased opportunity for invasive species to disperse into this habitat.
Logging/ Exploitation	2	Land ownership patterns, proximity to markets, accessibility, and other factors influence short-term habitat alterations like forestry operations. Full scale high-grading and poor logging practices will have very negative impacts on the structure and composition of adjacent forests.
Fire	3	Fire suppression has shifted these communities toward denser vegetation and more mesophytic plant composition than would naturally occur, making them more susceptible to climate change. Burning would increase their resilience to warmer climate and drought, as well as make them less prone to destruction by wildfire Prescribed burning will have to account for younger canopies whose trees may be more susceptible to fire than in the past.
Climate Change	4	Mafic glades and barrens may actually benefit from a changed climate, at least among the Piedmont examples. This benefit will only be realized if sites are protected from other forms of destruction, and for most, if fire is restored to them.

4.4.5.5 Impacts to Wildlife

Appendix 3 provides a list of SGCN and other priority species for which there are knowledge gaps and management concerns. Appendix 3-17 (wildlife) and Appendix 3-19 (plants) identifies SGCN that depends on or are associated with this habitat type.

It is uncertain how many priority species are associated with this habitat. Bog Turtles are known from a bog wetland at a mafic glade in Ashe County. For animal species, mafic glades and barrens are probably best regarded as a minor component. There may be land snail and moth species that utilize this habitat type; otherwise, mammals such as Bobcats and Raccoons are expected to utilize this community primarily as a movement corridor. The Gorgone Checkerspot butterfly is known in the state primarily from an ultramafic outcrop barren community at Buck Creek in Clay County

4.4.5.6 Recommendations

These communities are naturally rare in North Carolina, due to limited availability of suitable habitat. All of these communities are tied to specialized sites and are unable to migrate. Examples need to be protected and managed appropriately.

Surveys

Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Determine the effects of current drought conditions on vegetated communities.
• Map these sites in a GIS format to facilitate tracking changes over time in the habitat, as well as the associated species and facilitate landscape scale management of this rare habitat.
• Conduct detailed surveys, such as moth trapping, at Buck Creek Barrens, the largest mafic barrens site in the state.

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Monitor drought conditions and potential for catastrophic wildfire.

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Study population responses to a prescribed fire regime.
• Study the impact of various management scenarios on the habitat and associated species.

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Initiate a prescribed fire regime to prevent invasive plants and prevent habitat conversion.
• Protect this habitat through active management to remove invasive species.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Close sites to stop direct (trampling, loss of habitat to recreation developments such as trails, vistas, etc.) and indirect (disturbance) human impacts.
• Use easements and land acquisition to protect from long-term impacts such as housing development.

4.4.6 Grass and Heath Balds

4.4.6.1 Ecosystem Description

Classification of the Natural Communities of North Carolina, 4th Approximation (Schafale 2024) has described this natural community as Grass and Heath Balds Theme. There are eight community subtypes in this community.

- Grassy Bald (Grass, Sedge, Alder subtypes)
- Heath Bald (Catawba Rhododendron, Southern Mixed, Slate, Sand Myrtle, Low Elevation subtypes)

Balds are treeless shrub- or herb-dominated communities of the high Mountains. The treeless areas do not represent a climatic timberline and often occur near higher peaks that are forested. The ecological factors creating balds are not well understood. Harsh climate and shallow soil seem to be a factor in some, particularly heath balds, but many examples of both community types are being invaded by trees and, in the case of grassy balds, shrubs. Fire may have been a factor, but many bald sites do not appear prone to fire and are surrounded by vegetation that apparently did not burn.

Grassy balds are open meadows typically dominated by mountain oatgrass and sedges, with a fairly diverse mixture of other species. They usually occur on broad ridgetops. Heath balds are dense thickets of tall shrubs with Catawba Rhododendron and Mountain Laurel as the most common dominants. An unusual dominant at Roan Mountain is Green Alder, not found elsewhere in North Carolina. Most heath balds are on sharp spur ridges, but some occur on rounded peaks or ridgetops.

High-elevation communities are characterized by cool temperatures, relatively high moisture levels within forests, short growing seasons, exposed rock and acidic soils, and extreme weather events. Canopy trees are often misshapen due to persistent strong winds. Open communities (sparse-to-no tree canopy) such as heath or grassy balds and rock outcrops are scattered throughout. Spreading Avens (a federally listed endangered plant species) is endemic to high-elevation grassy balds (Wear and Greis 2012).

It has been discovered that some places that superficially resemble balds were cleared of forest in historical times, but other balds apparently were open throughout history. The presence of disjunct species which require open habitat suggests that some balds have been open since the Ice Age. Large herbivores, such as Elk and Bison may have kept grassy balds open through grazing. Another possibility is that Native Americans worked to keep grassy balds open for game by burning or by other clearing methods.

4.4.6.2 Location of Habitat

Grass and heath balds occur only in the highest mountain ranges of western North Carolina, notably in the Great Smokies, Plott Balsams, Great Balsams, Black/Craggy Mountains, Grandfather Mountain, Roan Mountain, and in the Amphibolite Mountains of Ashe County. According to the most recent Southeast GAP analysis, grass and heath balds comprise approximately 4,761 acres (about 1,927 hectares) of land cover in North Carolina (SEGAP 2007;; NatureServe 2007). This represents only 0.2% of land cover in the state.

4.4.6.3 Problems Affecting Habitats

Natural System Changes. Warmer temperatures, changes in precipitation or fire regime, or climate-change induced competition from offsite plants may threaten grassy balds (Wear and Greis 2012). Grassy balds and some of the heath balds are already seriously threatened by invasion from native trees and shrubs. The current invasion of native trees and shrubs, development, and conversion to pastures or Christmas tree plantations are much greater concerns than impacts from climate change.

Climate Change. Future climate conditions are expected to include warmer temperatures, longer growing season, and likely more hot spells and drought. Warmer temperatures may change the composition of these communities in uncertain ways. Some of the species of Grassy Balds are northern species that presumably would suffer. Much of the current climate in the high mountains is orographically determined and is quite different from the general regional climate. Much of the distinctive environment here depends on fog and orographic cloud cover. If these phenomena persist, they will ameliorate the effects of warming, drought, and fire. If they are disrupted, climate change effects will be much more drastic.

Invasive Species. Problems with exotic species invasion in Grassy Balds may increase with warmer temperatures and increased fire, but this is not certain. The most abundant exotic species at present are grazing-tolerant grasses that are from past grazing, and they are not known to be expanding where grazing is not occurring. Heath Balds do not suffer from exotic species invasion at present. No invasive species are known that are likely to become a serious threat to them.

4.4.6.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. The effect of climate change on the species of balds is particularly uncertain. Some species are at their southern range limits and some are northern disjuncts, and these may be directly harmed by warmer temperatures. Some are dependent on seeps or wet areas and may be harmed by more frequent or more intense drought. Habitat specialists and species with restricted ranges will likely be some of the greatest affected by the combined effects of habitat loss and climate change. Such populations are more vulnerable to extinction by rare events and susceptible to additional stressors such as climate change (DeWan et al. 2010). Table 4.4.6-1 summarizes the comparison of climate change with other existing threats.

Table 4.4.6-1 Comparison of climate change with other threats

Threat	Rank Order	Comments
Woody Succession	1	Trees and shrubs have been invading grassy balds in recent years. The ecological processes that kept them open in the past are not well known, and appear to no longer operate.
Development	2	Development (primarily housing) has had an impact upon both the habitat and the species utilizing it.
Climate Change	3	Heath balds are probably less likely to be strongly affected by climate change than grassy balds. Communities and species associated with this ecosystem are likely to be affected by changes in temperature and mild winters associated with climate change.
Conversion to agriculture/ silviculture	4	Conversion to pasture land has historically degraded some grassy balds and continues to be a threat even at otherwise protected sites. Agriculture activities that threaten these areas include Christmas tree production.
Wildfire	5	It is unclear if fire is likely to be harmful or beneficial. If wildfires increase, it could offset the problem of tree and shrub invasion and could allow balds to expand.
Invasive Species	6	The invasion of native shrubs and trees is a greater concern than exotic species in grassy balds. Problems with exotic species invasion in grassy balds may increase with warmer temperatures and increased fire, but this is not certain. Pasture grasses, Coltsfoot, and Angelica are the most common exotic species likely to invade grassy balds. In addition to these, the Roan Mountain area has been invaded by thistle, spotted knapweed, and garlic mustard. Some of these are currently restricted to the roadsides, but others (thistle in particular) have been found on the balds. Seeds are brought in on vehicles (trucks and tractors) and boots, and spread from roadsides and trails. Invasive exotics may be more of a problem than currently acknowledged.

4.4.6.5 Impacts to Wildlife

Appendix 3 provides a list of SGCN and other priority species for which there are knowledge gaps and management concerns. Appendix 3-17 (wildlife) and Appendix 3-19 (plants) identifies SGCN that depends on or are associated with this habitat type.

Many wildlife species that use grass and heath balds are threatened by impacts other than habitat loss. Timber Rattlesnakes are threatened not only by habitat loss but also by being subject to collection, disturbance of hibernacula/gestation sites, and persecution. There has been considerable effort undertaken in the northeastern United States to determine the impact upon Allegheny Woodrat populations from a roundworm parasite (McGowan 1993; Stone et al. 1993), though no studies have been conducted within North Carolina to assess the level of threat posed to woodrat populations.

4.4.6.6 Recommendations

These communities occur at the highest elevations so they are naturally rare in North Carolina. All of these communities are tied to specialized sites and are unable to migrate. Examples need to be protected and managed appropriately.

Surveys

Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Obtain baseline data on high-elevation bird species of grassy and heath balds.

Alder Flycatcher	Golden Eagle	Vesper Sparrow

- Obtain baseline data on mammal and reptile communities and habitat use (e.g., identify Timber Rattlesnake den sites).

Mammals	Reptiles

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Monitor priority small mammal and reptile population trends and habitat use. Small mammals Reptiles

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Investigate the feasibility of using some form of controlled grazing regime to control invasive plants.
• Study Timber Rattlesnake movements, use of hibernacula, and reproductive success at gestation sites. Timber Rattlesnake

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Initiate a prescribed fire regime to control invasive plants and prevent habitat conversion.
• Controlling invasive species and protecting or restoring areas is critical to protect these habitats against threats.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extentin order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Collaborate with partners to develop a management plan for high-elevation communities.

4.4.7 High-Elevation Cliffs and Rock Outcrops

4.4.7.1 Ecosystem Description

Classification of the Natural Communities of North Carolina, 4th Approximation (Schafale 2024) has updated this natural community as High Elevation Rock Outcrops Theme. High-elevation rock outcrops are extremely rare, have a very restricted range, and are subject to extreme environmental conditions. These communities occur on ridge tops, peaks, and upper slopes where soils are thin and discontinuous and rock dominates the surface. Even in the most rugged high Mountains they represent only a small minority of the landscape, generally at 4,000 feet in elevation and higher. In contrast, mid-elevations range from 2,000 to 4,000 feet and low elevations are below 2,000 feet. The vegetation is likely to be very patchy, reflecting the variability of the soil.

There are six community subtypes in this ecosystem.

- High Elevation Rocky Summit (Typic, High Peak, Little Bluestem Basic, Ninebark Basic, High Peak Lichen subtypes)
- High Elevation Granitic Dome

High-elevation granitic domes occur on the exfoliated outcrops that form when massive granitic rock breaks off in sheets parallel to the surface. Exfoliation produces smooth dome-shaped outcrops that lack crevices. Lichens and mosses occur on the bare rock. Soil and vegetation develop together on the rock surface as moss mats gradually deepen and are invaded by a succession of herbs. Soil mats are not anchored to the rock below and eventually fall off or are pulled up by falling trees, leaving the rock bare again. The shallow soils are generally dry, but some zones of seepage are usually present on the edge of the soil of adjacent forests. A number of wetland plants can occur in these saturated areas.

They have shallow soils and occur on fractured rock. The bare rock is similarly vegetated by patches of lichen and moss, and shallow soil mats may develop locally. The presence of fractures, however, offers patches of deeper, more permanent soil that can support deeper rooted plants, and can provide an opportunity to anchor soil mats. The vegetation pattern is less likely to shift over time.

4.4.7.2 Location of Habitat

High elevation cliffs and rock outcrops occur only in the highest mountain ranges within the Mountain ecoregion in the Great Smokies, Plott Balsams, Great Balsams, Black/Craggy Mountains, Grandfather Mountain, Roan Mountain, and in the Amphibolite Mountains of Ashe County. According to the most recent Southeast GAP analysis, rocky summit and granitic domes comprise approximately 1,180 acres (about 478 hectares) of land cover in North Carolina (SEGAP 2007; NatureServe 2007).

4.4.7.3 Problems Affecting Habitats

The conditions present at individual rock outcrops are unique, owing to geology, geography, elevation, moisture, and landscape position. They may contain discrete communities or they may be dispersed among a variety of other community types that are connected through local geology and landscape conditions. As such, the extent of habitat that each rock outcrop provides is dependent upon the entire set of conditions in and surrounding the surface rock. Those conditions influence its use by plants and animals dependent upon the surface rock and may include significant amounts of adjacent ecological community types.

Land Use. Common threats across the range of high-elevation rock outcrops include recreation, development, and forest succession. The two major problems most associated with low-elevation rock outcrops include development and recreational impacts. However, low-elevation rock outcrops are subjected to short-term habitat alterations (e.g., forestry operations) more often than high-elevation rock outcrops due to land ownership patterns, proximity to markets, accessibility, and other factors.

4.4.7.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. While climate change is not the most severe threat, a combination of synergistic effects with other existing conditions could stress these systems to the point where several species are unable to persist.

The effect of a changed climate is likely to vary widely among examples of these communities, depending on topographic sheltering, configuration of rocks and soil depth. These systems are tied to specialized small environments and will be unable to migrate as the climate changes. Many may change very little, while a few will shrink, will be disturbed by wind or flood, or will change substantially because of temperature changes or drought. Table 4.4.7-1 summarizes the comparison of climate change with other existing threats.

Table 4.4.7-1 Comparison of climate change with other threats to high-elevation cliffs and rock outcrops

Threat	Rank Order	Comments
Climate Change	1	Changes in temperature and mild winters will likely create the most impacts. Given the high number of endemics and disjuncts, climate-related changes greatly threaten biodiversity. Reduced winter snow and lack of seasonal snow packs will have negative effects on soil moisture.
Trampling	2	Trampling from recreational users (hikers and rock climbers) is probably the most immediate anthropogenic threat.

Table 4.4.7-1 Comparison of climate change with other threats to high-elevation cliffs and rock outcrops

Threat	Rank Order	Comments
Development	3	Logging and development are possible on private tracts. Development may not directly impact outcrops, but may increase access and therefore trampling.
Woody Succession	3	Trees and shrubs may invade if enough water is available during the growing season. Intrusion by alder, rhododendron, and other woody plants can cause rock outcrops to become overgrown.
Invasive Species	4	As temperatures increase, native and exotic species from lower elevations may be able to invade these areas more easily. Coltsfoot is the most common exotic species in high-elevation rock outcrops.
Pollution	5	There has been suggestion that air pollution could be having an impact upon the high-elevation rock communities of western North Carolina (TNC and SAFC 2000); however, there has not been definitive evidence of air pollution impacts upon wildlife species associated with high-elevation rock outcrops.

4.4.7.5 Impacts to Wildlife

Appendix 3 provides a list of SGCN and other priority species for which there are knowledge gaps and management concerns. Appendix 3-17 (wildlife) and Appendix 3-19 (plants) identifies SGCN that depends on or are associated with this habitat type.

While high-elevation rock outcrop habitat and low-elevation cliffs/rock outcrops support many of the same animals and plants, there are species of both plants and animals that are found exclusively at high-elevation rock communities (e.g., the Rock Vole, Longtailed Shrew, Allegheny Woodrat, and several rare plant species), and others found only in low-elevation cliffs/rock outcrop habitats (e.g., the Southern Appalachian Woodrat, Spotted Skunk, and Crevice, Green, and Southern Zigzag salamanders). The elevation limit for each of these species varies; however, there are distinctions in animal assemblages in rock habitats that are defined by elevation.

For many species associated with high-elevation rock outcrops, we do not currently know the entire spectrum of threats that are affecting populations due to inadequate levels of study or knowledge. Individual wildlife and plant species may face threats specific to either their particular location or the species itself. For example, Timber Rattlesnakes face threats in addition to habitat loss, including being subject to collection, disturbance of hibernacula/ gestation sites, and persecution. There has been considerable effort undertaken in the northeastern United States to determine the impact upon Allegheny Woodrat populations from a roundworm parasite that may have impacted populations in that region (McGowan 1993; Stone et al. 1993), though no studies have been conducted within North Carolina to assess the level of threat posed to North Carolina woodrat populations.

The decline of Peregrine Falcons during the last half of the 20th century has been widely attributed to the use of DDT and its concomitant effect on bird reproduction. The use of DDT was banned and Peregrine Falcon restoration efforts occurred in the late 1980s and 1990s; however, the falcons still face threats due to habitat loss to development and recreation impacts at individual cliff sites. Furthermore, the North Carolina population remains at fairly low density, thereby increasing the threat of stochastic events having significant population impacts.

The insect fauna of high-elevation rock outcrops is not yet well studied and a number of additional species may yet be added. The landscape requirements of these guilds also needs more study. Two endemic spiders in the Lampshade genus (*Hypochilus*) would be particularly vulnerable to extinction if they are intolerant to increases in temperature and drought, which seems likely (Huff and Coyle 1992). Their current restriction to extremely small ranges suggests that they have only a low level of dispersal ability and may be unable to shift their ranges fast enough to keep up with environmental change. Competition with the more widespread Lampshade Weaver (*H. pococki*) spider may further limit their ability to shift their ranges.

4.4.7.6 Recommendations

Of all the habitats in the state, this ecosystem is among the most vulnerable to the effects of climate change. This habitat type cannot be created, thereby making conservation the only option for these unique areas. Given the high number of endemics and disjuncts, climate-related changes greatly threaten biodiversity here. Several of the species face outright extinction and others, if lost, are unlikely to ever recover within the region.

Priority should be given to several measures that may secure them enough time and space to survive both short term environmental disturbances as well as adapt to longer term changes in the climate. Since virtually all examples of this theme are located on public lands and already managed to preserve their natural features, implementation of recommended interventions should be feasible.

Surveys

Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Survey for new Peregrine Falcon nests.

  Peregrine Falcon

- Obtain baseline data on small mammal communities and reptile communities and habitat use (e.g., identify Timber Rattlesnake den sites).

  Timber Rattlesnake

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Monitor endemic species closely for declines in the near future. Transplantation may be required to prevent extinction.

- Continue monitoring the Peregrine Falcon population.

  Peregrine Falcon

- Monitor priority mammal and reptile population trends and habitat use.

  Mammals Reptiles

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Reintroduce rare species to patches or mountain ranges where they have been lost, as well as to restored areas, to improve their prospects for survival in the future climate.
• Study Timber Rattlesnake movements, use of hibernacula, and reproductive success at gestation sites. Timber Rattlesnake

Management Practices
Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Maintain biologically significant areas, including Peregrine Falcon nesting areas, reptile den sites, and significant salamander occurrences through active management of outcrops to reduce the intrusion by alder, rhododendron, and other species that contribute to the disappearance of some vertebrates. Peregrine Falcon
• Control invasive species and protect or restore areas already affected by invasive species to protect against changing climate conditions.
• Use a hand crew to manually cut down encroaching woody vegetation with chainsaws or brush blades. Any use of herbicides and surfactants will need to be of low toxicity to wildlife.

Conservation Programs and Partnerships
Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Protect from trampling to allow the species pool to expand through suitable habitat, producing larger, more robust populations that would be better able to survive climate-related changes.

- Ensure that all existing high-elevation rock outcrops are high priorities for conservation action, as they are extremely rare, have a very restricted range, and are subject to extreme environmental conditions.

- Close sensitive areas at certain times (e.g., during Timber Rattlesnake emergence or Peregrine Falcon nesting) or permanently to stop direct trampling, loss of habitat to recreation developments, trails, vistas, etc., and indirect human impacts (disturbance).

  Peregrine Falcon   Timber Rattlesnake

4.4.8 Low Elevation Flatrocks, Cliffs, and Rock Outcrops

4.4.8.1 Ecosystem Description

Classification of the Natural Communities of North Carolina, 4th Approximation (Schafale 2024) describes this natural community as Low Elevation Cliffs and Rock Outcrops Theme. This broad ecosystem group encompasses many, though not all, of the community types at low to mid elevations that are too steep or rocky to support a closed tree canopy. The vegetation of these communities is generally very patchy, reflecting extreme variability in the depth and composition of soil and of available moisture.

Plants include forest species with broad site tolerances, species characteristic of a wide range of open habitats, and species specialized for rock outcrops. Rock outcrops typically are very dry, but seepage zones are often present and may support wetland vegetation. This community type generally occurs below 2,000 feet in elevation. In contrast, mid-elevations range from 2,000 to 4,000 feet and high elevations are above 4,000 feet.

There are numerous community subtypes included in this community description.

- Low Elevation Rocky Summit (Acidic, Basic, Quartzite subtypes)
- Low Elevation Granitic Dome
- Montane Cliff (Acidic, Mafic, Calcareous subtypes)
- Talus Vineland
- Piedmont Cliff (Acidic, Basic subtypes)
- Coastal Plain Cliff

Low elevation rocky summit communities occur in exposed positions on peaks, ridgetops, and upper slopes in the Mountain ecoregion. Low elevation rocky summits have fractured rock which allows growth of deep-rooted woody plants in places. Soil accumulates in pockets of varying depth and produces heterogeneous vegetation. Many variants potentially occur but are not well known.

Low elevation granitic domes occur generally below 3,000 feet elevation on exfoliated outcrops of granitic rock, where peeling of sheets of rock parallel to the surface produces a dome-shaped outcrop of solid rock. Soil mats that begin as moss clumps gradually thicken over time and follow a characteristic vegetational succession from herbs to shrubs and stunted trees. The unanchored mats are periodically destroyed by falling off or by being pulled up by falling trees, leaving the rock bare and beginning the succession anew.

Cliff communities occur on lower, more sheltered topographic sites and include Montane, Piedmont, and Coastal Plain subtypes. Montane cliffs are steep-to-vertical, sparsely vegetated rock outcrops on river bluffs, lower slopes, and other topographically sheltered locations. In general, they are generally created by streams undercutting a bluff but may occur somewhat above a stream. Like rocky summits, the rock is usually fractured and supports very patchy vegetation that includes woody plants rooted in crevices, as well as herbs in soil pockets, and mosses and lichens on bare rock. The Mountain and Piedmont/Coastal Plain types have flora typical of their regions, often combining plants from adjacent communities with typical outcrop plants.

North-facing cliffs have a cooler microclimate than the surrounding areas and sometimes harbor disjunct or regionally rare species characteristic of cooler, moister regions. In some cases these species are believed to be remnants from more widespread populations that existed in the Ice Ages. In the Mountain ecoregion, south-facing cliffs may support species more typical of the warmer Piedmont or even Coastal Plain.

The acidic, mafic, and calcareous types support different flora that reflect the rock chemistry. Mafic and calcareous cliffs contain calcium-loving species that do not occur on the more common Acidic cliffs. The floristic differences between calcareous and mafic cliffs are more subtle and reflect differences in the balance of basic elements.

Piedmont/Coastal Plain heath bluffs differ somewhat from the other community types in that they have little bare rock. They do, however, lack a closed tree canopy, apparently because of steepness. They are characterized by a dense shrub layer of Mountain Laurel or Catawba Rhododendron, which are otherwise essentially absent in the Piedmont and Coastal Plain. These communities occur on north-facing bluffs, and the cool microclimate is believed to be important to these species.

Granitic flatrock communities occur on flat to gently sloping exfoliated outcrops of granitic rocks and are scattered throughout the Piedmont region, from Virginia to Alabama. The rock outcrop is generally flush with the surrounding soil and has only minor irregularities. These communities are somewhat related to the granitic dome communities of the upper Piedmont and Mountains in that vegetation is sparse and very patchy. On bare rock, soil mats that accumulate in moss clumps undergo a gradual development, deepening and being invaded by a succession of plants.

4.4.8.2 Location of Habitat

Low elevation cliff and rock outcrop habitat is spread throughout the Mountain and upper Piedmont ecoregions. Piedmont examples include Sauratown Mountains inclusive of Pilot Mountain, and the Crowders, Uwharrie, and South Mountains. Flatrock communities are found primarily in the eastern Piedmont. Other habitat types are present even into the Coastal Plain, such as heath bluffs.

4.4.8.3 Problems Affecting Habitats

Conditions vary considerably within this habitat type, with a significant number having been impacted and/or lost due to numerous factors, while others remain functional "natural sites" and still others are specifically managed to minimize human impacts.

Climate Change. Low-elevation cliffs and rock outcrops are diverse communities that are expected to have a variety of responses to climate change. While some are dependent on moisture and may be harmed, others may actually benefit from increased drought and fire. This benefit will only be realized if sites are protected from other forms of destruction, and for most, if fire is restored to them through prescribed burning. These communities are naturally rare in North Carolina, due to limited availability of suitable habitat. Examples need to be protected and managed appropriately.

Some climate change models predict that rainfall will be concentrated during the fall, and there will be increased droughts in the spring and summer. Droughts could favor herbaceous species and grasses in open, dry outcrops, which tend to be rarer than the woody species associated with outcrops. Drought will kill trees on edges and soil islands. This already happens in current droughts and is part of the mechanism keeping flatrocks open. Increased length or severity of droughts might cause flatrocks to expand at the expense of adjacent shallow-soil woodlands. Herb species associated with granitic flatrocks tolerate drought at present or grow in the moist early growing season. It is unclear if they are at the margin of their tolerance, or whether they could withstand longer or more severe droughts. Drought in spring would be detrimental, while drought in other seasons might not be. A few additional flatrocks may be opened up by wind throw or drought mortality. Increased storms may blow down trees and pull up soil mats more frequently. Amount of bare outcrops and shallow soil mats may increase at the expense of deeper mats.

Increased temperatures could increase demand for water, a limited resource in these sites. Phenological shifts (earlier bloom periods, emergence from hibernation, nesting and breeding) in seasons may occur in a warmer climate. Exotic plants readily invade favorable microsites on many outcrops. Increased disruption of adjacent forests may bring seed sources closer to many outcrops.

Development. As with high-elevation rock outcrops, two major problems most associated with the low-elevation rock outcrops include development and recreational impacts. However, low-elevation rock outcrops are subjected to short-term habitat alterations (e.g., forestry operations) more often than high-elevation rock outcrops due to land ownership patterns, proximity to markets, accessibility, and other factors. The extent and degree of impact associated with such temporary alterations is unclear for most species. Regardless of the impacts or problems associated with short-term habitat modifications, the relative scarcity of low-elevation rock outcrop habitat across the landscape of North Carolina, and reliance upon it by numerous wildlife species lends greater significance to the need to identify and manage these habitats appropriately to conserve wildlife.

Fire Suppression. Low intensity fires could expand the open area and benefit some of the rare plants of outcrops. More mesic outcrops such as heath bluff communities are more likely to be harmed by fire. Landscape fragmentation and fire suppression practices likely will continue to prevent most fires from spreading very far. The central parts of granitic flatrocks are unlikely to burn even in droughts. Fire could affect the dry woodlands that form the edge zone of the flatrocks. However, most flatrocks occur in fragmented landscapes where fire is unlikely to spread. They are likely altered by lack of fire.

Dense woody vegetation around edges may become more open. Increased drought or fire might produce beneficial structural changes. Some outcrops have been altered by fire suppression and these changes may help return to more natural composition. Others will lose characteristic mesophytic species. The effect may be severe in a small number of outcrops. Some dry outcrops may expand into adjacent forests, while heath bluffs may shrink.

4.4.8.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. Granitic flatrocks are tied to specialized sites and cannot migrate. Communities will change in situ but it is uncertain how much. As with high-elevation rock outcrops, the two major problems most associated with the low-elevation rock outcrops include development and recreational impacts. For animals associated with cool, moist slopes or cliffs, particularly in relict situations, climate change represents the most significant threat, particularly in the Piedmont where their populations are typically small and highly isolated. For the plants associated with this theme, climate change is not expected to be a major threat. Development and changes caused by fire suppression are the most severe threats. In some areas, excessive deer browse is also a major threat. Table 4.4.8-1 summarizes the comparison of climate change with other existing threats.

Table 4.4.8-1 Comparison of climate change with other threats to low-elevation flatrocks, cliffs, and rock outcrops

Threat	Rank Order	Comments
Mining	1	Surface mining (e.g., gravel pits) would effectively eliminate this community.
Invasive Species	2	There are significant problems with invasive plants, at least in edge zones. Climate change will probably not make invasion worse, but drought disturbance of surrounding woodlands and edges may make them more susceptible. It is possible that some of the invasive species, such as Japanese Honeysuckle, Wineberry, and Asian Dayflower, will be harmed by drought more than the native species.

Table 4.4.8-1 Comparison of climate change with other threats to low-elevation flatrocks, cliffs, and rock outcrops

Threat	Rank Order	Comments
		Cliffs and rock outcrops have some problems with invasive plants, which can invade edge zones and more favorable soil pockets. Cogon grass may not already be present but is likely to increase with climate change. If climate change increases disturbance of adjacent forests, it may allow invasive plant seed sources to develop closer to rock outcrops that are now remote from them.
Development	2	Development on granitic flatrock communities may involve blasting or other fracturing methods to remove rock. Development of adjacent landscapes is likely to introduce pollution and sediment through stormwater runoff. There may also be increased opportunity for invasive species to disperse into this habitat. Development can have both direct and indirect impacts that severely threaten many unprotected examples. Improved access may increase recreational use that leads to trampling and poaching of rare plants.
Human Disturbance	2	Trampling from hiking and recreation activities, trash dumping, and other damage could occur from human disturbance. Where granitic flatrocks occur within forested habitats, timber removal can disturb vegetation on flatrocks.
Climate Change	3	These species tolerate drought at present, or grow in the moist early growing season. It is unclear if they are at the margin of their tolerance, or whether they could withstand longer or more severe droughts. More southerly flatrock species could find their way to our flatrocks.
Fire	3	It is unclear how much climate change will change fire frequency in the fragmented landscapes of the Piedmont and lower Mountains. Fire suppression has been a major factor degrading some of these communities. Fire may allow dry rock outcrops to expand, while mesic cliff and heath bluff communities could be harmed by intense fires. Fires during severe drought may be too intense and may cause damage to the characteristic plants and the shallow soils as well.
Logging/ Exploitation	4	Land ownership patterns, proximity to markets, accessibility, and other factors influence short-term habitat alterations like forestry operations.

4.4.8.5 Impacts to Wildlife

Appendix 3 provides a list of SGCN and other priority species for which there are knowledge gaps and management concerns. Appendices 3-17 (wildlife) and 3-19 (plants) identify SGCN that depend on or are associated with this habitat type.

Many wildlife species utilize the rock outcrop habitat without regard to arbitrary elevational distinction (e.g., Peregrine Falcon), and others will utilize only high-elevation rock outcrop habitats, at least according to what we currently know (e.g., Rock Voles and Rock Shrews). However, many wildlife species and even more plant species (Schafale and Weakley 1990) are either associated with high-elevation rock communities or low-elevation rock communities. The elevation limits for each species, however, are quite variable. Many low-elevation rock outcrop species of plants and animals are restricted to ranges outside high-elevation areas (e.g., Crevice Salamanders are only found in and around the relatively low-elevation Hickorynut Gorge). Still other wildlife may occur in both high- and low-elevation rock communities, but for various reasons may reach higher densities or have wider distribution in low-elevation rock outcrops (e.g., Timber Rattlesnakes).

The extent of habitat that each rock outcrop provides is dependent upon the entire set of conditions in and surrounding the surface rock. Those conditions influence its use by plants and animals dependent upon the surface rock and may include significant amounts of adjacent ecological community types. Water seepage through rock crevices may provide moisture for amphibians, mosses, lichens, and wetland vegetation. Reptile species may use rocky areas exposed to direct sunlight for basking or use openings amongst rocks for dens.

No species belonging to these guilds appear to be vulnerable to complete extinction due to the effects of climate change. However, both the Hickory Nut Gorge population of Crevice Salamander and the Piedmont populations of Red-backed Salamander exist as isolated disjuncts and are likely to be highly vulnerable to the effects of climate change. In both cases, extirpation of these populations would constitute loss of significant ecological as well as genotypic variants of their species.

DeWan et al. (2010) suggest that habitat specialists and species with restricted ranges will likely be some of the greatest affected by the combined effects of habitat loss and climate change. They also note such populations are more vulnerable to extinction by rare events and susceptible to additional stressors such as climate change.

4.4.8.6 Recommendations

Given the relative rarity of low-elevation rock outcrops across the state, measures need to be taken to conserve as much of this habitat as possible. This includes preservation measures, as well as conservation/management measures to ensure that species which rely upon these outcrops continue to be afforded the desired variety of habitat conditions into the future. Certainly a high priority should be placed upon acquisition or easement of land tracts which support low-elevation rock outcrops due to the fact that they are not abundant, they have numerous rare plant and animal associates, and remaining sites are subject to significant threats associated with both recreational and other development pressures.

In addition, necessary conservation actions include assigning appropriate management schemes to rock outcrops upon conservation lands to minimize negative impacts from human activities such as recreational use and development. Appropriate restrictions upon use of the areas need to be developed where none currently exist to minimize the direct impact upon the habitat and its occupants. The results of studies on the impact to low-elevation rock outcrops from surrounding habitat modification should be incorporated into appropriate management recommendations to minimize impacts upon wildlife species utilizing the rock outcrop. Mapping of these sites in a GIS format would facilitate tracking changes over time in both the habitat and the associated species and would facilitate landscape scale management of this rare habitat. Maintenance of biologically significant areas, including Peregrine Falcon nesting areas, reptile den sites, and significant salamander occurrences, is critical.

Flatrocks are naturally isolated, so migration is presumably very limited. However, presence of characteristic species across a number of widely separated outcrops suggests some potential for dispersal. Planting of species to facilitate movement of species to new locations is probably not appropriate. Since this unique habitat type cannot be recreated, it is more important to protect good quality flatrocks with the goal of protecting the range of variability, as well as the locations for future colonization and dispersal.

Surveys

Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Map these sites in a GIS format to facilitate tracking changes over time in both the habitat and the associated species, and to facilitate landscape scale management of this rare habitat.		
• Obtain baseline data on amphibian, small mammal, and reptile communities and habitat use (e.g., identify Timber Rattlesnake den sites).		
Amphibians	Small mammals	Reptiles Timber Rattlesnake

Monitoring

Monitoring is critical to assessing species and ecosystem health and in gauging resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Long-term monitoring is needed to identify population trends and to assess performance of conservation actions. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Continue monitoring the Peregrine Falcon population.
• Continue monitoring Green Salamander populations, as well as other salamanders of this habitat type (e.g., Crevice and Southern Zigzag salamanders). Crevice Salamander   Southern Zigzag Salamander

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Study the impact of various management scenarios on the habitat and associated species.
• Study Timber Rattlesnake movements, use of hibernacula, and reproductive success at gestation sites. Timber Rattlesnake
• Initiate genetic and morphological studies to clarify taxonomic status of plethodontid salamanders. Plethodontid salamanders
• Study habitat use by rock outcrop salamander communities, including movements in and among rock outcrop habitats (e.g., Green Salamander metapopulations). Green Salamander

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include

preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Protect these habitats through active management to remove invasive species.
- Burn around open, dry outcrops that naturally burned to restore more natural structure around the margins, and favor species that will tolerate drought and wildfire better.
- Maintain biologically significant areas, including Peregrine Falcon nesting areas, reptile den sites, and significant salamander occurrences.

  Peregrine Falcon | Amphibians | Reptiles
- Assign appropriate management schemes to rock outcrops on conservation lands to minimize negative impacts from human activities, including recreational use and development.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures climate change, but above all, it promotes ecosystem resilience

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Protect remaining examples and surrounding forests. Sites should be protected from human disturbance, including locations that are already protected through conservation measures. This may be through closure during particular times of the year or permanently prohibiting use of the site.
- Given the relative rarity of low-elevation rock outcrops across the state, measures need to be taken to conserve as much of this habitat as possible. This includes preservation measures, as well as conservation/management measures to ensure that species that rely upon these outcrops continue to be afforded the desired variety of habitat conditions into the future.

4.4.9 Mesic Forests

4.4.9.1 Ecosystem Description

Classification of the Natural Communities of North Carolina, 4th Approximation (Schafale 2024) describes this natural community as Piedmont and Coastal Plain Mesic Forests Theme. Mesic forests occur on sites that are moist but not wet. Mesic sites are among the most favorable environments for plant growth. They tend to support dense forests dominated by moisture-loving non-wetland trees such as beech, tulip poplar, and northern red oak. They usually have well-developed understory, shrub, and herb layers. They often contain species that are common in the mountain parts of the state or farther north but are rare in the southern Piedmont and Coastal Plain. Some species may be disjunct long distances from cooler areas. At least some of these disjuncts are remnants of wider distributions in the past, such as during the cooler, moister climate of the Ice Age.

This natural community has several subtypes.

- Mesic Mixed Hardwood Forest (Piedmont, Coastal Plain subtypes)
- Basic Mesic Forest (Piedmont, Coastal Plain subtypes)
- Piedmont/Coastal Plain Heath Bluff
- Cape Fear Valley Mixed Bluff Forest

Mesic mixed hardwood forests in the Piedmont are generally on north-facing slopes, sheltered ravines, or high terraces on the edges of floodplains. In the Coastal Plain, mesic forests occur in similar sites and also on moist portions of broad upland flats and on small island ridges surrounded by swamps. These sites are naturally sheltered from the fires that are a major natural shaper of vegetation in the Coastal Plain.

Basic mesic forests are much rarer than the mesic type and occur on soils that are neutral to slightly basic in pH. They are more diverse than the mesic mixed hardwood forests and they have species that require high pH. The basic mesic forest subtype often has rare and disjunct plant species and both variants of basic mesic forest (marl outcrop and terrace slope) are rare because of the scarcity of basic substrates on the Coastal Plain (Schafale and Weakley 1990).

4.4.9.2 Location of Habitat

The Coastal Plain and Piedmont subtypes cannot be separated by any particular species but differ in their overall flora. In the Piedmont, mesic mixed hardwood forest communities occur on mesic sites that have typically acidic soils. Good examples can be found at Umstead State Park, Duke Forest, Hill Demonstration Forest, Raven Rock State Park, and Eno River State Park in the central Piedmont and also examples in parts of Uwharrie National Forest. Basic mesic forest communities are scattered across the Piedmont; good examples are found in Caswell Game Land, Uwharrie National Forest, and Raven Rock State Park.

Several distinctive variants of these subtypes are recognized in the Coastal Plain, including the swamp island, mesic flat, and bluff/slope variants of mesic mixed hardwood forest, and the terrace slope and marl outcrop variants of basic mesic forests. Examples of the mesic mixed hardwood forest bluff/slope variant are found in Croatan National Forest, Merchant's Millpond State Park, and Cliffs of the Neuse State Park. Examples of the swamp island variant are found in the Great Dismal Swamp National Wildlife Refuge and along the Waccamaw River in Columbus County, and examples of the upland flat variant are found in Perquimans and Bertie counties.

4.4.9.3 Problems Affecting Habitats

There may be an increase in natural fires (due to increased drought and higher average temperatures), but landscape fragmentation and fire suppression practices will likely continue to prevent most fires from spreading very far in the Piedmont and in the dissected lands in the Coastal Plain where mesic forests occur. Mesic forests occur in sites sheltered from most fires, but wildfire during drought may increase the likelihood or severity of fires in them.

The importance of drought and hot spells in mesic sites is unclear. Most of these sites are mesic because of topographic sheltering such as north-facing slopes or deep ravines. These sites are buffered from extremes of weather. However, because they contain many species that are not adapted to hot and dry conditions, they may suffer stress from even slightly drier conditions. Although we are not aware of any identified problems from phenological disruption, there may be higher potential for it in these communities than others, because they have many spring ephemeral plants.

An increase in hurricanes or other severe storms likely would increase wind damage in forests. Increased storm disturbance will increase the potential for exotic plant invasion, especially if a seed source is present in nearby developed or disturbed areas or has already entered the community. Wind damage is often more severe in forests if there are adjacent openings such as logged or developed areas. If more intense storms increase flood heights, this will affect lower lying mesic forests. If wind throw stimulates salvage logging, this will further increase the damage to natural areas.

4.4.9.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. The greatest threats to Piedmont and Coastal Plain Mesic Forests are those from development and logging which are ongoing land uses. Climate change is less of a threat than ongoing concerns, but will exacerbate some of them. Although expected threats associated with climate change are the least significant to these forests, increased wind damage, droughts, and warmer temperatures may alter their structure and size. Table 4.4.9-1 summarizes the comparison of climate change with other existing threats.

Table 4.4.9-1 Comparison of climate change with other threats to mesic forests

Threat	Rank Order	Comments
Development	1	Destruction and indirect effects such as fragmentation and edge effect result from land development in suburban areas and even in many rural areas.
Logging/ Exploitation	1	Logging severely alters canopy structure and composition, and is a threat to all but the steepest unprotected examples. Invasive plants are a present and increasing threat. Both development of nearby areas and logging increase the potential for invasion.
Invasive Species	2	Plants such as Autumn Olive, Japanese Stiltgrass, Japanese Honeysuckle, Princess Tree, Tree-of-heaven, and Chinese Privet have taken resources from native vegetation and altered habitat structure and species composition. The extent of negative (and positive) impacts of exotic species on populations of native fauna is largely unknown.
Climate Change	3	The severity of climate change effects on these sheltered sites is uncertain. It is expected that the boundary with drier communities will shift, so that peripheral portions are lost, smaller or more marginal examples may be lost, and the total acreage will shrink. These communities often support species disjunct from cooler areas, and some of these species may be lost.
Fire Suppression	4	Fires that would have naturally swept through these sites (relatively infrequently in the Piedmont, perhaps more frequently in the Coastal Plain) have been suppressed, likely affecting the community composition of mesic plant species and exotics.

4.4.9.5 Impacts to Wildlife

Appendix 3 provides a list of SGCN and other priority species for which there are knowledge gaps and management concerns. Appendices 3-17 (wildlife) and 3-19 (plants) identify SGCN that depend on or are associated with this habitat type.

Fragmentation of mesic forests into smaller or narrower contiguous blocks is a concern for forest interior birds (like the Wood Thrush, Hooded Warbler, and Worm-eating Warbler), which may occur in lower densities or suffer lower productivity or survival in small habitat patches. Fragmentation by roads and development can be problematic for reptiles (especially Timber Rattlesnake s and Eastern Box Turtles), amphibians, and small mammals (particularly Eastern Mole) that suffer high mortality on roads when traveling between forest patches or between mesic forest and other habitats.

A lack of canopy gaps in this habitat has probably led to a reduced number of some avifauna such as the Eastern Wood-pewee, Hooded Warbler, and Kentucky Warbler. This reduction in canopy gaps has also caused a decline in midstory and understory vegetation, which has impacted species such as the Swainson's, Kentucky, and Hooded warblers, and Wood Thrush. The reduction in standing snags negatively impacts primary and secondary cavity nesting species and the lack of dead wood on the forest floor impacts herpetofauna and small mammals.

4.4.9.6 Recommendations

These communities occur in specialized microsites and are unlikely to migrate. To reduce the possible impacts from climate change, conservation or restoration of landscape connections to allow migration is most important. These sites often occur adjacent to riparian areas and floodplains, and protection of these sites will be dually beneficial to nearby streams.

Surveys

Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Direct initial efforts toward surveys to determine the current baseline distribution and status of species mainly associated with mesic forests (especially those that are state-listed or believed to be declining) for which that information is lacking.
• Focus secondary efforts on conducting surveys to understand current status, from which we can measure future population changes over time.

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats	
• Enhance current monitoring systems and protocols (e.g., MAPS and BBS)to better cover certain species that are not well covered by current monitoring efforts.	
• Establish long-term monitoring for small mammals and bats following initial surveys.	
Bats	Small mammals
• Conduct general long-term herpetofauna monitoring to track the effects of the loss of old growth characteristics in this habitat type.	
Amphibians	Reptiles

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Collect demographic information on all bat species; investigate specific habitat needs and conduct life history studies.
Bats

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Maintain connections between habitat blocks, not only to allow adjustments in range in response to climate change, but to maintain population resilience and adaptability more generally.
• Create transportation facilities that utilize longer bridges at streams and wetlands to minimize impacts (and thereby reduce mitigation requirements) and provide crossing options for wildlife that often travel riparian corridors and disperse to upland communities.
• For protected and unprotected sites, control the exotic plants that are present or may potentially invade.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Create cooperative programs with non-industrial foresters that promote and increase silvicultural practices (e.g.,canopy gap management, longer rotations, introduction of fire), as this could benefit birds of conservation concern as well as small mammals, bats, reptiles, and amphibians.
• Give high priority to protecting movement corridors that allow dispersal between habitat blocks, especially as development and roadways fragment the few remaining large tracts of habitat.
• Give priority to restoring connections that are lost due to construction of four-lane highways and other roads that create near-impassible barriers for all animals except those capable of flight.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Ensure that conservation actions include land acquisition, easements, and protection to promote remaining large, unfragmented tracts as well as management to maintain and reestablish mesic forest. This is a relatively rare forest type and great effort should be made to protect mesic forests and their species assemblages. Conservation of larger natural areas that include adjacent communities will lead to greater viability for all communities present.

4.4.10 Piedmont and Mountain Dry Coniferous Woodlands

4.4.10.1 Ecosystem Description

Classification of the Natural Communities of North Carolina, 4th Approximation (Schafale 2024) defines this natural community as Mountain Dry Coniferous Woodlands Theme. The vast majority of land in the Piedmont and Mountain ecoregions is dominated by hardwood forests. Less common are dry coniferous forests, which occur at middle to lower elevations in several kinds of specialized sites that are drier than most environments. They occur primarily in the Mountains and are found in a few mountain-like sites in the Piedmont. Piedmont longleaf pine forests, although dominated by coniferous trees, are included with the more closely related dry longleaf pine forests ecosystem group rather than here.

There are several community subtypes associated with this ecosystem.

- Pine-Oak/Heath (Typic, High Elevation, Linville Gorge subtypes)
- Carolina Hemlock Forest (Typic, Pine, Mesic subtypes)
- White Pine Forest
- Low Mountain Pine Forest (Shortleaf Pine, Montane Pine subtypes)
- Southern Mountain Pine-Oak Forest
- Southern Mountain Xeric Pine-Oak Woodland

The pine–oak/heath community occurs on sharp ridge tops and spur ridges, where shallow soils and exposure to drying winds and lightning prevent development of a closed hardwood forest. Extremely acidic soils, created by leaching and by the acidity of plant leaf litter, may also be a factor. The canopy, typically composed of Pitch, Table Mountain, and/or Virginia pines, is generally open with a dense, tall shrub layer dominated by Mountain Laurel or rhododendron occurring beneath the canopy. Herbs are few and sparse, but characteristic acid-loving species often occur in openings among the shrubs.

Carolina hemlock bluffs occur in settings similar to pine–oak/heath, but usually more on steep bluff-like side slopes. Carolina Hemlock dominates the canopy with a shrub and herb layer similar to pine–oak/heath but possibly more open. White pine forests are poorly understood communities. While White Pine is a common successional tree in mountain hardwood forests, natural forests most typically occur on the walls of steep gorges.

Low Mountain Pine Forests are yellow-pine-dominated forests or woodlands containing both montane flora and low-elevation species and occur below 2,000 to 2,500 feet in elevation. Southern Mountain Pine–Oak Forests are mixed, potentially open forests of low elevation mountain slopes and ridges.

4.4.10.2 Location of Habitat

These communities occur through the lower to middle elevations, the foothills, and are particularly abundant in the escarpment in the Mountain ecoregion. Pilot Mountain, Hanging Rock, and Crowders Mountain State Parks all have examples of the pine–oak/heath community. Owing to the relatively low-elevations occupied by dry coniferous forests in the region, significant amounts of this habitat occur in western North Carolina upon state-owned lands (Thurmond Chatham, South Mountains, and Green River Game Lands; South Mountains State Park; Dupont State Forest).

4.4.10.3 Problems Affecting Habitats

Most dry coniferous woodlands depend on a combination of fire behavior and dry soils, both driven by topography. However, an increase in extreme fires may be detrimental. Increased drought may increase southern pine beetle outbreaks, a major threat to the pine canopy. Fire suppression has caused these habitats to shrink in recent decades. Increased drought may favor pines over hardwoods and allow them to regain some of their lost area even without fire. Increased drought and fire may allow expansion. These communities occur in the driest mountain and foothill sites, and increasingly dry climate may allow them to expand into a broader range of topography and to higher elevations.

The structural effects caused by fire suppression and southern pine beetles greatly exceed any effect likely from climate change. The Hemlock Woolly Adelgid has already impacted some stands of Carolina hemlock, though not to the devastating effect as seen in Canada hemlock stands. Restoration of the structure, composition, and, most importantly, disturbance regimes of these communities will increase their resilience to environmental stressors. Without fire to promote pine regeneration, increased pine beetle mortality could hasten the shift from pines to hardwoods.

Warmer temperatures should allow spreading to higher elevation, but the acreage gain is likely to be limited. It may not occur if fires are suppressed. Increased wind damage may increase loss of mature pines and contribute to ongoing encroachment of hardwoods. Because the characteristic plants are drought tolerant as well as fire tolerant, an increase in drought may help them retain or regain dominance. In addition, if drought contributes to an increase in wildfire, this may benefit these communities.

4.4.10.4 Climate Change Compared to Other Threats

The most significant threats vary among the different community types. Piedmont and mountain dry coniferous forests will likely be resilient to the effects of climate change and may actually benefit from increased fire frequency and drought.

Lack of fire is the greatest threat to the majority of remaining pine–oak/heath. Not only will these forests not be able to reproduce themselves without fire, but those stands at higher elevations which are not regularly burned often develop dense Mountain Laurel/rhododendron understories that shade out other shrubs and herbaceous plants, thus lowering the habitat quality and diversity of wildlife which could utilize the area. Management efforts by multiple agencies to increase prescribed fire in fire adapted communities, including dry coniferous forests, are already positioning these communities for greater resilience. Table 4.4.10-1 summarizes the comparison of climate change with other existing threats.

Table 4.4.10-1 Comparison of climate change with other threats to dry coniferous forests

Threat	Rank Order	Comments
Fire	1	With the suppression of fire, many examples have disappeared or have become degraded by a lack of pine regeneration and invasion by hardwoods and shrubs. Suppression of fire has caused severe alteration and loss in pine–oak/heath.
Development	2	Development can lead to fragmentation and disrupt connectivity between patches for most wildlife except birds. Road crossings can lead to mortalities, especially for reptiles and amphibians. Development in or adjacent to this habitat often leads to a significant problems using prescribed fire as a management tool due to the proximity of residential or other development. Construction activities and other extensive removal of plant cover can make steep slopes prone to mud and/or rock slides, causing loss of topsoil and potentially causing property damage and threatening human safety.
Logging/ Exploitation	2	Logging is a threat to unprotected examples, particularly on pine–oak/heath and white pine forest.
Invasive Species	3	A major factor in loss of pine dominance is southern pine beetle outbreaks, which are often triggered by droughts. There are numerous native and exotic pests that can impact coniferous trees in this habitat (e.g., Southern Pine Beetle, Tip Moth, Pine Webworm, Schweinitzii root and bud disease, and red heart of pine disease). Localized and non-lethal infestations can be beneficial for wildlife by creating snags, a food source, and habitat diversity. However, extensive lethal outbreaks can dramatically shift the composition of the tree community, with implications for conifer-specialists like the Brown-headed Nuthatch. Control of the Hemlock Woolly Adelgid is crucial for the Carolina hemlock bluff communities. Without control, most or all of these communities may be lost in the near future.

Table 4.4.10-1 Comparison of climate change with other threats to dry coniferous forests

Threat	Rank Order	Comments
Climate Change	4	Climate change will act somewhat counter to existing threats rather than exacerbating them. However, these benefits are far from certain.

4.4.10.5 Impacts to Wildlife

Appendix 3 provides a list of SGCN and other priority species for which there are knowledge gaps and management concerns. Appendices 3-17 (wildlife) and 3-19 (plants) identify SGCN that depend on or are associated with this habitat type.

While Red-cockaded Woodpeckers are almost exclusively associated with longleaf pine systems, most animals that are associated with pines and other dry conifers also occur in mixed stands of hardwoods and conifers. Brown-headed Nuthatches and Chuck-wills-widows are also associated with dry woodlands and/or heathlands more generally.

Additional problems faced by individual species associated with dry coniferous forest include the lack of early successional habitat of this type or conversion of this habitat to other pine habitat (i.e., White Pine) for species such as Prairie Warblers, woodpeckers, and nuthatches. Timber Rattlesnake persecution in these habitats also remains a significant problem. Lack of management of the stands decreases the quality of habitat for woodland hawks by decreasing prey abundance and limiting their ability to hunt in dense understory growth.

The two species of moths that feed on bear oak have a highly confined distribution in North Carolina (as does their host plant). While climate change may create conditions such as increased fire that may favor the oak, the moths are likely to be highly vulnerable to extirpation if fires completely consume all available habitat in the few areas where the moth currently exists.

4.4.10.6 Recommendations

Conservation of good examples of all community types remains important. Because of the widespread loss of pine–oak/heath and the likely loss of Carolina hemlock bluff, restoration of degraded examples is also important. As in all communities, conservation of surrounding communities and protection or restoration of landscape connections will improve the viability of communities and allow native species to migrate to adjust to the changing climate.

Surveys

Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Determine the current baseline distribution and status of species mainly associated with dry coniferous forest (especially those that are state-listed or believed to be declining). Data is most severely lacking for reptiles, small mammals, and nocturnal birds.		
Nocturnal birds	Small mammals	Reptiles
• Survey white pine forest for breeding birds and other fauna. This habitat might now be utilized by species that formerly occurred in Canada Hemlock stands that have now shifted to White Pine habitats.		

Monitoring
Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Establish long-term monitoring efforts for small mammals and reptiles in the habitat. Monitoring protocols and procedures need to be developed or refined that will allow us to measure population trends of the priority wildlife species, as well as the health and distribution of this relatively rare habitat through time.
• Enhance current monitoring systems and protocols (e.g., MAPS and BBS) to better cover species not well covered by current monitoring efforts.

Research
Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics.

Priority Conservation Action, Examples of Focal Species or Focal Habitats	
• Continue research on topics including efficient and effective means to manage and improve the quality and quantity of dry coniferous forest, with a particular eye toward techniques that are applicable in our developing landscape. In the absence of fire, either as a natural event or as a management tool, research other means available to sustain this habitat across the landscape.	
• Research how the loss of hemlock affects salamander habitat use and microclimate.	
Salamanders	Hemlock

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Determine impacts of prescribed fire on these communities and the resulting effects on wildlife communities.
• Develop logistically and economically effective control strategies for controlling outbreaks of the most damaging insect pests and diseases.
• Regulate human activities on steep slopes that may cause excessive erosion or mud slides and develop and implement BMPs to mitigate erosion.
• Conduct prescribed burns and control invasive species, as these are the most important conservation actions to take in order to restore degraded sites and allow these communities to be more stable and resilient in the face of climate change.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Continue to support partnerships like the Southern Blue Ridge Fire Learning Network and the North Carolina Prescribed Fire Council to expand efforts at restoring disturbance regimes.
• Identify the best remaining examples of this habitat in the Mountains and western Piedmont and then to pursue easements or acquisition. The efforts of land trusts and government agencies should be coordinated to target the highest priority sites.
• Use land use planning to minimize development within large, unfragmented tracts of all woodland types in the western Piedmont.

4.4.11 Oak and Mixed Hardwood/Pine Forests and Managed Timber

4.4.11.1 Ecosystem Description

This ecosystem has an oak or mixed hardwood/pine component and occurs on both xeric and mesic sites, in the Piedmont, Sandhills, and Coastal Plain ecoregions. Oak forests were once the most common natural community type in the Piedmont ecoregion, occurring over most of the uplands. In the Sandhills and Coastal Plain ecoregions, they were much more limited, occurring primarily in dissected areas near streams.

Classification of the Natural Communities of North Carolina, 4th Approximation (Schafale 2024) provides updated descriptions for Piedmont and Coastal Plain Oak Forest Theme (Section 4.4.14). This natural community description includes dry oak–hickory forest, dry-mesic oak–hickory forest, basic oak–hickory forest, xeric hardpan forest and Piedmont monadnock forest (Schafale and Weakley 1990) as well as late successional pine originally planted for timber but is no longer managed for production. Without management these pine stands often have mixed hardwood components.

- Dry-mesic oak─hickory forest and dry oak─hickory forest are the most typical of the five community types, occurring on upland slopes and ridgetops on acidic soils. White oak is usually the most abundant tree in both. Post oak and southern red oaks are the primary associates in dry oak─hickory forests and northern red oak and black oak in dry-mesic oak─hickory forests.

- Piedmont monadnock forests, typically dominated by chestnut oak and scarlet oak, occur on scattered hills, which are resistant to the erosion affecting the surrounding land.

- Basic oak─hickory forests occur on upland flats and slopes in sites similar to dry and dry-mesic oak─hickory forests, but with soils that are not acidic. Most of the soils are apparently near neutral pH rather than truly basic and usually occur over mafic rocks such as gabbro and diabase. They are dominated by white oak in combination with post oak or black oak, and a number of understory, shrub, and herb species that are scarce or absent on acidic soils are present.

- Xeric hardpan forests are the most distinctive of the Piedmont and Coastal Plain oak forests. They occur on flat to gently sloping uplands with clay hardpans that restrict water and root penetration. This situation is most common on mafic rocks, but it also occurs on acidic shales. These sites may have shallow standing water in wet seasons but are extremely dry in dry seasons. The canopy is dominated by some of the most drought tolerant species in the state, post oak and blackjack oak, and is often somewhat open.

In addition to these natural communities, there are numerous acres of managed pine plantations, primarily of loblolly and shortleaf pines, as well as successional stands of these pines scattered across North Carolina (Huang et al. 2015). Successional communities, which may have a pine stand component, are addressed in Section 4.4.19 in this chapter.

Managed stands may have been thinned at one time to reduce overcrowding, subjected to prescribed fire to reduce fuel for wildfires, or herbicide applied to control insect or disease attacks. Scientific literature provides evidence that intensively managed loblolly pine stands can provide a diverse herbaceous plant community throughout a significant portion of a plantation's rotation that benefits conservation of biological diversity (e.g., Wigley et al. 2000, Loehle et al. 2005, Miller et al. 2009, Homyack et al. 2014), including species of special concern (Miller 2003, Duchamp et al. 2007, Wigley et al. 2007, Morris et al. 2010, O'Bryan 2014, Bender et al. 2015, Johnson 2015). Intensively managed pine forests may contain a diversity of habitat types and conditions, depending on different ages of intensively managed stands, different silvicultural treatments, presence of non-intensively managed stands, such as natural stands and riparian buffers, non-forested areas, and the interaction of these habitat conditions across the landscape (Wigley et al. 2000, Jones et al. 2008, Miller et al. 2009, Morris et al. 2010).

4.4.11.2 Location of Habitat

Mature hardwood and pine forests are found throughout the Piedmont ecoregion, though the total acreage has been declining in recent years. High-quality examples of oak forests in the Piedmont can be found on public lands such as Caswell Game Land, Umstead State Park, and Uwharrie National Forest. Examples of large size and good quality oak-dominated communities are now lacking in the Coastal Plain.

4.4.11.3 Problems Affecting Habitats

Management. Many of the problems impacting oak and mixed hardwood/pine forests, including fire suppression and even-aged forest management, result in a loss of habitat complexity and associated wildlife niches (Hunter et al. 2001a). Most Piedmont forests have been logged or cleared at least once within the past 300 years, and many have been cut multiple times. The quality of existing tracts ranges widely across the Piedmont and depends primarily upon the age of the canopy trees, management history, and size of the tract (Godfrey 1997).

Land Use. Some native forest stands are being replaced by even-aged pine plantations, resulting in decreased habitat value for forest species that rely on diverse forest composition and structure, such as Kentucky Warbler and Wood Thrush. Pine plantations do, however, provide increased opportunity to provide habitat for Brown-headed Nuthatches and Northern Bobwhite Quails, with proper management.

North Carolina is a major timber producer, with an estimated average 23.2 million cubic meters of wood products produced annually (Huang et al. 2015). Shorter rotation forestry limits the creation of old-growth forest dynamics, such as creation of canopy gaps, hollow trees, snags, and woody debris. In 2002, less than 1% of both hardwood and pine trees in the Piedmont measured greater than 19 inches diameter at breast height (Brown and Sheffield 2003), indicating that there are few old, large trees that help provide these old growth conditions. It should be noted, however, that tree diameter does not always correlate with tree age. Older stands will be more likely to be established and maintained on public land than on commercial forestland, though niche markets for larger timber may entice some landowners to extend cutting rotations.

Disease. Sudden Oak Death disease, which was detected at plant nurseries within North Carolina in 2004, could potentially have devastating impacts on oak forests across the state.

Climate Change. An increase in hurricanes or other severe storms may increase wind damage in forests. These effects are likely to be localized. Small scale wind disturbances can create canopy gaps, downed woody debris, and patches of early successional habitat which can be beneficial to both early successional and mature forest species. Large scale wind disturbances will benefit early successional species but will harm mature forest species.

Direct effects of the warmer climate on these communities are likely to be limited. Similar oak forests range well to the south of North Carolina where normal temperatures are higher. The most severe droughts and hot spells of recent record have had only limited effects on them. They can occupy some of the driest places on the Piedmont landscape. Increased drought may possibly favor oaks, but increased wind damage favors the understory species. If drought leads to severe wildfires, it would be harmful to oak forests, but the ease with which fires may usually be controlled in them makes this unlikely.

Fire Suppression. Lack of fire is leading to slow changes in composition, including reduced oak regeneration. In spite of benefits from fire, there is a need to control wildfires in drought conditions, to prevent intense fires, and to prevent whole patches of fragmented forest from being burned at the same time. Low intensity fires would be beneficial, but intense wildfires would be destructive. Increased prescribed burning will produce a more open canopy, reduced understory, increased herb cover with more grasses, and longer lasting canopy gaps.

4.4.11.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. While climate change is a significant concern for these communities, several other threats are more severe and may be a more immediate threat. Both the extensive examples in the Piedmont and the more limited range in the Coastal Plain continue to be rapidly destroyed by ongoing urban, suburban, rural, residential and commercial development. Continued population growth makes this the most severe threat, in the current and the future climate. However, the fragmentation and loss of extent caused by it will increase the alteration caused by climate change, as isolated communities are unable to migrate and species are unable to move to more favorable sites. Table 4.4.11-1 summarizes the comparison of climate change with other existing threats.

Table 4.4.11-1 Comparison of climate change with other threats to oak and mixed hardwood pine forest and managed timber

Threat	Rank Order	Comments
Development	1	Land use conversions in the Piedmont (primarily to suburban and exurban development) contribute significantly to the reduced condition of some tracts. The threat includes both direct and secondary impacts of development.
Logging/ Exploitation	2	Logging and exploitation are of greatest concern when accompanied by conversion to pine plantation or severe shifts in composition. Logged forests may be converted to successional pine forests or become dominated by maple or other hardwoods. Demand for biofuels may increase the risk of damage by logging or biomass harvest. However, logging remains an important source of income for many landowners and plays a role in helping to keep forested tracts from being sold for development.
Invasive Species	3	Nonnative plants such as Japanese honeysuckle and autumn olive have seriously impacted many upland forest stands. Exotic diseases and pests have the potential to induce a large magnitude compositional change, as was seen with American chestnut in the last century. Increased canopy disturbance by wind, drought mortality, or severe fire will hasten invasion. Gypsy moths are the most destructive defoliating insect attacking northern red oak, chestnut oak, and white oak. The Asiatic Oak Weevil attacks northern red oak seedlings and has the potential to seriously affect seedling growth because the larvae feed on the fine roots while the adults feed on the foliage.
Fire	4	There may be an increase in natural fires (due to increased drought and higher average temperatures), but landscape fragmentation and fire suppression practices likely will continue to prevent most fires from spreading very far in the Piedmont and in the dissected lands where oak forests occur in the Coastal Plain. Most oak forests are expected to benefit from increased fire frequency, as long as the fire intensity is not too high.wildfire
Climate Change	5	Piedmont and Coastal Plain oak forests are likely to be relatively resilient to the effects of climate change. These communities are tolerant of severe droughts, hot spells, and fires of low intensity. Development,

Table 4.4.11-1 Comparison of climate change with other threats to oak and mixed hardwood pine forest and managed timber

Threat	Rank Order	Comments
		logging, and invasive species are much more of a threat to these communities than climate change.

4.4.11.5 Impacts to Wildlife

Appendix 3 provides a list of SGCN and other priority species for which there are knowledge gaps and management concerns. Appendices 3-17 (wildlife) and 3-19 (plants) identify SGCN that depend on or are associated with this habitat type.

Development causes direct loss of forest habitat and also fragments remaining forested patches. Fragmentation of forests into smaller contiguous blocks is a concern for forest interior birds (like Wood Thrush and Hooded Warbler), which may occur in lower densities or suffer lower productivity or survival in small habitat patches. Animals with large home ranges or dispersal needs may become isolated or absent in small tracts. Fragmentation by roads and development can be particularly problematic for reptiles (particularly Timber Rattlesnake).

Historical data suggests that oak communities benefited from periodic fires (Abrams 1992;; Close 1996), and many oak species are fire tolerant. In pine stands, fire can play a very important role in reducing the midstory while enhancing structure in the understory. Fire helps to create snags, woody debris, and canopy gaps, and prepares a fertile seed bed, while also improving vegetative structure. The benefit of fire to understory plant development is highly dependent upon the density of canopy trees, with closed canopy stands suppressing the growth of grasses and forbs following fire. Cavity-nesting birds, arboreal mammals, and some frogs, lizards, and snakes are impacted by the lack of snags, while reptiles, amphibians, and small mammals are impacted by lack of woody debris. Many bird species, such as the Hooded Warbler, Red-headed Woodpecker, Eastern Wood-pewee, Northern Flicker, Nightjars, and many post-fledging juvenile birds utilize canopy gaps for cover, or for foraging habitat, as do some bat species. Lack of fire has also allowed some fire-intolerant mesophytic plant species to become quite common in oak-dominated communities, including the American beech (Franklin and Kupfer 2004). The resulting loss of acorn production may be limiting for some wildlife in the future.

There are many potential and realized impacts by imported Gypsy Moths and other non-native insects, kudzu, and other non-native pathogens, plants, and animals. Gypsy Moths are the most destructive defoliating insect attacking northern red oak, chestnut oak, and white oak. This insect repeatedly defoliates trees and has killed oaks in a wide area of the northeastern United States.

Rare invertebrate species associated with this ecosystem group occupy habitats at the dry to xeric extreme, with some occurring only on a few isolated monadnocks in the Piedmont. Moth species include Barrens Dagger Moth (*Acronicta albarufa*), Herodias Underwing (*Catocala herodias*) and Faded Gray (*Stenoporpia polygrammaria*), Northern Hairstreak (*Fixsenia ontario*), Rare Spring Moth (*Heliomata infulata*) and an unnamed moth (*Hemeroplanis* n. sp.), Mottled Duskywing (*Erynnis martialis*), Brown Elfin (*Callophyrs augustinus*), Frosted Elfin (*Callophyrs irus*), and a noctuid moth (*Ptichodis bistrigata*).

4.4.11.6 Recommendations

These communities occur in a fragmented landscape and migration may be problematic. Conservation of remaining examples and restoration of degraded sites and landscape-level connections would allow for adaptation in the future, as well as provide protection and promote the ecosystem viability under the current climate.

Surveys

Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Conduct surveys to document priority and common species in areas poised for development (edge of urban expansion) to establish baseline populations and identify problems before development expands.
• Determine the current baseline distribution and status of species mainly associated with oak and mixed hardwood/pine forests (especially those that are state-listed or believed to be declining) for which that information is lacking.

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Initiate long-term monitoring for breeding neotropical migrants (especially ground-nesters and cavity-nesters), bats and small mammals (e.g. moles, shrews, rodents), amphibians that use woody debris as a microhabitat, and Timber Rattlesnakes and other secretive reptiles.		
Neotropical migratory birds	Bats Small mammals	Amphibians Reptiles Timber Rattlesnake
• Monitor tree infestations and diseases to document potentially destructive organisms shortly after they show up, while there is still a chance to contain or eradicate the pest.		
• Develop standardized monitoring programs analogous to the Breeding Bird Survey for reptiles, amphibians and small mammals. Of particular interest is trend information for those species dependent upon snags and woody debris.		
Amphibians	Reptiles	Small mammals

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Research and identify important wildlife crossing areas; evaluate connectivity issues between intact and fragmented habitats used by priority species; work with partners to improve crossing and connectivity.
• Conduct long-term and large-scale replicated studies that have controlled experimental approaches and that focus on population demographics and the response of species to habitat manipulations, where appropriate, for oak/mixed hardwoods forest taxa including birds, bats, small mammals, amphibians, and reptiles.

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Create transportation facilities that utilize longer bridges at streams and wetlands to minimize impacts (and thereby reduce mitigation requirements) and provide crossing options for wildlife that often travel these riparian corridors and disperse to upland communities.
• Work with adjacent states on mutual planning and conservation for regional species concerns, especially since some priority species are likely to expand their range due to climate change impacts.
• Control invasive species in the short run, while populations are relatively limited and small, to prevent greater damage by them in the future.
• Use infrequent prescribed fire and canopy gap management to improve forest structural heterogeneity (frequent fire will limit shrub and understory development necessary to breeding bird species).
• Manage and protect mixed hardwoods/pine to promote future large, unfragmented tracts. This is especially important for amphibians, reptiles, small mammals, and bats.
• Target invasive and exotic species control at ecologically sensitive areas and at new and potentially manageable outbreaks.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Use landowner incentives to promote extending rotation lengths for timber.
• Give high priority to protecting movement corridors that allow dispersal between habitat blocks, especially as development and roadways fragment the few remaining large tracts of habitat. Maintaining and restoring connections between habitat blocks is critical, not only for allowing adjustments in range in response to climate change, but to maintain population resilience and adaptability more generally.
• Give priority to restoring connections that are lost due to construction of four-lane highways and other roads that create nearly impassible barriers for all animals except those capable of flight.
• Direct county and state-level land use planning to minimize development within large, unfragmented tracts of forests. This would be most appropriate and effective in the regions that are, as yet, not heavily developed, including Montgomery, Stanly, Randolph and Richmond counties in the southern Piedmont, and the northern tier counties of Surry, Stokes, Rockingham, Caswell, Person, and Granville.
• Concentrate planning for future infrastructure (roads, water lines, etc.) closer to existing development and avoid dissecting larger tracks of unfragmented forest.
• Make attempts to provide large core areas of forest and to connect isolated patches of forests. Cooper (2000) recommends that core areas be at least 16,000 acres in size to produce viable populations of forest-interior birds, like Scarlet Tanager. Large core areas will be important for reptiles like Eastern Box Turtle and Timber Rattlesnake, which suffer high mortality when crossing roads. Scarlet Tanager   Eastern Box Turtle   Timber Rattlesnake

4.4.12 Montane Oak Forests

4.4.12.1 Ecosystem Description

Classification of the Natural Communities of North Carolina, 4th Approximation (Schafale 2024) defines this natural community as Mountain Oak Forests Theme. Montane oak forests are found on Blue Ridge mountain and foothills slopes and ridges and are dominated by various species of oaks. They once included a large component of American chestnut before the blight in the early part of the last century eliminated it as a canopy species. There are several subtypes associated with this community (Schafale 2024).

- High Elevation Red Oak Forest (Typic, Rich, Heath, Orchard Forest, Stunted Woodland, Boulderfield subtypes)
- High Elevation White Oak Forest
- Chestnut Oak Forest (Dry, White Pine, Mesic, Boulderfield subtypes)
- Montane Oak-Hickory Forest (Acidic, Basic, Low Dry, White Pine, Boulderfield subtypes)
- Low Montane Red Oak Forest
- Calcareous Oak-Walnut Forest

These forests are dominated by a variety of oak species depending on soil moisture and location on or above the Blue Ridge escarpment or in the foothill mountains. Mountain Oak Forests are on open slopes, ridge tops, spur ridges, and low rises and flats in valleys. They are the majority of the middle elevation landscapes (Schafale 2024).

4.4.12.2 Location of Habitat

Montane oak forests occur in the Mountain ecoregion and foothill mountains on exposed sites such as ridge crests and south- to west-facing slopes, typically from about 3,000 to 4,500 feet elevation. The cover rugged areas in the South Mountains, Brushy Mountains, and other foothill ranges. According to the most recent Southeast GAP analysis, montane oak forest communities comprise over 272 thousand acres (about 110 thousand hectares) of land cover in North Carolina (SEGAP 2007; NatureServe 2007). This represents less than 1% of the state's land cover.

4.4.12.3 Problems Affecting Habitats

Fire Suppression. It is unclear if changes in fire regime will be beneficial or harmful to oak forests. Fire suppression has allowed non-fire-tolerant species, including tree species, to increase in montane oak forests. Many oak forests have seen a lack of oak regeneration that is likely related to lack of fire. If a warmer climate brought an increase in fire, it might offset some of the alterations caused by suppression of fire. Severe fires during droughts would cause extensive canopy mortality and be destructive to oak forests, especially if occurring with the increased fuel loads resulting from recent fire suppression.

Climate Change. Prolonged or severe drought stress has been associated with oak decline and with canopy mortality. Chestnut blight caused dramatic compositional shift by almost extirpating the American chestnut. Some more southern or low-elevation species may migrate into these communities. Impacts from higher temperatures, drought, fire, and wind damage will likely lead to other community types, or different suites of species, more suited to the change in climate due to competitive interactions of species in the seed bank during succession. Unfortunately, this may lead to a greater need for nonnative invasive species control after stand replacing disturbances, natural or man-made.

Drought. Drought may allow pine forests to expand at the expense of oak forests, it will also allow oak forests to expand to higher elevations and into more mesic sites now occupied by cove forests. The overall extent of oak forests may increase moderately. These communities should be able to move to higher elevations, while they are unlikely to lose much acreage at lower elevations.

Management. Homogeneity of stand age has resulted in decreasing habitat for bird species that rely on diverse understory development (lack of understory development). Increased wind damage, fire damage, and drought mortality will result in more canopy gaps and a younger average tree age, but may benefit some herbaceous species.

Invasives. Princess Tree and Tree-of-heaven are threats. Gypsy Moths and exotic tree diseases (sudden oak death, chestnut blight) are potential future threats. Fire Ants may be able to invade these communities and cause significant impacts if temperatures become warm enough.

4.4.12.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. Montane oak forests will likely be resilient to the effects of climate change and are expected to continue to occupy most of the sites they currently occur in and to remain the most abundant communities. Development remains the most severe threat to these communities. Table 4.4.12-1 summarizes the comparison of climate change with other existing threats.

Table 4.4.12-1 Comparison of climate change with other threats to montane oak forests

Threat	Rank Order	Comments
Development	1	According to Taylor and Kurtz (2008), the conversion of forest to development is the leading land use change occurring in the Blue Ridge Mountains (DeWan et al. 2010).
Logging/ Exploitation	2	Full scale high-grading and poor logging practices of the past have had very negative impacts on the structure and composition of the

Table 4.4.12-1 Comparison of climate change with other threats to montane oak forests

Threat	Rank Order	Comments
		resulting succession, but ensuring logging practices are geared toward restoration rather than purely short-term financial objectives will remove the negative impacts of logging.
Invasive Species	2	Past effects of chestnut blight, likely future effects of Gypsy Moth, and potential introduction of sudden oak death make this a severe threat. The Hemlock Woolly Adelgid's range is likely to expand as a result of climate change (Paradis et al. 2007).
Climate Change	3	Future climate is expected to include warmer temperatures, longer growing seasons, likely more hot spells and drought, and more severe storms. Mountainous regions are expected to experience some of the highest temperature changes. Orographic cloud cover, storms, and fog are less crucial in these communities than in those of the higher elevations, but are probably still significant. Since the readily available climate models don't account for these effects, the future climate experienced by these communities remains very uncertain.

4.4.12.5 Impacts to Wildlife

Appendix 3 provides a list of SGCN and other priority species for which there are knowledge gaps and management concerns. Appendices 3-17 (wildlife) and 3-19 (plants) identify SGCN that depend on or are associated with this habitat type.

No endemic species are associated with montane oak forests. Only three moths associated with this ecosystem group appear to be major disjuncts. Montane species adapted to cooler high-elevation sites may become locally extinct in the lower elevations of their range as temperature gradients change (DeWan et al. 2010).

Many species (e.g., Black-capped Chickadees, Green Salamanders, Seepage Salamanders, Crevice Salamanders, and Wehrle's Salamanders) have such a small range or clumped distribution within North Carolina that they are more susceptible to stochastic or genetic population declines or local extirpations than anticipated climate change impacts. Timber Rattlesnakes and other snake species are also subjected to persecution, which is an immediate threat.

Many neotropical migrant birds may also be experiencing winter range habitat loss. Since there is such abundance and diversity of species associated with oak forests, we may not know the exact habitat or life history requirements of individual species that are limiting factors to their population stability.

4.4.12.6 Recommendations

Because oak forest habitat remains abundant and widespread, the most critical conservation activities revolve around gathering information about the wildlife species that utilize it and the habitat itself. We must foster efforts to understand and implement appropriate management techniques (e.g., prescribed fire or thinning) for the benefit of the broadest array of oak forest-dependent wildlife, while taking into account specific needs of wildlife with more restrictive requirements (Artman and Downhower 2003; Ford et al. 2000).

Surveys

Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Give priority to gathering baseline information regarding the current distribution and status of oak forest-associated species that are rare or declining.

Wehrle's Salamander	Eastern Fox Squirrel	Timber Rattlesnake
Black-capped Chickadee	Bats	

- Expand surveys to include species for which we know very little about current status and distribution (e.g., , weasels, moles, shrews, bats, certain salamanders, and reptile species such as the Eastern Box Turtle).

Whip-poor-will	Bats	Salamanders
Nightjars	Small mammals	Eastern Box Turtle
		Reptiles

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Expand monitoring frameworks to account for species that are not suited to traditional long-term monitoring protocols or for species missed under systematic monitoring due to small population sizes or limited ranges in North Carolina.		
Nightjars (Goatsuckers)	Hawks	Owls
• Track oak habitat trends (e.g., rate of loss or conversion of the habitat and disease or pest affects) and consider trends in the development of long-term monitoring strategies for oak forests of the region.		

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Initiate genetic and morphological studies to clarify taxonomic status of numerous birds and amphibians (e.g., high-elevation birds, plethodontid salamanders).		
Plethodontid salamanders	High-elevation birds	
• Conduct life history and habitat use research on Northern Pinesnake.		
Northern Pinesnake		
• Conduct habitat use studies of neotropical migrants and many others using telemetry.		
Black-capped Chickadees	Worm-eating Warblers	
• Conduct habitat use and life history studies for bat species that may potentially use this habitat.		
Eastern Small-footed Bat	Silver-haired Bat	Northern Long-eared Bat
Hoary Bat		

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Study population responses of plant and wildlife species to habitat manipulations (large scale prescribed burning, oak savannah creation, canopy gap creation, etc.).
• Conduct Green Salamander movement studies either around embedded rock outcrops or between rock outcrops. Green Salamander
• Establish studies to determine both direct and indirect impacts of pest control measures upon oak forest-dependent species. Example questions are 'What is the impact of Gypsy Moth control strategies upon local and landscape scale wildlife populations?' and 'What is the impact upon invertebrates that serve as food for vertebrates?'

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Restore highly degraded stands; options include clear cutting and managing succession to control invasive species (i.e., ecological forestry).
• Foster efforts to understand and implement appropriate management techniques (e.g., prescribed fire or thinning) for the benefit of the broadest array of oak forest-dependent wildlife, while taking into account specific needs of wildlife with more restrictive requirements (Artman and Downhower 2003;; Ford et al. 2000;).
• Manage existing conservation lands, including the use of prescribed burning to diversify structure and composition of forest understory, and other silvicultural techniques to promote regeneration.. This provides an array of age class and structural composition and promotes long-term economic sustainability of montane oak forests.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Work with partners like Prescribed Fire Council and the Fire Learning Network to reinstate prescribed burning, which is perhaps the most important action that can make oak forests better able to withstand climate change.
• Create wildlife passages along highways and protect undeveloped connections.
• Identify and protect strategically important areas

4.4.13 Dry Longleaf Pine Communities

4.4.13.1 Ecosystem Description

Dry longleaf pine communities range from moist sites to excessively drained coarse sands which produce near-desert conditions for plants. Longleaf pine communities are scattered throughout the Sandhills and Coastal Plain ecoregions and extend into the southern Piedmont ecoregion. They were once the most abundant communities in the Coastal Plain, occupying most of the land that was not swamp or pocosin, but now occur as scattered remnants. With frequent fire, longleaf pine strongly dominates the canopy, which may range from sparse to fairly dense but is seldom completely closed. Classification of the Natural Communities of North Carolina, 4th Approximation (Schafale 2024) has several subtypes described for this theme.

- Dry Piedmont Longleaf Pine Communities
- Sand Barren (Typic, Coastal Fringe subtypes)
- Xeric Sandhill Scrub (Typic, Coastal Fringe subtypes)
- Pine/Scrub Oak Sandhill (BlackJack, Mixed Oak, Sandhills Mesic Transition, Coastal Plain Mesic Transition, Clay/Rock Hilltop, Coastal Fringe, Northern subtypes)
- Mesic Pine Savanna (Sandhills, Coastal Plain, Lumbee subtypes)

These communities have in common a regime of frequent, low-intensity natural fires which once crept across vast areas of the landscape. The ground cover is dominated by wiregrass and has a variety of other herbs and low shrubs. The structure and composition of these communities at present strongly depends on the extent to which these fires have continued or have been replaced by prescribed fire.

In the Sandhill community types a sparse midstory of scrub oaks is present, with the species varying with types and variants. In the mesic pine flatwoods type, oaks are absent and the community has a distinctly two-layered structure of trees and grass. The herb layer is often very diverse. With removal of fire, scrub oaks in the Sandhills community types and shrubs and hardwood trees in the flatwoods community types become dense and out-compete the herbs.

Piedmont longleaf pine forests are more poorly known. Most existing examples have a mixed canopy of longleaf, loblolly, and shortleaf pine, often mixed with southern red oak and post oak. These communities probably once also had a grassy understory, but it is not known if wiregrass was once dominant.

4.4.13.2 Location of Habitat

The best remaining examples of the dry longleaf pine habitat in the Coastal Plain are on the military bases of Fort Liberty, Camp Lejeune, Sunny Point, and Cherry Point, the Croatan National Forest, Holly Shelter Game Land, Goose Creek Game Land, and Sandhills Game Land. Most of the acreages on the above sites are in fair to good condition, due to regular prescribed burning. There are many other sites on both public and private lands where little to no burning has depleted the value of the habitat; these sites would thus be considered to be in poor condition. Piedmont longleaf pine forest examples are found mainly in Uwharrie National Forest.

4.4.13.3 Problems Affecting Habitats

Prescribed Fire. Severe wildfire in droughts or burning with excessive fuel loads may cause ecological damage. For particular species, especially insects, too frequent or too extensive burning (whether by wildfire or prescribed burns) can have major effects when coupled with loss of landscape integrity resulting from habitat loss. Effects may include some positive (longer growing season) and some negative (pest insect survival). Some of the insects most highly tied to dry longleaf habitats may be eliminated by increases in wildfires.

Climate. The most extreme Xeric Sandhill Scrub and Sand Barrens are dry enough that vegetation density is limited. Increased drought may possibly cause plant mortality and reduce vegetation density further. It may also cause sand barrens to develop in slightly less dry soils. These systems and their component species are well adapted to warm temperatures. Increased temperatures might increase the range of these systems in the northern Coastal Plain and in Virginia. However, the widespread conversion of uplands in this region, the fragmented distribution and lack of seed source for them, and their dependence on fire make natural expansion very unlikely. Warmer temperatures may allow some species of longleaf pine systems farther south to move into North Carolina. The limited tendency of most plants in these systems to invade new areas suggests that any such process would naturally be slow and limited.

Invasives. Warmer temperatures may allow the invasion of Cogon Grass and Nine-banded Armadillos. Once established, they are likely to expand more rapidly with a warming climate. Fire Ants are already a serious invader in these systems.

Severe Storms. General forecasts suggest an increase in severe storms. Increased drought conditions and increased thunderstorm intensity are likely to produce more wildfire. Increased wind storm damage could affect canopy structure. Longleaf pines are among the least susceptible trees to wind destruction, and it is unclear how significant increased wind will be to them. Some young planted coastal longleaf stands have shown significant damage from hurricanes and other strong winds. This usually occurs within a few years after the longleaf have emerged from the grass stage. Because of their slow reproductive rate and long life span, increased wind mortality would reduce average age and might reduce natural canopy density. This would be detrimental to Red-cockaded Woodpeckers and other species that depend on older longleaf pine trees. Increased plant productivity with a longer growing season may partially offset the effect of reduced tree age on structure.

4.4.13.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. The greatest threats to this system do not come from climate change. With their adaptation to dry conditions, fire, wind, and their range well to the south, these may be the most resilient systems to warming climate. Currently, the greatest threat comes from development pressure. Historically, conversion and exploitation destroyed most of this once extensive system, and these forces continue to consume the remnants. Table 4.4.13-1 summarizes the comparison of climate change with other existing threats.

Table 4.4.13-1 Comparison of climate change with other threats to dry longleaf pine communities

Threat	Rank Order	Comments
Development	1	Longleaf pine stands are very desirable areas for housing developments and golf courses. Development within this habitat can lead to fragmentation that disrupts connectivity between patches for most wildlife except birds. Road crossings can lead to mortalities, especially for reptiles and amphibians. These systems occur on some of the highest lands in the outer Coastal Plain, where development may become even more concentrated as sea level rises.
Logging/ Exploitation	2	Intensive pine straw raking impacts understory habitat by removing understory grasses and forbs, preventing their growth, and sometimes creating an almost bare sandy forest floor. Slow reproductive rates may limit regrowth once longleaf pines have been removed.
Conversion to agriculture/ silviculture	2	The threat of agricultural conversion has reduced in recent years (having greatly reduced habitat historically), but pine plantation conversion continues. Genetic improvements to planting stock have resulted in getting longleaf to gain height growth quickly, with most trees coming out of the grass stage within three years. However, these trees clearly have a less developed root system and are more susceptible to wind throw.
Fire	2	Prescribed burning is crucial for retaining these systems in both the present and the expected climate. Inadequate fire is an ongoing threat at many sites. For small, isolated habitat remnants, wildfires can cause permanent extirpation of insect and other animal populations. This is a problem at most unprotected examples and is the greatest threat to protected examples. Much of the plant diversity in these habitats is found in the transition zones between the longleaf communities and other adjacent wetter sites. Traditional

Table 4.4.13-1 Comparison of climate change with other threats to dry longleaf pine communities

Threat	Rank Order	Comments
		use of plowed fire lines in these transition zones has resulted in the eventual deterioration of these transition zones.
Biofuel Production	3	Industrial timber operations will be likely candidates for conversion to biomass production. It will be important to consider competing resource needs as alternative energy production increases the demand for biofuel products (DeWan et al. 2010).
Invasive Species	3	Fire Ants are a threat to many terrestrial animals, especially amphibians. There are numerous native and exotic pests that can impact coniferous trees in this habitat (e.g., Southern Pine Beetles, Red-headed Pine Sawflies, Tip Moths, Pine Webworms, Schweinitzii root and bud disease, red heart of pine disease, etc.). Early detection and control of invasive exotic species (such as cogon grass) will reduce the ecological damage caused by invasives and the cost of controlling them. Preventative measures such as forbidding sale and transport of invasive species will help reduce the risks and cost.
Climate Change	4	Climate change will likely exacerbate some of these problems.

4.4.13.5 Impacts to Wildlife

Appendix 3 provides a list of SGCN and other priority species for which there are knowledge gaps and management concerns. Appendices 3-17 (wildlife) and 3-19 (plants) identify SGCN that depend on or are associated with this habitat type.

Habitat loss and lack of fire affects bird species that rely on a grass-dominant understory and open pine ecosystems (Red-cockaded Woodpecker, Bachman's Sparrow, Brown-headed Nuthatch, Henslow's Sparrow, and Northern Bobwhite). Old growth characteristics (canopy gaps, red-heart fungus, cavities, snags, hollow trees) are lacking throughout, except where Red-cockaded Woodpeckers are managed, impacting both primary (e.g., woodpeckers) and secondary (e.g., rodents, bats, and other birds) cavity users. High-grading of stands, lack of gap management, and overstocked stands are leading to a lack of structural diversity for many species. Roads cause particularly high mortality to reptiles and amphibians.

Microhabitat features such as large woody debris have been lost, impacting reptiles and small mammals (Loeb 1999). Localized and non-lethal infestations can be beneficial for wildlife by creating snags, a food source, and habitat diversity. Extensive lethal outbreaks of native and exotic pests can dramatically shift the composition of the tree community, with implications for conifer-specialists like the Brown-headed Nuthatch.

Wildfires in drought are more likely to be too intense or too extensive and may harm some species. In small, isolated sites, an increase in wildfires may have catastrophic impacts on insects and other animals that depend on a metapopulation strategy for coping with environmental disturbances. For such species, lack of landscape connectivity can prevent restoration of populations through recolonization from unburned refuges. As a result, there may be a significant increase in local extirpations that may eventually lead to region-wide extirpations or even extinction of certain species. To protect sensitive insect populations, prescribed burns should include setting aside unburned refugia in every burn and preferably following a three year burn rotation among three different burn units.

Mild winters, with decreased cold damage, are likely to allow species from the south to move into North Carolina. In recent years, several longleaf pine-associated insects once thought to be restricted to Florida or the Gulf Coast have been found to be established in North Carolina. Although we lack the historic data to know for sure that these represent recent colonizations, this trend will undoubtedly accelerate with decreasingly cold winters. Fire Ant impacts are also a growing threat.

4.4.13.6 Recommendations

Because so few examples remain, at least outside of the Sandhills ecoregion, protecting and expanding remaining examples is crucial with or without climate change. Because these systems are likely to withstand the stresses of changing climate well, restoring more of them in the near future would produce more resilient natural landscapes. Protecting and restoring landscape connections is important to allow movements of mobile species and to improve the viability of small populations. The need for this is particularly important for disturbance-maintained habitats such as longleaf pine ecosystems and will increase with the stresses of a changing climate.

Surveys

Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Conduct surveys to document the distribution, relative abundance, and status of priority wildlife species associated with dry longleaf pine habitats.

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Develop monitoring for any North Carolina dry longleaf pine bird species that require specialized attention, since neither BBS nor standard point counts adequately sample for many species

American Kestrel	Common Nighthawk	Henslow's Sparrow
Bachman's Sparrow	Eastern Whip-poor-will	Red-headed Woodpecker
Chuck-will's-widow		

- Expand and/or target monitoring systems to be able to assess current population status and trend information for all wildlife species associated with dry longleaf pine habitats, in particular reptiles.

Coachwhip	Northern Pinesnake	Southern Hognose Snake

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Develop long-term research studies to investigate various methods for restoring and maintaining longleaf pine ecosystems, including use of herbicides, fire, clearcutting, site preparation techniques, management practices.

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Where possible, allow fire to burn through transition zones to maintain these sites instead of plowing fire lines through them.
• Suppress Fire Ant colonies—particularly where multi-queen colonies have developed—in all protected natural areas.
• Restore landscape integrity to protect insect populations associated with longleaf pine habitats.
• Develop strategies for pine straw raking that minimizes impacts to understory habitat structure.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Work cooperatively with other agencies to define sustainable forestry criteria for biomass production.
• Provide landowners with the option to purchase longleaf seedlings that stay in the grass stage longer. This will allow the trees to better establish their root systems in the hurricane zone and will also provide a longer period of high-quality early successional habitat.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Give high priority to protecting and expanding the few remaining examples regardless of climate change. Because these systems are likely to withstand the stresses of changing climate well, restoring more of them in the near future would produce more resilient natural landscapes.

4.4.14 Piedmont and Coastal Plain Oak Forest

4.4.14.1 Ecosystem Description

Classification of the Natural Communities of North Carolina, 4th Approximation (Schafale 2024) includes this natural community as Piedmont and Coastal Plain Oak Forests Theme. They are the predominant natural forests of the Piedmont, with the exception of the foothills area, and are limited in extent but widespread in dissected uplands in the Coastal Plain (Schafale 2024). There are several subtypes associated with this community.

- Dry-Mesic Oak-Hickory Forest (Piedmont, Coastal Plain subtypes)
- Dry Oak-Hickory Forest (Piedmont, Coastal plain subtypes)
- Dry-Mesic Basic Oak-Hickory Forest (Piedmont, Coastal Plain subtypes)
- Dry Basic Oak-Hickory Forest
- Piedmont Monadnock Forest (Typic, Pine, Heath subtypes)
- Mixed Moisture Hardpan Forest
- Swamp Island Evergreen Forest

Oak forests can occur on many different well-drained upland soil types in the Piedmont and less sandy soil types in the Coastal Plan (Schafale 2024). These forests may have a closed or nearly closed canopy where not broken by gaps, a moderate-density understory, and a patchy sparse to moderate shrub layer (Schafale 2024).

4.4.14.2 Location of Habitat

Most Oak Forests in the Piedmont are found on upland slopes and ridgetops while Coastal Plain examples are found on dissected slopes of stream and river bluffs. Examples of Piedmont and oak forests can be found on several public lands, including Caswell Game Lands, William B. Umstead State Park, Morrow Mountain State Park, Hanging Rock State Park, Kings Mountain Ridge, and Uwharrie National Forest. In the Coastal Plain they occur on the Croatan National Forest.

4.4.14.3 Problems Affecting Habitats

Development. The greatest threats to remaining examples of oak-hickory forests are destruction and degradation associated with development and conversion to successional forests by logging. While all remaining oak-hickory forests regenerated after past logging, present-day harvests often result in regeneration by species other than oaks. Conservation of the best examples and areas important to landscape connectivity is the most important action needed for this habitat.

Fragmentation. As with other formerly widespread community types, fragmentation is a concern. Past and ongoing land use changes associated with development not only reduce the extent of habitat but leave remaining oak—hickory communities as isolated patches. While this habitat remains common and most of its component species are widespread, most natural oak-hickory forests are on dissected landscapes comprised of multiple community types and are not extensive. While most component species are abundant and widespread, some species, particularly mammal and bird species, may only be able to persist in large areas or they may be excluded from areas near the forest edge. The chances for some of these animals to survive may be enhanced by protecting forested connections between larger forested blocks.

Fire Suppression. Fire is believed to have been a natural part of all Piedmont and Coastal Plain oak forests. While its frequency and importance are not precisely known, regular fires give a competitive advantage to oaks, hickories, and shortleaf pine relative to most other tree species. There is now much concern that these species are not regenerating. Other species are much more abundant in forest understories and are increasing in the canopy. Harvests that once resulted in regeneration of oaks now often lead to stands of other species. Fires also lead to more open canopy conditions and greater cover and diversity of herbs. Low intensity fires would be beneficial but intense wildfires can be destructive. Regular fires also reduce fuel loads and reduce the potential for catastrophic canopy-killing fires. The restriction of oak forests in the Coastal Plain to fire-sheltered sites suggests a need for fires to be less frequent than in the longleaf pine communities that occupied the uplands. The Xeric Hardpan Forests appear to have changed most with removal of fire, but fire probably had similar, if less dramatic, effects on the other community types. Most or all rare plants in this group are likely to benefit from fire and the habitat conditions it creates.

Invasives. The occurrence of invasive and non-native plants is a problem for oak—hickory forests in some places and is likely to continue to spread. Princess tree and tree-of-heaven can invade disturbed areas and occupy canopy gaps in some places. Autumn olive has come to dominate the shrub layer in some forests, and species such as trifoliate orange represent a potential threat. Several herbaceous exotic plants also invade these forests, particularly those with basic soils. It is unclear if a warmer climate will exacerbate their spread; however, increased canopy disturbance by wind, drought mortality, or severe fire will hasten the spread of invasive species.

Climate Change. Most oak forests are tolerant of drought. Increased occurrence or longer periods of drought may favor oaks relative to weedy mesophytic species, but increased wind damage favors the understory species. If drought leads to severe wildfires, it would be harmful to oak forests, but the ease with which fires may usually be controlled in them makes this unlikely. Increased wind throw would probably favor existing understory maples over the long-lived oaks. Older trees will withstand fire better than younger ones but will be more susceptible to wind. Increased wind throw would reduce the average longevity of trees. The most severe droughts and hot spells of recent record have had only limited effects on oak forests. These forest types occupy the driest places on the Piedmont landscape. In general, the effects of drought, fire, and storm winds are small relative to the effects of development and logging.

4.4.14.4 Climate Change Compared to Other Threats

Climate change is far from the most significant threat to Piedmont and Coastal Plain Oak Forests. Similar oak forests range well to the south of North Carolina where conditions are similar to predicted future climate conditions. Direct effects of the warmer climate on these communities are likely to be limited and may even reduce some of the increase in mesophytic species. If fires increase, this may be beneficial, but an increase in intense fire would be harmful. Most fire that will occur will be from controlled burning, but weather conditions that make burning more difficult will be detrimental as it limits application opportunities. Most or all rare plants in this group are likely to benefit from more canopy openings and more fire. Table 4.4.14-1 summarizes the comparison of climate change with other existing threats.

Table 4.4.14-1 Comparison of climate change with other threats to Piedmont and Coastal Plain oak forests

Threat	Rank Order	Comments
Development	1	The extensive examples in the Piedmont and the more limited range examples in the Coastal Plain continue to be rapidly destroyed by ongoing urban, suburban, rural, residential, and commercial development. Continued population growth makes this the most severe threat in the current and the future climate. However, the fragmentation and loss of extent will increase the alteration caused by climate change, as isolated communities are unable to migrate, and species are unable to move to more favorable sites.
Extractive Uses/ Timber Harvest	2	Typical past logging practices, both high-grading and clearcutting, have had negative impacts on forest structure and composition, often converting oak forest to other types. Incentives for logging practices geared toward restoration rather than purely short-term financial objectives will reduce (but not eliminate) the negative impacts of logging. While many examples harvested in the past regenerated as oak forests, many harvested at present become dominated by successional pine, maple, or other hardwoods and it is unclear if oak dominance will return. The loss of old trees caused by increased disturbance coupled with future climate conditions will exacerbate impacts caused by timber harvest. Demand for biofuels may reduce timber rotations and may provide incentives to harvest additional areas that have not been commercially viable.

Table 4.4.14-1 Comparison of climate change with other threats to Piedmont and Coastal Plain oak forests

Threat	Rank Order	Comments
Invasive Species	3	Tree-of-heaven, princess tree, autumn-olive, and other invasive plants are likely to continue to expand regardless of the climate. A number of smaller invasive plants are increasing in disturbed oak forests and pose a risk of increase. Emerald ash borer is a severe threat to the ash component of Dry and Dry—Mesic Basic Oak—Hickory Forest. Exotic diseases, such as the sudden oak death fungus, represent a severe potential threat even under the current climate. Increased drought may make forests more susceptible to other diseases and pests.
Fire Suppression	4	The threat posed by fire regime alteration is less certain in rank. Lack of fire is causing slow changes in composition, including reduced oak regeneration. The growth of dense shade-tolerant understories and the consequent failure of oaks to regenerate is likely a result of prolonged fire suppression. It is an ongoing problem regardless of climate change. Climate change may exacerbate it; if it makes controlled burning more difficult, but ongoing development and population growth has a much greater effect. Wildfires are likely to remain easy to control in the Piedmont.
Climate Change	5	In the future climate, there may be an increase in natural fires (due to increased drought and higher average temperatures), but landscape fragmentation and fire suppression practices likely will continue to prevent most fires from spreading very far in the Piedmont and in the dissected lands where oak forests occur in the Coastal Plain. Most oak forests are expected to benefit from increased fire frequency, as long as the fire intensity is not too high. Direct effects of the warmer climate on these communities are likely to be limited. Similar oak forests range well to the south of North Carolina. The most severe droughts and hot spells of recent record have had only limited effects on them because they occupy the driest places on the Piedmont landscape.

4.4.14.5 Impacts to Wildlife

Appendix 3 provides a list of SGCN and other priority species for which there are knowledge gaps and management concerns. Appendices 3-17 (wildlife) and 3-19 (plants) identify SGCN that depend on or are associated with this habitat type.

Rare species of animals, primarily insects, associated with these natural communities occupy habitats at the dry to xeric extreme, with some occurring only on a few isolated monadnocks in the Piedmont. Species that are confined to monadnocks or other small patches of habitat may be vulnerable to increased perturbations, such as fire, if their entire block of habitat is affected by any one event. Species confined to isolated habitats are unlikely to respond to climate change by migration.

4.4.14.6 Recommendations

To reduce the possible impacts from habitat fragmentation, fire suppression, and climate change, conservation or restoration of landscape connections is most important for Piedmont and Coastal Plain Oak Forests. Although oak forest habitat remains abundant and widespread, because of the rapid land development and conversion, the most critical conservation activities revolve around securing land from these activities. Other needs include gathering information about the habitats themselves but also the wildlife species that utilize these habitats, and the unique plants associated with them. Management of these habitats can be better informed by continuing to develop techniques for safe and beneficial controlled burning.

Surveys

Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Give priority to gathering baseline information regarding the current distribution and status of oak forest-associated species that are rare or declining species.

Bats	Timber Rattlesnake	Georgia Aster
Eastern Fox Squirrel	Dwarf-flowered Heartleaf	Schweinitz's Sunflower

- Expand surveys to include species for which we know very little about current status and distribution,

Amphibians	Small mammals	Eastern Box Turtle
Bats	Eastern Whip-poor-will	Reptiles

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing landscape and changing climate. These efforts will inform future decisions on how to manage species and their habitats. Studies should identify population trends and assess impacts from conservation or development activities. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Track oak habitat trends (e.g., rate of loss or conversion of the habitat and disease or pest affects) and consider trends in the development of long-term monitoring strategies for oak forests of the region.
• Track the effects of fire on species in these habitats, especially rare and poorly understood species.

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps assess the vulnerability of priority species to further imperilment. It also aids in identifying possibilities for improved management and conservation.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Study population responses of plant and wildlife species to habitat restoration and management (large scale prescribed burning, woodland/savanna restoration, etc.).
• Study population responses of plant and wildlife species to habitat fragmentation and degradation to better inform managers and plans.

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include,

preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Foster efforts to understand and implement appropriate management techniques (e.g., prescribed fire or thinning) for the benefit of the broadest array of oak forest-dependent wildlife while considering specific needs of wildlife with more restrictive requirements (Artman and Downhower 2003; Ford et al. 2000).
• Manage existing conservation lands by using prescribed burning to diversify structure and composition of forest understory. Protect older trees, which may become increasingly scarce with increased wind disturbance. Provide an array of age classes by managing for uneven-aged stands rather than a patchwork of even-aged stands.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be fully utilized to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Work with partners including the NC Prescribed Fire Council, the Fire Learning Network, and NC Forest Service to reinstate and increase prescribed burning.
• Support efforts to create wildlife passages along highways and protect undeveloped connections. These provide safer movement between oak—hickory habitats fragmented by highways. Protecting the connections will preserve cover and food resources provided by these habitats.
• Identify and protect strategically important areas, especially in areas that harbor populations of SGCN.

4.4.15 Maritime Forests

4.4.15.1 Ecosystem Description

Classification of the Natural Communities of North Carolina, 4th Approximation (Schafale 2024) has updated this natural community to Maritime Upland Forests Theme. These communities encompass dry to mesic forest and shrubland communities on sandy soils within a few miles of the coast or on barrier islands. They are dominated by plant species that are relatively tolerant of salt and are rarely found inland. Communities that occur on barrier islands and coastal spits are impacted by salt spray, an important ecological influence on plant composition and structure. These communities are subject to extreme natural disturbance by wind, heavy salt spray, or saltwater intrusion during storms, and recovery may take several years (Schafale 2024).

Subtypes in this natural community include:

- Maritime Shrub (Stunted Tree Subtype, Wax-Myrtle Subtype, Bayberry Subtype)
- Maritime Evergreen Forest (Mid-Atlantic Subtype, South-Atlantic Subtype)
- Maritime Deciduous Forest
- Coastal Fringe Evergreen Forest (Typic Subtype, Sand Spit Woodland Subtype)
- Calcareous Coastal Fringe Forest (Northern Subtype, Southern Subtype)
- Coastal Fringe Shell Woodland
- Marsh Hammock

Within the theme, a barrier island setting easily distinguishes Maritime Shrub, Maritime Evergreen Forest, and Maritime Deciduous Forest from other communities, while Coastal Fringe Evergreen Forest and Calcareous Coastal Fringe Forest are distinguished by mainland locations inland of the sounds or marshes. Marsh Hammocks are distinguished by location on small islands embedded in marshes. A few examples of Maritime Shrub or Maritime Evergreen Forest may occur on backbarrier islands in locations where spray of salt or brackish water in the sounds produces similar conditions. See Classification of the Natural Communities of North Carolina, 4th Approximation for complete descriptions and lists of plants associated with each subtype (Schafale 2024).

4.4.15.2 Location of Habitat

Maritime Upland Forests are found throughout the barrier islands and coastal inlands. Barrier island examples can be found at Buxton Woods, Theodore Roosevelt State Natural Area on Bogue Banks, Brown’s Island, Bald Head Island, Cape Hatteras National Seashore, Shackleford and Core Banks, Brown’s Island, Bear Island in Onslow County, Fort Macon State Park, Bogue Banks, and Fort Fisher.

Only one good example of Maritime Deciduous Forest remains at Nags Head Woods in Dare County; an additional example occurs in nearby Kitty Hawk Woods. Maritime Swamp Forest examples can be found in in Buxton Woods and Nags Head Woods. Examples of Calcareous Coastal Fringe and Coastal Fringe Evergreen Forests can be found on marsh islands at Swanquarter National Wildlife Refuge and higher uplands at Goose Creek State Park.

4.4.15.3 Problems Affecting Habitats

Land Use. Any loss will be very significant for these already-rare communities. The acreage completely lost from this system by community shifts and destruction may be catastrophic. New sites for these communities may be generated as the coastal landscape changes, but only in places not already destroyed by development. Most barrier island examples occur in complexes that are distant from each other, but connections within the complexes can be threatened both naturally by rising sea level and by human actions such as hydrological alteration.

Succession. With limited dune development in many parts, maritime swamp forests are vulnerable to erosion of the foredunes and increased overwash. If erosion breaches swales and exposes them to sea water intrusion or overwash in storms, they will likely become maritime grasslands. If they are low enough to have irregular tidal inundation, they will become brackish marshes. A lack of fire to maintain some variants of these habitats is also leading to successional changes in many of these sites. Burning is almost impossible to conduct in areas surrounded by homes.

Climate Change. The net change in acreage of this type will likely be drastic only if sea level rises faster than new examples can develop. Increased natural disturbance by wind, salt spray, and storm surge intrusion will be significant. Some of these communities consist of species that can recover from these disturbances, but increased frequency will result in death and regeneration, more time spent in recovery stages and shifts toward the most tolerant species.

4.4.15.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. Climate change may be the biggest threat to remaining examples of this ecosystem group, especially in places where topography or development limits potential for elevational migration. A combination of synergistic effects with other existing conditions could stress these systems to the point where several species are unable to persist. Residential and commercial coastal development leading to fragmentation and overall reduction of habitat is the single most important factor leading to the existing loss of this habitat. Table 4.4.15-1 summarizes the comparison of climate change with other existing threats.

Table 4.4.15-1 Comparison of climate change with other threats to maritime forests

Threat	Rank Order	Comments
Development	1	Almost all maritime forest habitat is found in areas close to the beach, where human population growth is booming. The creation of numerous small clearings for houses will likely have far-reaching effects on the dynamics of these habitats (Schafale and Weakley 1990).
Climate Change	1	Sea level rise may be the biggest threat, outside of development.
Drainage/ Impoundments	2	Construction of larger dunes can either prevent overwash saltwater from reaching these wetlands or trap water that might otherwise run off. Maritime wetland forests may be destroyed by impoundment, ditching, and by extensive well pumping that lowers the water table.
Groundwater Depletion	3	Control of ground water extraction is likely to be difficult, as coastal towns seek water sources from perched aquifers that are shrinking due to erosion and saltwater intrusion. Ground water pumping, ditching, and impoundment associated with development are threats which can be mitigated.

4.4.15.5 Impacts to Wildlife

Appendix 3 provides a list of SGCN and other priority species for which there are knowledge gaps or management concerns. Appendices 3-17 (wildlife) and 3-19 (plants) identify SGCN that depend on or are associated with this habitat type.

These habitats are important breeding and migration stopover points for many migratory birds, and key breeding areas for populations of the eastern painted bunting (Hunter et al. 2000; Johns 2004). These communities are also important for some snake species for which we have little status, distribution, or demographic information. The presence of dense canopies is a key habitat element in maritime forests; many maritime forest-associated herpetofauna, and their prey, are adapted to survive under particular sun and shade regimes (Bailey et al. 2004).

There are feral animal impacts (horses, goats, cows, pigs, cats) on some of the barrier islands (e.g., Shackleford Banks and Brown's Island). Wood et al. (1987) reported that grazing by ungulates can inhibit expansion of maritime forests. Feral horses have been shown to alter the composition of entire communities through grazing and trampling, though trampling may be the greater impact because it degrades soil structure (Turner 1987; Jensen 1985; Porter et al. 2014). In addition, egg predators such as Raccoons and foxes that typically did not inhabit most of the Outer Banks are now widespread because of the increased amount of food available now that people inhabit the area.

The Buxton Woods White-footed Mouse might be the only animal essentially limited to this habitat type. The Dukes' Skipper occurs mainly in ecotones of maritime forests and adjacent marshes. All guilds linked to this group are associated with other ecosystems that provide greater acreage of habitat.

4.4.15.6 Recommendations

Most of the remaining maritime forests and swamps on the barrier islands are under conservation, as are many of the estuarine fringe communities. Substantial opportunities to protect additional examples are limited. There is value in protecting additional examples in the broader, more stable parts of barrier islands such as Kitty Hawk Woods, where these communities have the best chance of surviving. There is value in protecting estuarine fringe examples where there is opportunity for them to migrate inland.

Surveys

Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Determine the status and distribution of amphibians and reptiles in maritime communities.
• Conduct migration surveys to determine bird use, especially during the fall.
• Conduct small mammal surveys on barrier island systems to verify species status, distribution, and community composition.

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Establish MAPS and migration banding stations in this habitat type.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Establish long-term monitoring of amphibians and reptiles, once survey data has been established. Amphibians Reptiles
• Carefully monitor loss of this habitat from sea level rise.
• Continue long-term monitoring and banding work being done by the USGS on and support the goals and objectives of the Painted Bunting Working Group that involves Florida, Georgia, South Carolina, and North Carolina. Eastern Painted Buntings

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Conduct cooperative research with western states to determine the genetic relationships between Eastern and Western Painted Buntings. Eastern Painted Bunting
• Conduct genetics research on all “Kingsnake” species. Kingsnake species
• Document the habitat selection and competition factors related to Indigo Buntings and Painted Buntings in these habitats (Kopachena and Crist 2000). Eastern Painted Bunting Indigo Bunting
• Initiate productivity and habitat use research on priority species.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
Eastern Painted Bunting	Coachwhip	Eastern Kingsnake
Eastern Spadefoot	Eastern Coral Snake	Northern Scarletsnake
Southern Dusky Salamander		

- Consider maritime forests in the far southeastern portion of the state to be potential Eastern Woodrat reintroduction sites, as they were historically supported in those locations.

  Eastern Woodrat

- Examine demographics, population dynamics, and the specific habitat requirements of the Buxton Woods White-footed Mouse.

  Buxton Woods White-footed Mouse

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Where possible, remove or exclude feral animals. Exclosure plots and electric fences should be considered as methods to prevent grazing or trampling (Porter et al. 2014).

- Control the number of feral horses and contain populations of free roaming horses to reduce habitat damage (Porter et al. 2014).

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Make remaining coastal maritime habitats a priority for land acquisition efforts. Though coastal uplands are essentially the most costly areas to acquire in the state, it is essential to acquire remaining undeveloped maritime forests, both on barrier islands and on the mainland.
• Pursue reestablishment of maritime forest habitats, including initiation of prescribed burning of appropriate maritime habitats, where possible.

4.4.16 Maritime Grasslands, Dunes, and Beaches

4.4.16.1 Ecosystem Description

Classification of the Natural Communities of North Carolina, 4th Approximation (Schafale 2024) has separated this natural community into the Maritime Grasslands Theme and the Maritime Wetlands Theme (Schafale 2024). Maritime grasslands are found on barrier islands and similar coastal areas. They are dry-to-moist communities and includes several subtypes associated with dune grass, maritime dry grassland, maritime wet grassland, and upper beach communities.

- Dune grasslands include bluestem subtype, northern subtype, and southern subtype (Schafale 2024). They occur on the line of foredunes just behind the active beach and on unstable sand dunes farther back on barrier islands. The loose, shifting sand with its low water holding capacity and low nutrient reserves makes these environments habitable by only a handful of specialized plant species. Sea oats grass is the dominant plant in most examples, with American beach grass dominating examples in the northern part of the state. Artificial dune stabilization by planting of grasses or placing sand fencing modifies the natural dune structure and dynamics. Dredged or mined sediment is sometimes used to widen the beach and/or construct new dunes. Constructed beaches/dunes are often susceptible to faster rates of erosion than natural beaches/dunes.

- Maritime grasslands include the dune grass southern, bluestem, and northern subtypes; live dune barren, stable dune barren southern and beach heather subtypes; and maritime vine tangle communities. These communities occur on more stable sands in the interior of barrier islands. They may be on low, stable, old dunes, but are most typically found on sandy flats on low islands that lack continuous foredunes. Seawater over washes the low islands during severe storms and kills any invading woody vegetation. The dominant vegetation includes Seaside Little Bluestem and American beachgrass but overall plant diversity is fairly low.

- Maritime wet grasslands include numerous subtypes: southern hairgrass and switchgrass subtypes; interdune marsh and pond subtypes; maritime swamp forest typic and cypress subtypes; maritime shrub swamp dogwood, red bay, willow subtypes; estuarine fringe pine forest loblolly pine and pond pine subtypes; and estuarine beach. They occur on dune swales and other depressions on barrier islands, occasionally on sand flats elevated above tide levels. Some examples may even be flooded for substantial periods. There is a wide variety of vegetation associated with the range of hydrologic conditions. As noted in Schafale (2024) they are extremely dynamic and subject to extreme natural disturbance by wind, heavy salt spray, saltwater intrusion during storms and storm waves.

- The upper beach type is not technically a grassland, but is closely related to the other community types. The Classification of the Natural Communities of North Carolina, 4th Approximation (Schafale 2024) has placed this community in the Estuarine Communities Theme as Upper Beach northern and southern subtypes. It occurs above the mean high tide line behind the intertidal beach. The environment is harsh for plants, with almost constant salt spray and with periodic flooding and reworking of sand during storms. A handful of mostly annual, salt-tolerant herbs occur as sparse patches and scattered individuals on the sand. Small mounds of sand may develop around the few perennial plants, such as sea oats and marsh elder, forming the beginnings of dunes.

4.4.16.2 Location of Habitat

Maritime grasslands are located in the Coastal Plain ecoregion on barrier islands and Atlantic Ocean shore areas.

4.4.16.3 Problems Affecting Habitats

Overwash. These communities are well adapted to overwash and this may or may not be harmful to them. It may reverse the artificial exclusion of overwash that has altered some examples, such as those on parts of Bodie and Hatteras islands and the Currituck Banks. Overwash is important for transporting sand to the back of barrier islands, allowing them to migrate landward with rising sea level. Increased erosion of foredunes and possible disappearance of whole barrier islands will substantially reduce acreage.

Sea Level Rise. This group will likely shrink drastically in the near future. The most extensive examples occur on narrow barrier islands which are most likely to disappear or be substantially altered by erosion. Examples should survive where barrier islands are able to migrate. Examples should survive on larger, more stable, higher islands, and may migrate to higher elevations or expand there at the expense of maritime upland forest and maritime wetland forest. Much of the narrower part of the Outer Banks could disappear entirely (Riggs 2010). With the loss of area will come increased fragmentation, which is already a problem in smaller examples that are isolated by developed areas.

Barrier islands can be expected to migrate landward, if allowed to, and could survive if sea level does not rise too rapidly. The wider, more stable, and generally higher parts of barrier islands are likely to remain. Grassland communities will also shift and change as the result of increased storm activity and its associated erosion, increased salt spray, overwash, and saltwater intrusion. Increased coastal erosion may breach the foredunes, allowing overwash which can offset the effects of artificial barriers (e.g., sand fencing and plantings) installed to reinforce the stability of the primary dune.

Increased natural disturbance and milder temperatures can be expected to change composition. Species native to comparable communities farther south may be able to migrate in. Because the harsh physical environment already limits species present, and because the expected changes on surviving islands are mostly increases in processes already active, the degree of compositional change is expected to be limited in most of these communities. Structural changes may be more significant. However, the wet grasslands in particular may be more drastically affected.

Invasives. New exotic species may appear or become invasive in the warmer climate. Beach vitex (*Vitex rotundifolia*) is an invasive species introduced through gardening centers and can outcompete some of the native dune vegetation such as sea oats. Although many patches of vitex have been eradicated along coastal dune systems, effort is needed to remove remaining patches and document any new patches that may become established. ,Mild winters may allow new exotic species to invade or may allow more natural compositional change that will be locally substantial but may be negligible over larger areas.

4.4.16.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. While the climate is expected to be warmer, and rainfall change estimates vary widely, the most important effects on these systems will be rising sea level and an increase in storms. Table 4.4.16-1 summarizes the comparison of climate change with other existing threats.

Table 4.4.16.1 Comparison of climate change with other threats to maritime grasslands

Threat	Rank Order	Comments
Development	1	Ongoing development, including artificial foredune build-up, is the most severe threat to the remaining unprotected examples. Beach houses, motels, and other structures, and the infrastructure that supports them, have caused a significant stabilization effect on the beaches that will be difficult to reverse.
Climate Change	1	Sea level rise and increased storm intensity associated with climate change are the most severe threats to the conservation areas where most of the remaining maritime grasslands occur.
Invasive Species	2	Feral populations of horses have been documented to have a severe effect on maritime herbaceous communities (Porter et al. 2014) and particularly on populations of seaside little bluestem. Beach vitex is the only invasive plant species that is a severe threat at present. Its abundance is limited, and control should be feasible with effort. Additional exotic species are likely to appear with a warmer climate.

4.4.16.5 Impacts to Wildlife

Appendix 3 provides a list of SGCN and other priority species for which there are knowledge gaps and management concerns. Appendices 3-17 (wildlife) and 3-19 (plants) identify SGCN that depend on or are associated with this habitat type.

A genetic study of the Crystal Skipper (*Atrytonopsis* n. sp. 1) indicated that its population is subdivided into three distinct groups, one at Fort Macon and a nearby dredged-material island, one at Emerald Isle, and one at Bear Island. These findings indicate that dispersal may be fairly infrequent across ocean inlets as well as wide strips of maritime forest and development.

The Seaside Dusted Skipper is one of the rarest species in the state. Even if it turns out to be an isolated population of the Loammi Skipper, that species is also highly threatened and currently only known to exist in Florida. The Fort Macon population of a moth (*Faronta aleada*) in the *Noctuidae* family appears to be associated with the same habitat as the Crystal Skipper, but not necessarily Seaside Little Bluestem. Sea level rise may have an effect through increased fragmentation of the restricted range of these species. However, the sites they occupy are among the most stable in this type of habitat and likely to persist.

The beach/dune habitat is particularly important to sea turtles, beach-nesting birds, and shorebirds. Many of the bird species rely on the dynamic nature of the beach and need storms to recreate wide beaches with bare sand and shell overwash areas. The swash zone (the area between high and low tide) is particularly important to beach invertebrates which are a food source for fish and waterbirds. These habitats are also well imitated by dredged-material islands within our sounds that are often devoid of the predators that have invaded the barrier beaches.

Several of the bird species we are most concerned about require early successional habitat for nesting and these habitats have been destroyed or severely altered. Predators (native and nonnative) have increased many-fold; many of these species (cats, Herring and Great Black-backed Gulls, Raccoons, foxes, Coyotes) were not present before the beach became populated with people and their associated trash. These predators have caused significant problems for beach-nesting birds and sea turtles. Vehicle use has also created disturbance issues as well as direct impacts to nesting turtles and birds. Chronic human disturbance is becoming a problem at many sites. People are now able to access even the most remote beaches via shallow draft boats and personal watercrafts. Direct and indirect disturbance, not only by humans but also by their pets, causes problems for nesting and non-nesting birds.

Grazing by feral horses is a significant threat to some protected areas, such as Shackleford Banks and the Rachel Carson Preserve and Currituck National Wildlife Refuge. Grazing and trampling contribute to loss of dune elevation (Porter et al. 2014) and has severely damaged the maritime grasslands in these sites. Patches of Seaside Little Bluestem, which support some of the rarest insects in the state, are now almost absent outside of artificial horse exclosures. Wild horses and other large mammals (including domestic dogs) are also generally incompatible with beach-nesting birds. These mammals inadvertently step on nests and chicks, and cause colony abandonment by adult birds.

Beach renourishment and beach bulldozing can cover or destroy macro-invertebrates in the swash zone and on the beach that foraging shorebirds and surf fishes depend upon. These activities can also disturb nesting female sea turtles and destroy their incubating eggs when conducted between May and November. Even under the best survey conditions, all sea turtle nests cannot be found and marked or relocated to prevent take from these activities. Beach renourishment can also lead to more development and possibly decrease washover and increase vegetation, thus decreasing the amount of suitable nesting habitat for beach-nesting birds. Landscaping choices (e.g., introduced species such as Vitex) can also strongly affect the dune system.

Shoreline protection measures can limit access to suitable sea turtle and shorebird nesting habitats. Placement of sandbags, hay bales, and riprap stones and other shoreline hardening measures are barriers to natural sediment transfer that renourishes beach. Hardening is often associated with protection of nearby development and exacerbates loss of natural sediment renourishment (SASMI 2024).

4.4.16.6 Recommendations

In general, conservation and restoration of natural composition and function, and conservation of surrounding natural areas are the best ways to improve the ability of these communities to adapt to climate change. Development and historically free-ranging livestock have destroyed much of the original maritime grasslands and continue to represent the most severe threats to remaining unprotected examples. Although massive changes are likely, at least some examples can survive if given sufficient protection and where natural beach cycles are allowed to operate.

Surveys

Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Surveys are needed to document the distribution, relative abundance and status of wildlife species associated with beach/dune habitats. Priorities for conducting surveys need to focus on species believed to be declining, at risk, or mainly dependent on these communities.
• Secondary priority for surveys should be for species for which current distribution information is already available or for species that are considered common.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Conduct shorebird surveys throughout the year to better understand population fluctuations for breeding, wintering, and migratory birds.		
American Oystercatcher	Piping Plover	Wilson's Plover
• Determine distribution and status of wintering shorebirds (Sprandel et al. 2000).		

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Continue support for regular colonial waterbird surveys (currently conducted coast-wide roughly every three years).		
• Continue sea turtle nest and stranding monitoring.		
• Monitor introduced nonnative species effects (especially plants and invertebrates) on native coastal wildlife, including sea turtles.		
• Monitor status and reproductive success of coastal shorebirds.		
Black Skimmers	Common Terns	Least Terns
Caspian Terns	Gull-billed Terns	Piping Plovers
• Determine seasonal numbers and distribution of shorebirds (Dinsmore et al. 1998).		

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Identify causal factors responsible for low beach-nesting bird reproductive success; initiate predator impact studies (e.g., Ghost Crabs, Fire Ants, gulls, foxes, Raccoons, coyotes, feral cats, etc.) (Wolcott and Wolcott 1999).
• Experiment more with creation of overwash fans or ephemeral ponds for nesting or foraging birds.
• Continue sea turtle DNA research to better determine nesting habits and needs.
• Work with owners and managers of buildings containing nesting least terns to increase reproductive success while allowing owners/managers to maintain good public relations.

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Although protected by law in North Carolina, feral horse herds should be restricted from some areas where they currently roam free. Such restrictions would be particularly beneficial at Shackleford Banks and Currituck National Wildlife Refuge (Porter et al. 2014). Fence off portions of barrier islands where feral horses still occur to allow recovery of maritime grassland communities. Shackleford Banks; Currituck National Wildlife Refuge
• Where sand supply is abundant and substrate is appropriate, restore overwash processes that carry sand from the seaward to the landward side of an island and may allow landward migration and improve prospects for survival.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Collect seeds of the rarest plant species associated with maritime grasslands (especially annual species) to protect genetic diversity and maintain a source of local material that can be used to reestablish populations if species are extirpated or severely impacted within North Carolina.
- Control predators (not limited to exotic species) through education efforts, trapping, or other means to increase sea turtle and beach-nesting bird reproductive success.
- Make efforts to address beach lighting, sand fencing, sand pushing, and beach stabilization issues so that sea turtles have a better chance for nesting success.
- Continue the use of bird decoys and sound broadcasts to attract colonial nesting birds to better nesting sites.
- Continue coordination to influence where dredged material is placed to be most beneficial/least detrimental to beach-nesting birds, foraging shorebirds, and sea turtles.
- Reduce disturbance from off-road vehicles, people, and their pets on coastal beach and dune systems. Continued support for and enhanced coordination among coastal management agencies regarding existing restrictions and programs aimed at regulating beach activities is also critical.
- Continue and expand the use of living shorelines as the preferred shoreline stabilization method to protect and restore salt marsh, especially in lieu of bulk heads where appropriate.
- Obtain funding for the implementation of projects that focus agricultural farmland easements within marsh migration areas to avoid urbanization of those zones.
- Inventory and prioritize coastal marsh migration areas based on specific strategies (i.e., acquisition, conservation based on inevitable natural processes and existing land uses, most vulnerable to sea level rise, management for marsh movement on conservation lands purchased with public funds).

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Continue coordination with waterbird working groups such as the North Carolina Waterbird Committee. American Oystercatcher Working Group — Piping Plover Recovery Team — Royal Tern Working Group
• Future recommendations from the North American Waterbird Conservation Plan should be implemented (Kushlan et al. 2002).
• Maintain the NC Sea Turtle Project with federal, state, local collaborators and volunteers to document and protect sea turtle nests found along the coast.
• Recommended actions in the NOAA & USFWS Recovery Plans for sea turtles should be followed.
• Work with local governments to better manage for new development in lowlying areas near coastal marshes to avoid blocking potential migration pathways.

4.4.17 Sand, Shell, and Wrack Active Shoreline

4.4.17.1 Ecosystem Description

North Carolina's coastline features a string of barrier islands, long and mostly narrow islands that lie parallel to the mainland and were formed by naturally occurring offshore sand or sediment deposited over geological time. They are separated from the mainland by relatively shallow sounds, bays, tidal inlets, or the mouth of large river systems that drain to the Atlantic coast (NOAA 2014). Natural forces such as wind, waves, and storms act on these islands, causing constant change, movement, erosion, and growth. Interior to the natural barrier islands, maintenance dredging of the Atlantic Intercoastal Waterway and various tidal inlets along North Carolina's coast produces sand that has been used to create artificial spoil islands located near the barrier islands. Both island types provide shoreline habitats that are important to wildlife.

The active sand, shell, and wrack shoreline is comprised of sand, small shells, shell debris, seaweed, and other marine detritus deposited between the low and high tide line. Water movement within the swash zone (Kelly and Dodd 2010) and saltwater inundation from tidal flooding along the beach prohibits plant growth, so vegetation communities are not included in this community type. The structure and availability of beach landscapes is subject to naturally occurring changes caused by wave action (swash), high tides, and storm surge and can vary daily (FitzGerald et al. 2007). This habitat is often referred to as 'beach' but represents a different community than described in Maritime Grasslands, Dunes and Beach (Section 4.4.16). However, maritime grassland, maritime forest, tidal wetlands, and estuarine wetlands are the vegetated communities most likely to be located adjacent to this community.

This habitat provides important forage sites for several species of resident and migrating shorebirds as well as decapod crustaceans (e.g., ghost crabs) (Schlacher and Lucrezi 2010). Most shorebirds feed above the swash limit to a few meters into the water, while others feed on the beach above the active swash limit such as Ruddy Turnstones and Sanderlings (Burger et al. 1977; Nordstrom et al. 2006). Where the active shoreline transitions to other community types it may provide nesting sites. They are also vital nesting sites for sea turtles and Diamondback Terrapins and they support numerous other small mammals and invertebrates. Beach communities that are subject to low-energy wave action provide important spawning habitat for marine animals such as Horseshoe Crabs (family *Limulidae*) (Nordstrom et al. 2006; NOAA 2014).Sandy beaches also have a rich interstitial community comprised of both micro- and macrofaunal species (e.g., Hydrozoa, Turbellaria, Trematoda, Nematoda, Gastropoda, Arthropoda) (McLachlan and Brown 2010).

4.4.17.2 Location of Habitat

Sand, shell, and wrack shoreline is coastal zone habitat found on barrier islands and other Atlantic Ocean shore and estuarine areas between the low tide line and the vegetated lower sand dune (fore dune) communities.

4.4.17.3 Problems Affecting Habitats

Development. Development along shorelines and other coastal waterfronts often result in use of bulkheads and other protective barriers meant to protect buildings and infrastructure from wave action and inundation hazards. Seawalls and groins built to protect beaches from erosion result in narrower intertidal zones and altered wrack assemblages, which in turn contributes to reduced numbers of invertebrate forage needed by shorebirds (Dugan and Hubbard 2006). Bulkheads and wave breaks can impede turtle access to nesting and foraging sites or reduce the amount of sandy areas that are accessible for nesting (Wnek et al. 2013;; Roosenburg 1990).

Beaches near residential and commercial developments may be subject to raking or grooming to remove debris and trash or to improve aesthetics, especially during busy summer seasons. Beach grooming is likely to result in decreased species abundance and biomass because it damages or removes foraging resources (Dugan et al. 2003; Hubbard et al. 2013). Nordstrom et al. (2012) noted there is less natural swale and dune development on beach areas subject to raking because wrack materials were removed.

Beach Nourishment. Beach nourishment is often used as a coastal management strategy to restore shoreline, combat coastal erosion, protect coastal infrastructure, and to widen the beach in order to increase recreation opportunities. Dredge materials pumped from offshore marine sands or maintenance of boating lanes and inlets are often the source of material for nourishment projects. Adding sand to the beach is often considered an ecologically preferred option for erosion defense but there are associated detrimental ecological effects (Speybroeck et al. 2006; Manning et al. 2013; Viola et al. 2013) when materials are randomly mixed sediments that do not match the particle size and content of the receiving areas; sediments have high concentrations of organic solids; marine sediments have a high salt content; or there are high levels of contaminants in the material (Wnek et al. 2013).

Pollution. Pollution of aquatic systems has been linked to deformities in snapping turtle hatchlings and is suspected to be a contributing factor in nest failures (Wnek et al. 2013). Onshore vehicles are also a source of fuel and oil contaminants that introduce pollution to small areas of sand and the subsurface invertebrate community.

Onshore Driving. Vehicle use on the beach was found to have a significant negative effect on invertebrate abundance and diversity through compaction of the sand and interstitial habitats (Schlacher et al. 2008). Vehicles driven on sandy beaches leave vehicle tracks that make it difficult for female sea turtles and hatchlings to travel between the water and nesting sites (Schlacher and Lucrezi 2010). Inattentive drivers can kill turtles on the beach by running over them and illegal access by drivers into restricted beach areas can destroy shorebird nesting sites by crushing them or by disrupting nesting behavior. Unattended pets and children allowed to enter shorebird nesting areas also can destroy or disrupt nests.

Climate Change. With climate change, it is projected that future tropical storms and hurricanes will become more intense with higher wind speeds and larger waves. Combined with sea level rise, models suggest that 100-year coastal flood levels will occur every 1-30 years by late in the century (Marsooli et al. 2019). As sea level rises, storms of a given magnitude reach higher elevations and produce more extensive areas of inundation (FitzGerald et al. 2007). Climate change is expected to severely impact this habitat through inundation and erosion from rising sea levels and storm surge (DeWan et al., 2010; Karl et al., 2009; Band and Salvensen, 2009).

The effects of sea level rise will be greater than the inundation caused by rising ocean waters because of the permanent or long-term loss of sand from beaches. The loss results from complex feedback-dependent processes that operate within onshore coastal elements (e.g., nearshore, beach face, dunes, tidal inlets, tidal flats, marshes, and lagoons). Long-term beach erosion due to accelerated sea level rise may eventually lead to the deterioration of barrier island chains in North Carolina and others along US East and Gulf coasts (Williams et al. 1992; FitzGerald et al. 2007).

Invasive Species. Wild horses and other large mammals are also generally incompatible with beach nesting birds. These mammals inadvertently step on nests and chicks, and disturbance or encroachment on nesting sites can cause colony abandonment by adult birds. Feral horses graze dune vegetation, resulting in destabilization and erosion (Sabine et al. 2006).

4.4.17.4 Climate Change Compared to Other Threats

A comparison of climate-related impacts to other threats is not included in this description because the NCNHP vulnerability assessments completed in 2010 did not include sand, shell, and wrack shoreline as a community type. In a report developed by the Faculty Committee on Global Climate Change at the University of North Carolina Wilmington on the potential impacts of climate change, significant loss in the width of several coastal North Carolina beaches was predicted to occur between 2003 and 2030.

4.4.17.5 Impacts to Wildlife

Appendix 3 provides a list of SGCN and other priority species for which there are knowledge gaps or management concerns. Appendices 3-17 (wildlife) and 3-19 (plants) identify SGCN that depend on or are associated with this habitat type.

Sea turtles typically nest at night from March through November, which encompasses the busy summer recreation season when proximity to residential and commercial development will increase the probability of encounters with people and domestic pets. Shorebird nests located on sand, shell, or wrack materials are usually well-camouflaged, making them subject to destruction by pedestrians and beach-driven vehicles and predation by dogs allowed to roam beach and dune areas. The presence and density of nest predators such as Raccoons, foxes, and Opossums may increase because they are attracted by easily accessible food waste that an increased human presence creates.

Habitat quality affects the survival of populations that utilize this habitat (Wnek et al. 2013) and animals that utilize beach habitats for nesting are particularly vulnerable to loss of habitat, to structures that restrict their access to foraging and nest sites, and to intrusions that disturb their nesting or foraging behaviors. Female terrapins are reported as showing nest site fidelity and return to the same beach for nesting (Roosenburg 1990). Piping Plovers, American Oystercatchers, terns, skimmers, and sea turtles are additional examples of species that are vulnerable to loss of beach habitats for nesting or foraging.

Diamondback Terrapins and sea turtles nest on sand dunes, bay, and sound beach areas, and artificial spoil islands and shoreline structures built in these areas to reduce erosion can impede them from coming on shore to nest (Wnek et al. 2013). Trash and waste materials deposited along the shoreline create another access hazard for hatchlings leaving nests and can become an ingestion or entanglement hazard for foraging animals (Nevins et al. 2014).

Sediment composition in nesting areas affects micro-environmental conditions such as temperature, carbon dioxide and oxygen levels, and moisture content, which in turn affects water exchange, metabolism, and development of embryos in the nest chamber (Wnek et al. 2013). Sex determination of turtle embryos is dependent on temperature of the nest during incubation and biophysical conditions such as soil temperature and moisture affect survivorship, length of incubation period, energy stores, and sex ratios of hatchlings (Roosenburg 1990; Jeyasuria and Place 1997; Wnek et al. 2013). Embryos that did not survive in nests constructed in dredge soils were dessicated, most likely due to high saline content or the presence of organic and inorganic contaminants (Brooks et al. 1991; Miller and Dinkelacker 2008; Wnek et al. 2013).

4.4.17.6 Recommendations

In general, conservation and restoration of natural composition and function, and conservation of surrounding natural areas are the best ways to improve the ability of these communities to adapt to climate change. Protection of a large and diverse pool of examples is the best way to ensure that many survive the future stresses.

Surveys

Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Conduct distributional and status surveys for pelagic and shore birds, small mammals, and reptiles that may utilize this habitat.

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible. These monitoring efforts will gauge resilience and inform future decisions on how to manage aquatic species.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Develop long-term monitoring to identify population trends and to assess performance of conservation actions. Monitoring plans should be coordinated with other existing monitoring programs where feasible. Use of automated devices such as acoustic recording units and wildlife cameras should be considered.
• Design an ecological monitoring system that can measure how the beach ecosystem responds to human pressures particular to the coastline. Use long-term monitoring to measure the changing health of the beach in response to long-term and cumulative pressures (Peterson and Manning 2001).
• Conduct ecological monitoring before, during, and after construction of shoreline hardening structures and beach renourishment projects to best understand the extent to which the beach ecosystem changes. Monitoring should also continue well after project completion to understand long-term effects of this anthropogenic disturbance, as well as cumulative effects of multiple nourishment projects. Scientists should use a scientifically and statistically robust monitoring design that looks at multiple indicators of beach ecosystem health. Analysis of data should include a test of statistical power (Peterson and Manning 2001).

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Research to facilitate appropriate conservation actions includes habitat use/preferences, spawning location and timing, fecundity, population dynamics, population genetics, feeding, competition, and predation.

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Minimize the negative effects on beach ecology from beach renourishment projects by following a set of BMPs that include proper sediment choice, timing, spatial implementation, site-based design, ecological monitoring, and minimizing conflicts of interest (Hennessey et al. 2011).
• Break large renourishment projects into smaller project zones in order to minimize impacts of direct burial to turtle nests. Intersperse project zones with untouched beach to facilitate recolonization of invertebrate fauna (Speybroeck et al. 2006).
• Complete renourishment projects before the start of the warm season to improve chances of invertebrate recolonization. Project implementation should be avoided at times that coincide with critical life stages of sensitive species, such as beach-nesting turtles or piping plover nesting seasons (Speybroeck et al. 2006).

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Although protected by law in North Carolina, feral horse herds should be restricted from some areas where they currently roam free. Such restrictions would be particularly beneficial at Shackleford Banks and Currituck National Wildlife Refuge (Porter et al. 2014). Use exclosures to fence off portions of barrier islands where feral horses still occur, allowing recovery of maritime grassland communities.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

4.4.18 Successional Communities (Herb, Shrub, Woody)

4.4.18.1 Ecosystem Description

Successional communities can be described as grassland, shrubland, or woody types and are found in upland terrestrial landscapes as well as wetlands.Successional uplands are dominated by herbaceous vegetation and/or shrub cover because most trees have been removed, either through natural means or by human activity. Where tree species exist they are young and often not much taller than shrubs.

Successional wetlands are primarily dominated by herb and shrub communities that develop on frequently flooded, semi-permanently flooded, or other wetland sites following disturbance, either natural or manmade. Natural examples of successional wetlands include the communities that form as beaver ponds become filled-in with sediments, particularly following abandonment of a pond by the beavers. Artificial examples include habitats that form along routinely maintained corridors (e.g., power line easements, rights-of-way) and where borrow pits, farm ponds, drainage ditches, or larger reservoirs become filled-in.

- Grassland types can be either uplands or wetlands and are dominated by herbaceous vegetation such as mixed grasses, wildflowers, and vines. Examples of this habitat include fallow farm fields, hayfields, pastures with native grasses, savannas, prairies, meadows, and mountain balds. Grass balds are a unique community and are described in Section 4.4.6. While areas such as ball fields, golf courses, intensively managed horse farms, and mowed lawns are dominated by grasses, they do not provide quality grassland habitat for priority species.

- Shrubland types have a mixture of young saplings, shrubs, and woody plants typically less than ten feet tall with scattered open patches of grasses, wildflowers, and vines. Vegetation composition is generally dependent on disturbance frequency and patterns. Hedgerows, clear-cut and regenerating forests, field borders, large canopy gaps, and transportation or utility rights-of-way in dry to mesic uplands are often shrubland communities. Scattered mature trees may be present but not to the point that they shade out the beneficial understory vegetation. Shrubland habitats provide structural diversity that offers a variety of nesting sites, escape cover, and food for wildlife.

- Woody types represent late stage successional communities that have not developed the characteristics of a specific natural community. Dominant trees in the overstory and shrubs in the understory are often dense and most likely composed of common weedy species or nonnative invasives.

The niche that successional communities occupy probably has always existed, having once been associated primarily with openings created by natural disturbances such as storms, floods, or fire. Since they rely on patterns of disturbance to maintain them, these communities are characteristically transient, constantly emerging across the landscape. They are composed primarily of native species of annual plants, reptiles, small mammals, birds, and insects that are associated with successional habitats and are often found nowhere else. While early successional communities can be found statewide, composition and species associations will be highly correlated with the ecoregion where they occur.

Successional habitats in the Mountain ecoregion may range from broad ridge tops (containing a variety of unique grass and herb species) to lower elevation fields, meadows, pastures, and clear-cuts resulting from agriculture or forestry activities. Montane 'old fields' are open grassy areas that have occasionally been invaded by bald species but generally are either in agricultural use or have been abandoned to forest. Human influences, herbivore grazing, and environmental factors such as topographic position, climate, and natural fires have all played a role in the creation and maintenance of montane early successional areas.

All have been modified by human activity and all are subject to natural succession once controlling mechanisms, such as grazing or cutting, have been eliminated. Without the return of the management factors, natural succession will limit the longevity of these habitats and their dependent plant and animal species. Though many montane early successional habitat types support species uniquely dependent on them, other types provide little benefit to plant and animal species, especially those patches of small size, and thus could only be considered marginal wildlife habitat at best. These kinds of places generally reflect human use and activity as the primary goals of their management and include a number of places such as large lawns, monoculture hayfields, golf courses, residential development, and even urban development.

In the Piedmont, Sandhills, and Coastal Plain ecoregions, early successional habitats are often found associated with agricultural or forestry activities and can contain a diverse assemblage of plants, with Piedmont prairies being a notable example of this (Davis et al. 2002). Historically, the Piedmont contained some prairie-type habitats (Barden 1997) with high plant, and presumably insect, diversity that were maintained through fire and herbivore grazing. Today, remnant tracts of prairie are found primarily along powerline rights-of-way and sites managed specifically for prairie restoration and maintenance. Successional wetland communities associated with beaver pond complexes are adapted to frequent disturbances and are likely to be among the most resilient and adaptable to the effects of climate change. By storing water during times of drought and mitigating the effects of flooding, they are also likely to enhance the survival of species found in adjoining habitats as well.

There are excellent opportunities for quality early successional habitat of large patch sizes for wildlife on industrial forestland in the Coastal Plain. Intensively managed habitats such as large lawns, golf courses, high production agricultural fields, monoculture hayfields, and intensively managed commercial timber stands often have low species and structural diversity that will have limited habitat value for wildlife.

4.4.18.2 Location of Habitat

This habitat type can be transient and is difficult to map but it occurs statewide. Powerline easements and other utility corridors are most likely to be perpetually maintained as successional habitat. Other examples are often found at the transition between agricultural fields and nearby woodlands, created by disturbances like clearcutting, disking, or burning.

4.4.18.3 Problems Affecting Habitats

Climate Change. Increased temperature is likely to have a strong effect on the composition of the plant communities in this group. These changes are also likely to affect host-plant specialist insects, but impacts to other animals are difficult to predict. Increased frequency of severe droughts is likely to have a strong effect on the composition of the plant communities in this group. These changes are also likely to affect host-plant specialist insects but impacts to other animals are difficult to predict. With milder winters and warmer average temperatures, Nutria populations could expand their range and become more invasive.

Beaver ponds can be a nuisance to landowners when they flood farm fields or commercial timber. Their activities cause damage to trees and property, which often results in the destruction of beaver dams. Several techniques have been developed to minimize beaver damage while maintaining some benefit from impounded waters. If allowed to continue their expansion, ecosystems in this group are likely to gain resilience and adaptability in the face of climate change. Wetlands associated with beaver-pond complexes are among the best buffered against the effects of drought. However, prolonged droughts may cause significant local extirpation and hydrologic instability, with increased frequency of severe flooding as well as severe droughts likely to lead to degradation of these habitats.

Invasive Species. Successional communities are currently among the most heavily infested with exotic invasive species. With increases in overall temperature, more invasions are likely, especially from tropical and sub-tropical regions. Integrated pest management practices should be preferred over more indiscriminate application of pesticides. The effects of exotic plants, insects, and animals on early succession habitat and native wildlife populations are poorly understood. Impacts are likely to vary widely depending on the species involved, environmental conditions, and management activities.

Fire Ants are a species of particular concern, especially regarding their potential impact on herpetofauna, small mammals, and ground nesting birds. While invasive species should be treated aggressively with eradication as the goal wherever an exotic is just beginning to be established, control measures should always be carefully targeted, including the use of species-specific biological control agents.

Development. Construction of new infrastructure to support development or to move facilities inland in response to sea level rise can lead to destruction of successional wetlands, especially smaller isolated patches. The hydrologic connectivity of larger wetlands may be affected when crossed by roads or underground utilities. Roads can cause heavy mortality for reptiles and amphibians and can effectively isolate breeding populations, or separate wetland habitats from upland habitats that are used during non-breeding portions of amphibian and reptile life cycles.

Land Use. Routine land disturbance by agricultural operations provides the best opportunities for early succession habitat creation and maintenance in North Carolina. However, the value of modern farmland for early succession wildlife has been reduced as economic pressures, improvements in equipment and herbicides, and social factors have all led to larger, more uniformly shaped row crop fields, as well as “cleaner” fields with fewer weeds in the fields and less weedy edge. Few row crop fields are managed to include a fallow rotation. Some beneficial practices, such as no-till planting, have had mixed success in being adopted. In pastureland, the extensive use of exotic cool-season grasses has reduced habitat quality for wildlife. Cutting hay in mid-summer and overgrazing can adversely affect nesting grassland birds.

Clear-cutting timber creates early succession habitat for a short period of time until newly planted timber matures and the understory grass, forb, and shrub layers are shaded out, typically 7 to 15 years after replanting. Economic pressures, improvements in timber production practices (e.g., equipment, herbicides, genetically improved trees) have reduced the amount of time to canopy closure, contributing to loss of early succession habitat. Intensive site preparation can reduce the quality and quantity of herbaceous cover during the early phases of stand establishment.

Fallow or un-mowed areas are seen by many as “messy” and “weedy,” and an indicator of a lack of caring or effort by a landowner. This widespread public perception is partially responsible for fallow habitats being reduced in habitat quality or eliminated. Early succession cover in powerline rights-of-way and roadsides is often adversely affected by too frequent or poorly timed mowing. In addition, many areas of fallow ground near houses or businesses are frequently mowed to maintain a neat appearance, while opportunities exist to convert some of these areas to suitable wildlife cover.

Piedmont prairies contain highly diverse and specialized plant and insect communities. Currently, only small remnant tracts remain. Fire and/or low intensity agricultural operations are necessary to maintain prairie communities. Current restoration efforts are focused on plant conservation and have been implemented on small acreages that have limited value for area-sensitive grassland species such as Grasshopper Sparrow and Eastern Meadowlark. Grasslands larger than 20 acres should be pursued to benefit these species.

Wildfire. Suppression of wildfires and lack of controlled burning eliminates an important source of early succession habitat creation and maintenance within many forested habitats. Concerns about uncontrolled fire, liability, air quality, social acceptance, and smoke management, and lack of landowners with the experience and equipment to conduct controlled burns have limited the use of fire on private lands.

4.4.18.4 Climate Change Compared to Other Threats

Comparing climate change to other ecosystem threats can help define short- and long-term conservation actions and recommendations. The effect of a changed climate is likely to vary widely among examples and many may change very little, while others will change substantially because of human reaction to the impacts of climate change such as temperature changes or drought.

Loss of habitat and fragmentation of landscapes are the most significant threats to this ecosystem group. While development of yet more intensive agricultural and silvicultural practices, and loss of still more areas to development, would continue even in the absence of climate change, these impacts are likely to be exacerbated both directly and indirectly by the effects of climate change. Climate change will contribute to the loss of the large blocks of habitat or fragmentation that creates barriers between blocks that are critical for the survival of species in this group. Development of habitat has become the limiting factor for priority species utilizing this habitat. Across the state, increased exploitation of wild or semi-wild lands for energy production is likely to be the most important indirect effect of climate change on this group. Table 4.4.18-1 summarizes the comparison of climate change with other existing threats.

Table 4.4.18.1 Comparison of climate change with other threats to successional communities

Threat	Rank Order	Comments
Conversion to agriculture/ silviculture	1	The greatest threat to this habitat group is habitat loss due to development of more intensive agricultural and silvicultural practices. Modern, industrialized farming leaves fewer unutilized areas in and adjoining fields, such as hedgerows, groves of shade trees, and weedy forest-field ecotones. Fewer fields are left fallow for very long. Pastures and hayfields are more intensively managed, using heavier applications of herbicides, pesticides, and fertilizers. Mowing of hayfields is also now conducted much more frequently than it has been in the past.
Fragmentation	1	More pressure will be placed on the utilization of marginal agricultural or silvicultural lands for energy production, including the development of otherwise "green" sources such as biomass, wind, and solar energy. Increased frequency and severity of

Table 4.4.18.1 Comparison of climate change with other threats to successional communities

Threat	Rank Order	Comments
		environmental perturbations may disproportionately affect ecosystems composed primarily of annuals or r-strategist species in general, particularly if landscapes continue to become more and more fragmented.
Pollution	2	Communities may be in close proximity to areas that are commonly quite polluted. Farm fields and pine plantations are regularly sprayed with biocides or fertilizers; powerline rights-of-way are now routinely sprayed with herbicides to keep them open; roadside rights-of-way are subject to pollutant laden runoff from the road surfaces as well as application of salt and other chemicals used to prevent icing in the winter; ruderal areas located near industrial areas are subject to both air- and waterborne pollutants emanating from the industrial plants. All of these pollutants can play a major role determining species viability within the semi-natural habitats used by this group.
Invasive Species	2	Two species that are likely to spread into new areas, particularly at higher elevations due to increased temperatures, are Kudzu and Fire Ants. Both of these exotic species have strong impacts on early successional and other ruderal habitats. Along with changes in agricultural practices, loss of some habitat patches or connections between them may be attributable to the smothering invasion of kudzu.
Climate Change	3	Impacts from land use changes are likely to accelerate at least indirectly due to climate change, with more demand for biofuels or other forms of energy production utilizing “waste grounds.” Like other native ecosystems, early successional habitats are also likely to be affected by increased temperatures, prolonged droughts, more frequent fires and storms, and especially invasion of exotic species.

4.4.18.5 Impacts to Wildlife

Appendix 3 provides a list of SGCN and other priority species for which there are knowledge gaps or management concerns Appendices 3-17 (wildlife) and 3-19 (plants) identify SGCN that depend on or are associated with this habitat type.

Upland Communities. The quantity of early successional habitat is generally not lacking but the quality is often questionable for most species of wildlife. Species found in successional communities occur widely throughout the state, although there are also some regional variations (e.g., Henslow's Sparrows are restricted to the Coastal Plain and Vesper Sparrows breed only in the Mountains). Changes in plant species composition may also have strong impacts on the composition of insect species, since many have narrow host plant preferences. The vertebrate fauna may show far fewer effects, however, since most, if not all, do not depend on a particular composition of plant species.

Two species associated with early successional habitats, Bewick's Wren and Regal Fritillary, are believed extirpated from North Carolina. Several other species are declining, with Eastern Henslow's Sparrows, Golden-winged Warblers, Appalachian Cottontails, and Grizzled Skippers listed as Federal Species of Concern, and a number of additional rare species tracked by NCNHP. Many of the species associated with this community type that are of conservation concern are primarily northern species and are likely to be significantly affected by the effects of climate change.

Species in this habitat group are completely dependent on their ability to disperse from one habitat patch to another: their habitats themselves are normally very transient and the species associated with them need to keep constantly on the move to keep up with their shifting landscape. Although many of the species associated with successional habitats are quite mobile, small mammals, reptiles, and at least some birds and insects are less mobile and highly vulnerable to the effects of habitat fragmentation. At least some of the declines noted in this group of species is likely due to decreased connectivity between habitat patches, in addition to the decreased extent of these habitats overall.

Disturbed and artificially created/maintained habitats are particularly susceptible to invasion by exotic species, which in some cases can have significant impacts on the native species associated with early successional habitats. While most compositional changes are likely to have mixed effects, invasion by some exotic species can produce severe impacts, greatly reducing the diversity of both animal and plant communities. The Appalachian Bewick's Wren may have been extirpated from North Carolina due to competition with exotic house sparrows and European Starlings, along with brood parasitism by Brownheaded Cowbirds, an invasive species in this area that arrived from the Great Plains (Potter et al. 2006).

Wetland Communities. With stable beaver populations, Beaver ponds can be maintained for decades. Beaver ponds are a natural community, but result from modification of other community types. With or without climate change, Beaver pond ecosystems are likely to further spread across the state, recreating habitat conditions that existed prior to the great loss of Beavers and their associated species that began with European settlement of North America. This spread will likely have a positive effect on successional wetland inhabitants. The main limiting factor for this reoccupation is human tolerance for Beaver activities and competition with humans for use of bottomlands. A reduction in the number of Beaver ponds will place more importance on man-made ponds as the primary habitat for many lentic aquatic species.

Changes in insect species composition, especially among herbivorous groups, are likely to occur due to changes in plant composition as well as the direct effects of climate change on the insects themselves. Eight very rare species associated with this habitat group are entirely confined to these habitats in North Carolina, including the federally endangered Saint Francis' Satyr. Vertebrate composition is less likely to change if habitat structure remains fairly constant.

While often small in size, cumulatively successional wetland habitats provide critical breeding habitat for many species. Wetland habitats are especially important as breeding sites for amphibian species. Small wetlands can also be important breeding habitat for crayfishes. Wading birds, waterfowl, and songbirds may also use small wetland communities for nesting and feeding areas. Dead trees in beaver ponds are important foraging and nesting habitat for woodpeckers, such as the Red-headed Woodpecker, and for Wood Duck nesting.

Freshwater wetlands near coastal communities provide an important source of fresh drinking water for wildlife, which will become more important in areas subject to saltwater intrusion. Depending on geographic siting in the landscape, successional wetlands may also provide connectivity between adjacent upland habitats.

Nutria are considered a serious pest species in the US because they eat a variety of wetland and agricultural plants and their burrowing damages streambank, impoundments, and drainage systems. As warming trends increase, the range of Nutria, a nonnative and often invasive mammal, is likely to expand and populations currently limited by intolerance to cold winters will quickly expand.

4.4.18.6 Recommendations

Loss of habitat and fragmentation of landscapes are the most significant threats to this ecosystem group. Protection of agricultural reserves that maintain traditional farming practices offers the best hope for protecting areas still supporting high-quality examples of this habitat group, including populations of its rarer species. Support for traditional or environmentally sustainable agricultural and silvicultural methods will help maintain this ecosystem group. Maintaining habitat connectivity across the landscape is also critical, both to maintain the resilience of these ecosystems in face of environmental perturbation and to allow shifts in range and species composition to take place.

Surveys

Distributional and status surveys need to focus on species believed to be declining or mainly dependent on at-risk or sensitive natural communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Conduct surveys for species associated with successional habitats, including species for which current distribution information is already available or for species that are considered common.		
Blue Grosbeak	Eastern Meadowlark	Eastern Cottontail
• Continue surveys for all amphibian species associated with small wetland communities.		
Dwarf Salamander	Four-toed Salamander	Mole Salamander
Eastern Tiger Salamander		
• Gather better information about the status and distribution of more common species associated with Piedmont wetland habitats.		
Eastern Ribbon Snake	Three-lined Salamander	

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Develop long-term monitoring strategies to document population trends, from which conservation strategies can be specifically designed to target those species.
• Expand and/or target monitoring systems to assess current population status and trend information for all wildlife species associated with this habitat.
• Monitor amphibian populations to detect incidence of fungal and viral infections (e.g., iridoviruses, chytridiomycosis).

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Investigate Nutria population densities, population growth rates, dispersal range, and extent of property damage from burrowing and herbivory.

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Research and identify important wildlife crossing areas; evaluate connectivity issues between intact and fragmented habitats used by priority species; work with partners to improve crossing and connectivity.

- Research and identify important wildlife crossing areas; evaluate connectivity issues between intact and fragmented habitats used by priority species; work with partners to improve crossing and connectivity.

- Focus habitat use studies on bats and small mammals to clarify how small mammals and bats use ,early succession habitats.

- Study the efficacy and practicality of toad tunnels and other wildlife crossings that allow passage under roadways and help maintain connectivity between wetland metapopulations.

- Determine minimum upland buffers required to sustain at-risk amphibian populations.

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Maintain and restore connections between habitat blocks, not only to allow adjustments in range in response to climate change, but to maintain genetic connectivity, population resilience, and adaptability more generally.
• Develop transportation facilities that utilize longer bridges at streams and wetlands to minimize impacts (and thereby reduce mitigation requirements) and provide crossing options for wildlife that often travel riparian corridors. Wildlife underpasses should be constructed for all new highway projects, as these reduce wildlife–vehicle collisions, conserve important travel corridors, and provide linkages for bear populations and many other wildlife species.
• Limit the development of roads or other infrastructure within large unfragmented blocks, as this would promote the development of denser human settlement or create connectivity barriers through fragmentation.
• Work cooperatively with other agencies to define sustainable forestry criteria for biomass production.
• Allow beaver pond complexes to develop in natural areas where direct impacts to rare species are not at issue.
• Work with partners to develop property tax incentives to mitigate damages suffered by landowners.
• Explore strategies to promote techniques for managing beaver damage that minimize the loss of quantity and quality of beaver ponds.
• Explore management strategies to eradicate undesirable species, such as bullfrogs, from wetlands.
• Maintain sufficient surrounding habitat for seasonal wetlands in order to support the life history requirements of amphibian and reptile populations. Every effort should be made to

Priority Conservation Action, Examples of Focal Species or Focal Habitats
maintain continuous gradients between wetland and upland sites; roads, agriculture, or forestry operations between complimentary sites may render them ineffective at supporting amphibian and reptile populations (Bailey et al. 2004).

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Protect existing large blocks of habitat and restore connections between these blocks, as this will not only benefit the species in this group, but will enhance the viability of the state's native biodiversity overall.
• Protect smaller tracts that are situated between blocks so they can function as a corridor between conservation sites.
• In the Coastal Plain, give a high priority to protecting movement corridors that allow inland migration away from inundating areas along the sounds and seacoast.
• Over the state as a whole, give a high priority to restoring connections that are lost due to construction of four-lane highways and other roads that create near-impassible barriers for all animals except those capable of flight.
• Preserve riparian buffers and floodplains, especially where clearcutting near wetlands causes higher solar radiation and an increase in probability of wetlands drying out.
• Place a high priority on protecting wetlands and adjacent uplands through acquisition or easement.

4.4.19 Sparsely Settled Mixed Habitats

4.4.19.1 Ecosystem Description

This community type represents large tracts of open land that have not been developed and may have only periodic encroachment from human activities. It may contain a mixture of community types, where vegetation may be natural or a mixture of planted and natural species. Their lack of habitat specificity makes it difficult to assign these communities to any one ecosystem group, all of which represent distinguishable habitat categories. These landscapes often serve as movement corridors for wide-ranging animal species, particularly carnivores near the top of the food web. These species often use a wide variety of habitat types in their pursuit of food, mates, and other resources.

4.4.19.2 Location of Habitat

Sparsely settled mixed habitats occur statewide but are more characteristic of the lower Coastal Plain and the Mountains, particularly in areas which have relatively low human populations. Within the lower Coastal Plain, the largest blocks are on the Albemarle-Pamlico Peninsula, and in the Mountains within national forests.

4.4.19.3 Problems Affecting Habitats

Development and inundation can be expected to reduce availability of large blocks of undisturbed or unfragmented habitat. This trend will continue so long as the human population continues to grow and new ways are found to exploit even the most marginal of lands for human uses.

Sea level rise is likely to affect large areas of the easternmost (outer) Coastal Plain where many important wildlife refuges are located. Inundation of wildlife refuges will result in dispersal inland to Piedmont areas. Movement inland can be expected, but there are far fewer potential refuge areas in the inner Coastal Plain and Piedmont to support viable populations of large predators or venomous snakes than there currently are in portions of the outer Coastal Plain. Movement corridors that allow inland migration away from inundating areas along the sounds and seacoast are critical.

Increased temperatures are likely to have only a minimal effect on this group overall, although a northward shift in range can be expected for the Least Weasel, a primarily boreal species, perhaps leading to its extirpation from the Mountains of North Carolina.

4.4.19.4 Climate Change Compared to Other Threats

Climate change will contribute to the loss of the large blocks of habitat or fragmentation that creates barriers between blocks that are critical for the survival of species in this group. Development of habitat has become the limiting factor for priority species utilizing this habitat.

Across the state more generally, increased exploitation of wild or semi-wild lands for energy production is likely to be the most important indirect effect of climate change on this group. Table 4.4.19-1 summarizes the comparison of climate change with other existing threats.

Table 4.4.19-1 Comparison of climate change with other threats to sparsely settled mixed habitats

Threat	Rank Order	Comments
Development	1	Development activities such as residential subdivisions, road construction, and retail development have displaced and will continue to displace wildlife and place them in closer contact with humans. Reduction and fragmentation of large areas of open space will continue to accompany the expansion of the human population; climate change is likely to exacerbate these ongoing impacts. Construction of highways and access roads, increases in traffic, and other effects associated with infrastructural or industrial development needed to support new forms of energy extraction will create impacts.
Persecution	1	Direct persecution remains the largest limiting factor on abundance and range of species in this habitat.
Climate Change	2	The most important direct impact of climate change is likely to be the loss of a large number of coastal refuges due to sea level rise.
Land Use Changes	2	Plans to use grasses like switchgrass and Miscanthus as biofuels may result in these marginal areas being put into short rotation production as the demand for alternative fuels increases. There is evidence that some species, such as Black Bears, are negatively impacted by wind turbine farms due to loss of mast-producing forests (Loder 2008).

4.4.19.5 Impacts to Wildlife

Predatory species utilizing this habitat play an important ecological role in all the ecosystems they occupy by regulating the abundance of species lower down in the food chain, particularly herbivorous mammals. Many of these high-level predators are generalists that have declined in both abundance and range due to conflicts with humans, with the majority now considered to be of conservation concern. Although all of the species included within this guild are highly adaptable and make use of a wide range of habitat types, the majority are considered rare or threatened in North Carolina. These include the Red Wolf, Least Weasel, Eastern Diamondback Rattlesnake, Timber Rattlesnake, and Pigmy Rattlesnake.

Others, like the Black Bear and White-tailed Deer, are currently expanding their range across the state and are currently not considered to be of conservation concern. The status of the Longtailed Weasel is unknown and based on harvest trends, may be declining. Bobcats are common and their populations appear to be stable.

Sea level rise may lead to inundation of large parts of the Coastal Plain, including the Albemarle-Pamlico Peninsula where large reserves have been set aside for Red Wolves, Black Bears, and other wildlife. It is likely several large wildlife refuges clustered around the sounds will be inundated, including Alligator River, Pocosin Lakes, Lake Mattumuskeet, Swanquarter, Cedar Island, and Mackay's Island National Wildlife Refuges, and the North River, Gull Rock, and Goose Creek Game Lands. Loss or even moderate reduction of these refuges is likely to strongly affect the survival of the pack of red wolves that has been restored on Albemarle-Pamlico Peninsula, as well as the largest population of Black Bears along the North Carolina coast.

While some movement inland can be expected, there are far fewer potential refuge areas in the Inner Coastal Plain and Piedmont to support viable populations of large predators or venomous snakes than there currently are in portions of the Outer Coastal Plain. Drought and wildfire may cause animals to range further away from more protected areas as they search for food, water, and cover. This can bring them into conflict with people and roads with high-volume traffic that are common conditions in the Piedmont. Residents in the central Piedmont have expressed safety concerns when Black Bears are sighted, and bears have been killed when attempting to cross busy roads and highways, or directly by local law enforcement officials that are not knowledgeable of normal bear behavior.

Black Bears are tied to forested areas, and in the southeastern US forest distribution matches the distribution of bears very closely. In many parts of the region, bears are dependent on oak trees for their energy-rich acorns and on a diversity of soft mast species (e.g., blueberries, blackberries). Where oaks are not the dominant species, diversity in forest types and ages can provide mast-producing hardwoods and shrubs. Bears are opportunistic omnivores, but low food supplies and an increase in fragmented habitat may result in increased bear movement into developed areas and leading to human-caused mortalities (e.g., vehicle, depredation).

Increased temperatures may cause some latitudinal shifts in the ranges occupied by members of this group, but the effects are likely to be mixed. Least Weasels are probably the only species likely to shift its range as a consequence of increased warming. In the Mountains, they may retreat toward the north, becoming less common or even potentially extirpated from the state. In the Coastal Plain, Eastern Diamond-backed Rattlesnakes are currently at the very northern edge of their range and very rare in the state. With warming temperatures there is the potential they will increase in abundance. However, that potential could very well be offset by increased development and fragmentation, as well as persecution.

4.4.19.6 Recommendations

Conflicts with humans have resulted in the restriction of these species to large blocks of mixed habitat where human density and intrusion are minimal. Even Black Bears, which in some areas have adapted to human presence as garbage raiders, are highly unlikely to persist without these large, sparsely settled blocks of habitat. These species require large blocks of habitat where density of human settlement or intensity of human intrusion is relatively low. More than any other, this group requires landscape-level conservation, particularly the protection of large areas of habitat—natural or mixed—from increased density of human settlement.

Surveys

Distributional and status surveys need to focus on species that utilize this community.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Conduct surveys for species for which current distribution information is already available or for species that are considered common or invasive.

  Coyote | Gray Fox | Raccoon

- Develop long-term monitoring strategies to document population trends, from which conservation strategies can be specifically designed to target those species.

  Coyote

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. These efforts will inform future decisions on how to manage species and their habitats. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Develop long-term monitoring strategies to document population trends, from which conservation strategies can be specifically designed to target those species.

- Expand and/or target monitoring systems to assess current population status and trend information for all wildlife species associated with this habitat.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Research and identify important wildlife crossing areas; evaluate connectivity issues between intact and fragmented habitats used by priority species; work with partners to improve crossing and connectivity.

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Maintain and restore connections between habitat blocks, not only to allow adjustments in range in response to climate change, but to maintain genetic connectivity, population resilience and adaptability more generally.

- Transportation facilities that utilize longer bridges at streams and wetlands not only minimize impacts (and thereby reduce mitigation requirements) but also provide crossing options for wildlife that often travel riparian corridors. Wildlife underpasses should be constructed for all new highway projects, as these reduce wildlife-vehicle collisions, conserve important travel corridors, and provide linkages for bear populations and many other wildlife species.

- Limit the development of roads or other infrastructure within large unfragmented blocks, as this would promote the development of denser human settlement or create connectivity barriers through fragmentation.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Work cooperatively with other agencies to define sustainable forestry criteria for biomass production.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships utilized to the fullest extent in order to high-quality resources. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Protect existing large blocks of habitat and restore connections between these blocks in order to benefit the species in this group and to enhance the viability of the state's native biodiversity overall.
• Protect smaller tracts that are situated between blocks so they can function as a corridor between conservation sites.
• In the Coastal Plain, give a high priority to protecting movement corridors that allow inland migration away from inundating areas along the sounds and seacoast.
• Over the state as a whole, give a high priority to restoring connections that are lost due to construction of four-lane highways and other roads that create near-impassible barriers for all animals except those capable of flight.

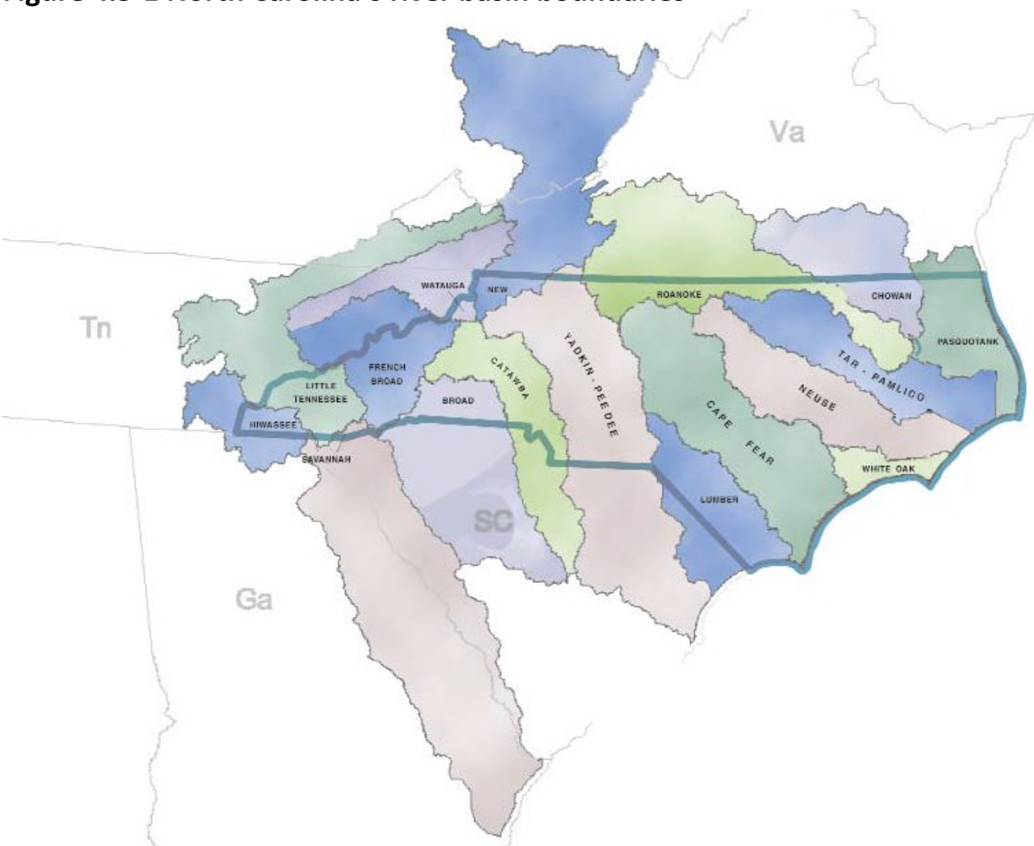
4.5 River Basins

4.5.1 Introduction

In an assessment of southeastern states, North Carolina ranked third highest in overall diversity of stream types (Warren et al. 1997).The richness of North Carolina's aquatic fauna is directly related to the geomorphology of the state, which defines the major drainage divisions and the diversity of habitats within them. Watersheds of large rivers are commonly referred to as basins (Griffith et al. 1999) and North Carolina uses the basin concept as a spatial framework for assessment and management of drainage systems across the state.

Figure 4.5-1 provides a map depicting the boundaries of the 17 major river basins in North Carolina as designated by the NC Department of Environment and Natural Resources (NCDENR). While 11 of the river basins have headwaters that begin in North Carolina, only four basins are contained entirely within the state (Cape Fear, Neuse, Tar-Pamlico, White Oak). The other river basins have waters that drain across adjacent states (Georgia, South Carolina, Tennessee, and Virginia). Information about the river basins is available online at the NCDENR Division of Water Resources Basin Planning Branch web page http://portal.ncdenr.org/web/wq/ps/bpu.

Figure 4.5-1 North Carolina's river basin boundaries



Five western basins in the state are part of the Interior Basin and drain to the Mississippi River and the Gulf of Mexico (Hiwassee, Little Tennessee, French Broad, Watauga, and New). North Carolina boundaries for these five river basins, along with the Savannah River Basin, have boundaries entirely within the Mountain ecoregion, which dominates the western third of the state. Generally, streams in the Mountain ecoregion are relatively high gradient with cool waters, have boulder and cobble-gravel bottoms, and are of low to moderate fertility. Larger streams and rivers have historically supported exceptionally diverse warmwater communities.

The other 12 basins of the state are part of the Atlantic Slope and flow to the Atlantic Ocean. The headwaters of the Broad, Catawba, and Yadkin - Pee Dee River Basins drain the eastern slopes of the Mountains. These river systems drain toward the ocean through the rolling topography of the Piedmont, where all but three of the remaining river basins originate. The Piedmont is a mosaic of broad valleys interspersed with highlands of varying topography and geology. Streams in the Piedmont are generally warmwater systems, have cobble-gravel and sand bottoms, and are of intermediate gradient and fertility.

The Fall Line marks a change in topography from the Piedmont to the flat terrain of the Coastal Plain. The North Carolina basins of the White Oak, Chowan, and Pasquotank rivers are entirely within the Coastal Plain ecoregion and are characterized by low gradient warmwater streams with sand and mud bottoms and high fertility. Natural lakes and extensive wetlands are important aquatic habitats found only in North Carolina's Coastal Plain ecoregion.

A method developed by the US Geological Survey (USGS) spatially organizes drainage areas (DAs) by dividing watersheds into successively smaller hydrologic units based on four levels: regions, subregions, accounting units, and cataloging units (Seaber et al. 1987). The hydrologic units are arranged or nested within each other, from the largest geographic area (regions) to the smallest geographic area (cataloging units). Regional hydrologic units are identified by a unique two-digit hydrologic unit code (HUC) but smaller units may represent the most useful planning unit. The HUCs and associated maps have undergone extensive review by principle federal, regional, and state water-resource agencies and are widely accepted for use in planning and data sharing (Seaber et al. 1987). In North Carolina, 12-digit HUCs are commonly used for sharing aquatic resource data.

Surface water classifications are another tool used in North Carolina to manage and protect state waters. The NC Division of Water Resources (NCDWR) assigns primary classifications to freshwaters to designate the highest and best uses (e.g., drinking water supplies, recreation) for conservation within the surface waters. Each classification has an associated set of water quality standards to protect those uses. All waters must at least meet the standards for Class C (fishable/swimmable) waters. The other primary classifications provide additional levels of protection for water contact recreation (Class B) and drinking water (Water Supply Classes I through V). Streams, rivers, and lakes may have several classifications applied to the same area because they protect different uses or special characteristics of the waterbody (NCDWR 2014c).

Water classification data are available from the National Hydrography Dataset (NHD), a database that interconnects and uniquely identifies the millions of stream segments or reaches that comprise the surface water drainage systems in the United States. The NHD provides a national framework that allows information to be linked by stream reach address to an organization thereby allowing water quality data to be shared with other organizations, analyzed using a Geographic Information System (GIS), and easily integrated into many different types of applications to the benefit of all (USEPA 2014b). Datasets containing water classification information is available online from http://www.horizon-systems.com/nhdplus/NHDPlusV2_data.php.

4.5.2 Aquatic Biodiversity and Imperilment

The southeast region has the highest aquatic species diversity in the entire United States (Burr and Mayden 1992;; Taylor et al. 1996;; Warren et al. 2000;; Williams et al. 1993). Southeastern fishes make up two-thirds of US fauna, and nearly half of the North American fish fauna (Burr and Mayden 1992). Molluscan diversity in the region is globally unparalleled, with 91% of all US mussel species found in the southeast (Neves et al. 1997). Crayfish diversity and global importance in the region rivals that of mollusks (Taylor et al. 1996), and crayfish in the southeast comprise 95% of the total species found in all of North America (Butler 2002a). North Carolina freshwaters support a significant proportion of that diversity with at least 210 freshwater fish, 125 mollusk, and 45 crayfish species native to the state.

Unfortunately, patterns of imperilment for aquatic species are similar amongst taxonomic groups. Collen et al. (2014) reports almost one in three freshwater species is threatened with extinction worldwide which, in comparison, is proportionally greater than the risk of extinction for terrestrial species (Burkhead 2012). More than two-thirds of the nation's freshwater mussel and crayfish species are extinct, imperiled, or vulnerable (Williams et al. 1993, Neves et al. 1997, Master et al. 1998). The majority of these at-risk species are native to the southeast.

- North Carolina ranks third among southeastern states in number and percentage of imperiled fishes (Warren et al. 1997).
- Freshwater mollusks are suffering even greater declines, with numerous mussel and aquatic snail species that formerly occurred in the southeast now presumed extinct (Neves et al. 1997).
- Among crustaceans listed as endangered or threatened in the United States, more than half are from the southeast (Schuster 1997).
- Twelve species of North Carolina crayfish are listed as species of concern or rare in the state, with their small native range the primary factor in their vulnerability to habitat loss and competition (Clamp 1999; Taylor et al. 1996). Threats specific to crayfish include pollution and impoundment, but competition with nonindigenous species is also a primary threat to many species (Taylor et al. 1996).

National and regional causes of declines among all aquatic taxa are widely attributed to habitat destruction and degradation and the introduction of nonnative species (Williams et al. 1993; Taylor et al. 1996; Etnier 1997; Warren et al. 1997; Collen et al. 2014). The medium-sized rivers and creeks that provide important habitat for many aquatic species are frequently impounded and substrates have been altered by erosion and sedimentation. Habitat alteration from nonpoint source pollution and flow alteration (i.e., impoundments) is the primary cause of population declines for a large percentage of southeastern fishes considered imperiled (Etnier 1997; Collen et al. 2014). Not surprisingly, nonpoint source pollution and the effects of dams and impoundments are also the leading historic and current threats to freshwater mollusks (Bogan 1993; Neves et al. 1997; Richter et al. 1997). The complex life cycles and habitat requirements of mussels make them especially vulnerable to these perturbations (Adams 1990; Bogan 1993; Neves et al. 1997).

In North Carolina, threats to biodiversity are similar to those listed above and include point and nonpoint source pollution, hydrologic alteration, physical habitat manipulation, and pollution. In recent decades, water quality has improved in many watersheds that were historically polluted primarily by point source discharges; however, overall habitat degradation continues to threaten the health of aquatic communities. Increased development and urbanization, poorly managed crop and animal agriculture, and mining have impacted aquatic systems with point and nonpoint source inputs. Impoundments on major rivers and tributaries drastically alter the hydrologic regime of many North Carolina waterways and result in habitat fragmentation, blockage of fish migration routes, and physical habitat alterations.

The US Environmental Protection Agency (USEPA) reports that North Carolina contains approximately 37,662 stream/river miles; 311,236 acres of lakes and impoundments; and 3,121 square miles of coastal bays (USEPA 2013a). Information summarized from a USEPA Clean Watershed Needs Survey, NPDES permits, and water quality assessments indicates more than half of the rivers are rated as ‘impaired’ because they are not meeting biological criteria or due to impaired aquatic communities. The USEPA reports more than half of the lakes and reservoirs in the state are impaired due to mercury contamination (USEPA 2013a). The NC Division of Water Resources (NCDWR) has rated all waters in the state as impaired based on a statewide fish consumption advisory issued by the NC Division of Public Health (NCDPH) for mercury contamination (NCDPH 2014).

4.5.3 Aquatic Conservation Priorities, Strategies, and Recommendations

There has been increased attention focused on analysis of aquatic biodiversity, patterns of imperilment, and threats to distill priorities for proactive management and/or conservation triage. A few efforts have gone beyond (or bypassed) identifying specific priorities to propose strategies that address long-term aquatic conservation needs and actions to address these priorities. These efforts were outlined in the 2005 WAP (NCWRC 2005). To the greatest extent possible and where applicable, this guidance, as well as more recent efforts, have been incorporated into this Plan.

The following sections outline aquatic conservation priorities, strategies, and recommendations that are applicable throughout North Carolina. The remaining portions of this chapter describe the 17 river basins, which are organized alphabetically. These descriptions provide a more detailed view of the threats, needs, and conservation priorities within each basin. A complete list of all SGCN species can be found in Appendix 3. Aquatic SGCN species associated with each basin are listed in Appendix 3-18.

4.5.3.1 Aquatic Conservation Priorities

Conservation priorities have been identified for each river basin at the cataloging unit or stream reach scale and were categorized using two tiers to indicate relative importance when considering the limited resources available for conservation initiatives. The recommendations were developed by Commission biologists through review of their field data as well as data from several agencies and research organizations. The review considered a combination of factors such as the presence of federal- or state-listed species; distribution of priority species; high species diversity; unique habitats, or high-quality habitats in the subbasin; and the importance of the watershed to downstream populations.

Priority areas identified in this chapter are represented by 12-digit hydrologic unit code (HUC) watershed boundaries and 1-km riparian corridors and characterized as Tier 1 (highest priority) and Tier 2 (high priority) recommendations for conservation. Figures depicting the locations of priority areas are provided in each river basin description. In addition to recommendations provided for each river basin, the following general recommendations are applicable statewide in all river basins. Appendix J provides a list of all 12-digit HUC priorities statewide; this list is available for download as an Excel file from the NCWRC web page: http://www.ncwildlife.org/plan.

4.5.3.2 Conservation Strategies

Historically, aquatic conservation and management strategies have typically focused on a few commercially or recreationally significant game fish species, with stock enhancement as a primary goal. The passage of the 1973 Endangered Species Act and 1972 Clean Water Act (with amendments) stressed ecosystem protection and allowed for focused attention on all species and their habitats. Ecosystem management is likely the most effective strategy for conserving rare aquatic species because it factors in ecological relationships, land-use patterns, and threats to habitat and water quality. It is a complicated and often costly approach and relies heavily on cooperation among federal and state agencies, local governments, private organizations, and individual citizens. However, its holistic approach can benefit all species within the watershed.

The US Fish and Wildlife Service (USFWS) has led in the development of detailed conservation strategies for mussels in the US (Biggins et al. 1997) and fishes in the southeast (Bibb et al. 2002). Both of these important documents identify specific goals and detailed strategies for achieving them.

Jenkinson and Todd (1997) provided a historical perspective of mollusk management in the United States and propose general strategic guidance for habitat protection, population enhancement, harvest controls, public appreciation, and invasive species control and prevention. Some region-scale strategies have recently been drafted and are identified in the applicable river basin descriptions. Conservation efforts have only recently been focused on crayfish. Taylor et al. (2007) identifies the present state of crayfish management (and crustaceans in general) and the challenges that face developing adequate management plans.

Surface water classifications are one tool that state and federal agencies use to manage and protect streams, rivers, lakes, and other surface waters in North Carolina. Classifications and their associated protection rules may be designed to protect water quality, fish and wildlife, or other special characteristics. Each classification has associated standards that are used to determine if the designated uses are being protected. The NC Division of Water Resources (NCDWR) has assigned some waterbodies in the state supplemental classifications. Some examples include:

- High Quality Waters (HQW) or Outstanding Resource Waters (ORW) designation when they either have excellent water quality or they are a significant resource to humans or wildlife (NCDWQ 2015d). The requirements to be classified as ORWs are more stringent than those for HQWs and in some circumstances, the unique characteristics of the water and resource require that a specialized management strategy be developed (NCDWQ 2011d, NCDWR 2015a, 2015d).

- NCDWR's trout waters (Tr) designation protects freshwaters for natural propagation of trout and survival of stocked trout on a year-round basis. Trout water designations are used only in the Mountain ecoregion.

In addition to the best-use classifications, NCDWR also monitors waters of the state to determine if they are supporting their use classification(s) and assigned use-support ratings. These ratings are published in the most recent 303(d) impaired waterbodies list (USEPA 2014a; NCDWR 2015a).

Another conservation strategy is the listing of species for federal protection under the Endangered Species Act (ESA) and for state protection under North Carolina General Statutes. Chapter 3 Species, Section 3.1.1 provides information about regulatory protections. Table 4.5-1 provides a summary of the listing status designations.

Table 4.5-1 Federal and state listing status abbreviations.

Federal Listing Status	State Listing Status
E – Endangered; a taxon which is in danger of extinction throughout all or a significant portion of its range.	**E – Endangered**; any native or once-native species of wild animal whose continued existence as a viable component of the state's fauna is determined to be in jeopardy or listed as a federal endangered species.
T – Threatened; a taxon which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.	**T – Threatened**; any native or once-native species of wild animal which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range or listed as a federal threatened species.
C - Candidate; taxa for which USFWS has on file enough substantial information on biological vulnerability and threat(s) to support proposals to list them as endangered or threatened.	**SC – Special Concern**; any species of wild animal native or once-native to North Carolina which is determined to require monitoring but which may be taken under regulations adopted under state laws.
At-Risk: species under review and awaiting final listing determinations.	

4.5.3.3 Recommendations

While much progress has been made toward understanding basic distribution of many priority species, especially fishes, information is still lacking on the distribution of some species, and population strength and trend data are rare. These gaps are especially pronounced among mollusks and crustaceans. While considerable knowledge gaps exist for freshwater mussels, they are even greater for snails and pea clams. Likewise, information vital for effective management of crayfish is insufficient and such information for microcrustaceans (e.g., water fleas, seed shrimp, scuds) is practically nonexistent. Performing extensive field surveys and collecting voucher specimens are important steps in developing conservation measures for aquatic species.

Much of the aquatic insect data tracked by the NC Natural Heritage Program (NCNHP) is provided by the Biological Monitoring group of the NC Division of Water Resources (formerly Division of Water Quality). However, there is no clear jurisdiction over most of these taxa, and there is a scarcity of biologists focused on these groups. Knowledge levels and data availability for insects, terrestrial gastropods, and arachnids are the lowest of any animal groups in the state. These taxa are an integral part of the ecosystems they share with other invertebrate and vertebrate species. Opportunities to expand our knowledge and understanding of these groups should be taken when possible, and the establishment of habitat-based projects that are mutually beneficial to these groups and to higher taxa should be a focus.

The following recommendations should be considered appropriate to implement statewide and where appropriate in all river basins.

Surveys

General surveys are needed to complete primary distributional status for SGCN and other priority species.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Complete distribution and status surveys for aquatic snails, crayfish, mussels, fish, and nonnative species.
• Coordinate sampling with other resource management groups.

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to continued impacts to state waters. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. These efforts will inform species and habitat management decisions. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Conduct long-term monitoring to assess performance of specific conservation actions: stream restoration projects; species restoration projects; improvements in flow regions below dams; improvements in best management practices (BMPs).

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Assess nonnative species impacts and monitor populations of potentially injurious nonnative species and their impacts on priority species.
• Establish protocols, schedules, and sites for long-term population monitoring.

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Investigate potential for augmentation or restoration of priority species populations in restored or improved habitats.
• Resolve taxonomic problems and develop species descriptions (if required).
• Review available information and support life history investigations where lacking.
• Support investigations into impacts from habitat fragmentation, especially those due to impoundments or other anthropogenic factors.
• Focus analysis and synthesis of inventory and monitoring data and reporting to inform decision making pertaining to initial species listing and status revision.
• Investigate species vulnerability to impacts from invasive and nonnative species (e.g., Asian Clam) and exposure to chemicals (e.g., endocrine-disrupting compounds) and other pollutants.

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats. In addition, education about, and regulation and prevention of the introduction and spread of exotic or invasive species are vital.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Expand aquatic species restoration efforts through increased capacity for captive culture of priority species.
• Eradicate or control invasive and injurious nonnative species within lentic and lotic systems.
• Support county soil and water conservation measures such as BMP recommendations to address sediment and erosion related to agricultural activities.
• Work through the Federal Energy Regulatory Commission (FERC) relicensing process and other opportunities to mitigate negative impacts from hydropower development and support mitigation and restoration efforts.
• Increase stormwater management, erosion control, and education along with associated inspections of all sites with potential for erosion.
• Evaluate regulatory issues and develop rules that address water quality issues and other threats to priority species and habitats.
• Work through site-specific management plans to protect and conserve waters containing federally listed species.
• Support implementation of low-impact development and better stormwater management through program coordination, cooperative projects, and technical guidance.
• Support clean-up efforts and stricter regulation of Confined Animal Feeding Operations (CAFOs), in addition to promoting best management practices (BMPs) and improvements for animal waste treatment.
• Identify specific priority areas for habitat conservation and restoration. Criteria include areas with high species diversity, rare species, and endemic species; specific areas that are critical

Priority Conservation Action, Examples of Focal Species or Focal Habitats
to the survival of priority species (e.g., particular streams or spawning sites); and areas recognized by previous national and/or regional prioritization efforts.
• Support incentive and information programs that help reduce sedimentation and erosion (e.g., fencing livestock from streams, improve tilling practices), minimize pesticide and herbicide use, modernize wastewater treatment facilities, and so forth.
• Prioritize education other measures to prevent the introduction or spread of invasive nonnative species, particularly crayfishes, Zebra Mussels, and land-locked river herring species (e.g., Blueback Herring, Alewife), as well as nonnative and invasive aquatic and riparian plants.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Support the strategic planning efforts of partner agencies, local governments, and other conservation organizations.
• Support and implement comprehensive land-use planning that reduces secondary or cumulative impacts upon water quality and natural resources.
• Develop and support programs that provide technical guidance and assistance to property owners and businesses on how they can reduce impacts and achieve conservation goals.
• Develop and support education and outreach programs, and distribute materials, deliver presentations, and participate in activities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Prioritize education and other measures to prevent the introduction or spread of invasive nonnative species, including nonnative and invasive aquatic and riparian plants.
• Incorporate aquatic priorities into the NC Division of Mitigation Services (formerly NC Ecosystem Enhancement Program [NCEEP]) Watershed Enhancement Program prioritization process, into game lands management, and into game lands acquisitions.
• Support conservation and restoration of streams and riparian zones in priority areas (acquisition, easements, and buffers).
• Support the development and application of an aquatic nuisance species management plan with other agencies/groups.
• Guide academic research projects to help achieve specific conservation goals and objectives.
• Support water quality rules and watershed designations that conserve habitats for priority aquatic species. Outstanding Resource Water and High-Quality Water designations should be supported wherever the criteria are met, especially in watersheds that support priority species.
• Support local and regional land-use planning efforts to affect water quality and habitat conservation, establish riparian buffers along streams, implement low-impact development, and improve stormwater management (e.g., secondary and cumulative impacts).
• Support and utilize species-listing processes and associated programs to conserve imperiled species and their habitats. When warranted, make recommendations for state listing to the Commission's Nongame Wildlife Advisory Committee.
• Develop and disseminate news and educational print and electronic media. Products could include stand-alone documents, press releases, newspaper and magazine articles, and displays. Improve and maintain existing web resources to provide information about aquatic species, habitats, and conservation priorities.
• Continue to seek opportunities for direct outreach in all river basins.

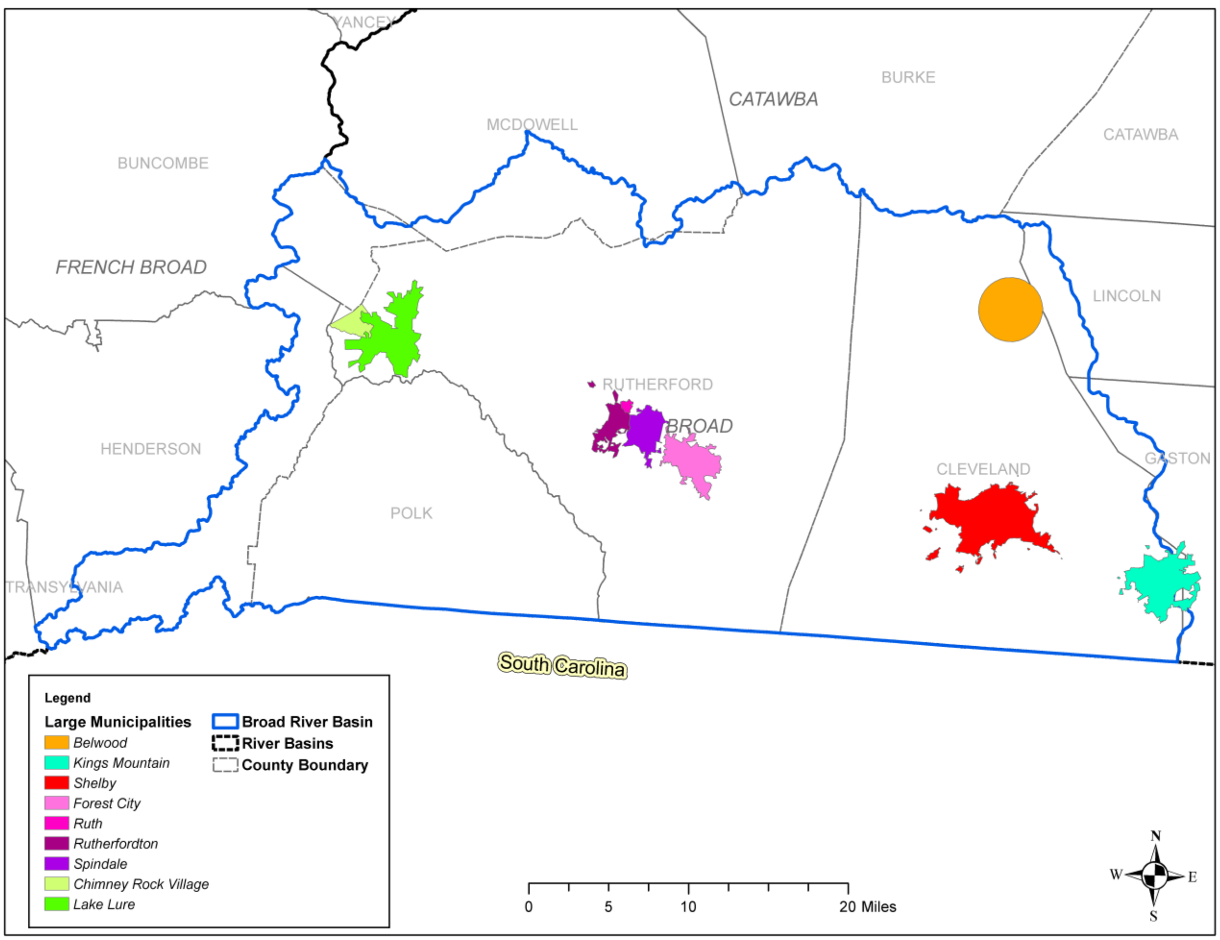
4.5.4 Broad River Basin

4.5.4.1 River Basin Description

The Broad River Basin originates in North Carolina and flows into South Carolina, where it is part of the Edisto-Santee River Basin. The western part of the basin includes headwaters and major tributaries that begin in the Mountain ecoregion and flow southeastward through the foothills to form the Green and Broad Rivers.

The Broad River Basin is located along the boundary with South Carolina and encompasses all or part of 10 counties: Buncombe, Burke, Cleveland, Gaston, Henderson, Lincoln, McDowell, Polk, Rutherford, and Transylvania. Municipalities in the basin range in population size from about 200 to 21,000 people and much of the population can be found around the towns of Spindale, Rutherfordton, Forest City, and the City of Shelby (NCDWQ 2008). Figure 4.5.4-1 depicts the geographic location of the Broad River Basin.

Figure 4.5.4-1 Location of the Broad River Basin



In the central part of the basin, the First Broad and Second Broad Rivers drain from the easternmost part of the Mountains and flow south across the foothills and Piedmont to merge with the lower Broad River before it crosses into South Carolina. The Broad River merges with the Saluda River near Columbia, South Carolina to form the Congaree River, which flows into Lake Marion and eventually into the Atlantic Ocean.

The North Carolina part of the basin covers about 1,513 square miles (28% of the entire watershed) with nearly 3,756 miles of freshwater streams and 3,159 acres of lakes (NCDWR 2015h). Nearly 73% of the land in the basin is covered by forest or shrubland, about 22% is agricultural lands, and 3.5% is urban or developed land (NCGAP 2009).

The Commission manages nearly 36,000 acres of game lands in the Broad River Basin area, including parts of the South Mountains Game Land and Green River Game Land. Crowders Mountain, Chimney Rock State Park, and Hickory Nut Gorge and Hickory Nut Falls are well known state park destinations.

The North Carolina Natural Heritage Program (NCNHP) has identified numerous Significant Natural Heritage Areas, Dedicated Nature Preserves, and Managed Areas in the basin that represent exceptionally rare natural communities and features that have a very high need for conservation. Many of these locations are actively managed for biodiversity through disturbance that mimics natural processes.

Overall, stream gradients in the basin decrease as the topography changes from the Mountains to the foothills and into the rolling landscape of the Piedmont. Soils in the Piedmont generally contain greater proportions of sand and clay and have higher erosion potential than those in the upper portion of the basin. Stream habitats in the lower basin are generally dominated by runs and pools with high proportions of sandy and silty substrates. This geographic and geologic change provides a variety of habitats for both rare and common aquatic species, but the higher erosion potential can result in greater impacts from excess sediment loading from disturbed areas.

4.5.4.2 Aquatic Resource Conditions

Surface waters of the state are assigned a classification that carries standards for protecting the best intended uses of that water. There are more than 1,878 miles of freshwater streams in the basin that have been classified by NCDWR for best uses (NCDWR 2015a). Classification categories include aquatic life, recreation, fish consumption, and water supply. Overall, more than 34% of the monitored streams that have data available support intended uses; however, the lack of data for more than half the basin provides an unclear assessment of overall water quality. It is important to note that all waters in the state are rated as impaired based on a state-wide fish consumption advisory for mercury contamination.

Some waterbodies in the basin have supplemental classifications such as High-Quality Waters (HQW) or Outstanding Resource Waters (ORW) because they either have excellent water quality or they are a significant resource to humans or wildlife (NCDWQ 2014c). The requirements for classification as an ORW are more stringent than those for an HQW and in some circumstances, the unique characteristics of the water and resource require that a specialized management strategy be developed (NCDWQ 2011d; NCDWR 2015a, 2015d).

There is one HQW Special Management Strategy Area in the eastern corner of the basin (Henderson County): Lake Montonia (15 acres) (NCDWR 2015c). This area requires site-specific provisions to protect resource values (e.g., no new discharges or expansion of existing discharges) as described in NC Administrative codes (see 15A NCAC 02B.0225).

There are about 515 miles of streams in the Broad River Basin designated as trout (Tr) waters. This is not the same as the Commission's designated public Mountain Trout Waters, which is used to designate waters that support trout and are open to public fishing.

4.5.4.3 Aquatic Species

Appendix 3 provides lists of aquatic SGCN and other priority species for which there are knowledge gaps or management concerns. Appendix 3-18 identifies aquatic SGCN associated with aquatic communities found in this river basin.

In addition to the crayfish, freshwater fish and mussels, and aquatic snails found in the basin, there are also species that have both aquatic and terrestrial stages to their life history. The following list of SGCN are also associated with the aquatic communities in the Broad River Basin

Common Name	Scientific Name	Federal Status	State Status
AMPHIBIANS			
South Mountain Gray-cheeked Salamander	*Plethodon meridianus*	--	--
Blue Ridge Gray-cheeked Salamander	*Plethodon amplus*	--	--

4.5.4.4 Threats Affecting Aquatic Species

Water Quality. In addition to the best use classifications, NCDWR also monitors state waters to determine if they are supporting their use classification(s) and assign use supporting ratings. Most water quality problems that result in impaired ratings due to failure to meet water quality standards can be attributed to nonpoint source pollution. These ratings are published in the most recent 303(d) impaired waterbodies list; there are 14.6 stream miles and 252 reservoir acres reported as exceeding standards for fecal coliform in the Broad River Basin (NCDEQ.2022).

There are five permitted Confined Animal Feeding Operations (CAFOs) in the basin with eight waste lagoons associated with the facilities. Animal-waste lagoons and sprayfields that discharge nutrients and bacteria contamination near or into aquatic environments through runoff, percolation into groundwater, and volatilization of ammonia and the release of bacterial contamination can significantly degrade water quality and endanger health (Mallin 2003; Mallin and Cahoon 2003; NCDEQ 2024(a)).

Pollution. Water quality problems are attributable to both point and nonpoint sources. Point sources are primarily wastewater treatment plants and industrial discharges. Both municipal wastewater treatment plants and industrial sources discharge colored effluents to streams in the basin, especially in the Second Broad River watershed. The impacts of these effluents at permitted levels are generally regarded as minimal, but effects on native aquatic communities from other solutes in these and other discharges are unclear. Problems with meeting permitted discharge limits have occurred at several wastewater treatment plants in the basin (NCDWQ 2003, 2008).

Sedimentation is the main water quality issue and stream sedimentation is severe across the Piedmont portion of the basin. Standards have been exceeded for turbidity in several stream segments in the basin (NCDWQ 2008). Other sources of nonpoint pollution include lawns, golf courses, and impervious surfaces.

Land Use. Poorly managed pasture lands contribute substantially to overall soil and streambank erosion. Often, riparian vegetation is minimal or nonexistent and cattle have unlimited direct access to streams which contributes to habitat degradation. Overall lack of riparian vegetation is a widespread problem throughout the basin. Major causes of sedimentation in the basin are land clearing activities (e.g., construction, row crop agriculture, timber harvest, and mining), streambank erosion, and runoff from unpaved rural roads and eroding road grades (NCDWQ 2003, 2008).

Water Use. Hydraulic and hydrologic alterations to streams, through accelerated streambank erosion and channel instability, contribute both directly and indirectly to habitat degradation. Streams have been channelized in both rural and developed areas in the basin. Development and urbanization also increase impervious surfaces and often produce drainage patterns and structures that speed the runoff of rainwater and alter hydrograph curves. Property along the Broad River and Lake Lure is being developed for second homes, vacation lodges, and recreational facilities such as golf courses and horse farms. Hydrologic alteration can cause flash flooding which further accelerates streambank erosion and channel degradation.

Impoundments. There are significant impacts to native aquatic communities in the Broad River Basin from impoundments; however, they are not as widespread as in some of the other basins in the Mountain ecoregion (e.g., Hiwassee, Little Tennessee, and Catawba). According to the National Aquatic Barrier Inventory Tool (SARP 2024) there are

Lake Lure, Kings Mountain, and Lake Adger impoundments appear to have the greatest impact on aquatic resources. Impacts include thermal and hydrologic alteration to tailwaters, water quality and quantity issues associated with nonexistent or inadequate flow, direct effects of impoundment, fragmentation of upstream populations, and loss of genetic diversity caused by barriers between populations.

Several existing impoundments are used for water supply and new impoundments are proposed within the basin for the same reason. As human population increases in the region, water supply is an increasing burden on surface waters. Water withdrawals, impoundments, and interbasin water transfers can significantly alter habitats for native aquatic species.

Invasives. Nonnative species in the Broad River Basin include the Rusty Crayfish, Asian Clam, Common Carp, Channel Catfish, Smallmouth Bass, Muskellunge, Rainbow and Brown trout, and Warpaint Shiner. Some reservoirs have landlocked populations of introduced Blueback Herring and Alewife, anadromous species that normally migrate between fresh and coastal waters in areas where they are native. The Saffron Shiner is native to other river basins in the state, but has been introduced and occurs as a nonnative species in the Broad River Basin.

Nonnative vegetation can also negatively impact native aquatic communities. This includes both aquatic and riparian plant species and nonnative plant pathogens that can alter riparian vegetation and affect aquatic habitats (e.g., Hemlock Wooly Adelgid). Presently, specific impacts from nonnative species in the Broad River Basin are unclear and more information is needed to inform appropriate management actions.

4.5.4.5 Basin Specific Recommendations

Conservation priorities that apply statewide to all river basins are presented in Section 4.5.3.3. Priority watersheds identified in the Broad River Basin are shown in Figure 4.5.4-2 (at the end of this section).

Surveys

General surveys are needed to continually update distributional status for SGCN and other priority species. Appendix 3-18 provides a list for all SGCN associated with the Broad River basin.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Fish—survey for priority and state listed species on a routine basis.		
Santee Chub	Snail Bullhead	V-Lip Redhorse
Seagreen Darter	Thicklip Chub	Jumprock species

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Freshwater Mussels – continue to track mussel population health in priority areas such as Green and Broad rivers.		
Creeper	Green River	Broad River
• Crayfishes – continue inventories and update status of priority species.		
Broad River Spiny Crayfish Broad River Stream Crayfish	Carolina Foothills Crayfish	
• Aquatic Snails – inventory primary distribution; determine potential habitats and distribution surveys for all species.		

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to continued impacts to state waters. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities, and invasive species. These efforts will inform species and habitat management decisions. While long-term monitoring sites have been established and baseline data gathered in most areas of the basin for fishes and crayfishes, a comprehensive approach to long-term monitoring is still lacking for mussels. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Fish—monitor priority and state listed species on a routine basis.
• Mussels – monitor priority species in priority areas (Green and Broad rivers; Cove Creek).
• Crayfishes – monitor priority species.

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Resolve taxonomic problems and species descriptions (if required) for mussels in the genus *Elliptio*.
• Resolve taxonomic issues and species descriptions if required for crayfish in the genus *Cambarus*.
• Investigate impacts from habitat fragmentation and invasive species in the basin.
• Investigate aquatic community response to stream restoration projects in priority areas.
• Support research to improve habitat conditions in regulated rivers.

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats. In addition, education about, and regulation and prevention of the introduction and spread of exotic or invasive species are vital. Specific issues in this basin include high rates of erosion and sedimentation, secondary and cumulative impacts upon water quality, riparian vegetation restoration and conservation, water supply watershed protection, and protection of headwaters.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Incorporate management goals for aquatic community conservation and focus on restoration and enhancement of critical habitats and communities for Green River and South Mountain Game Lands.
• Reintroduce extirpated freshwater mussel and fish species in restored or improved habitats as opportunities become available.
• Provide support for land protection, particularly in riparian areas through acquisition or easements.

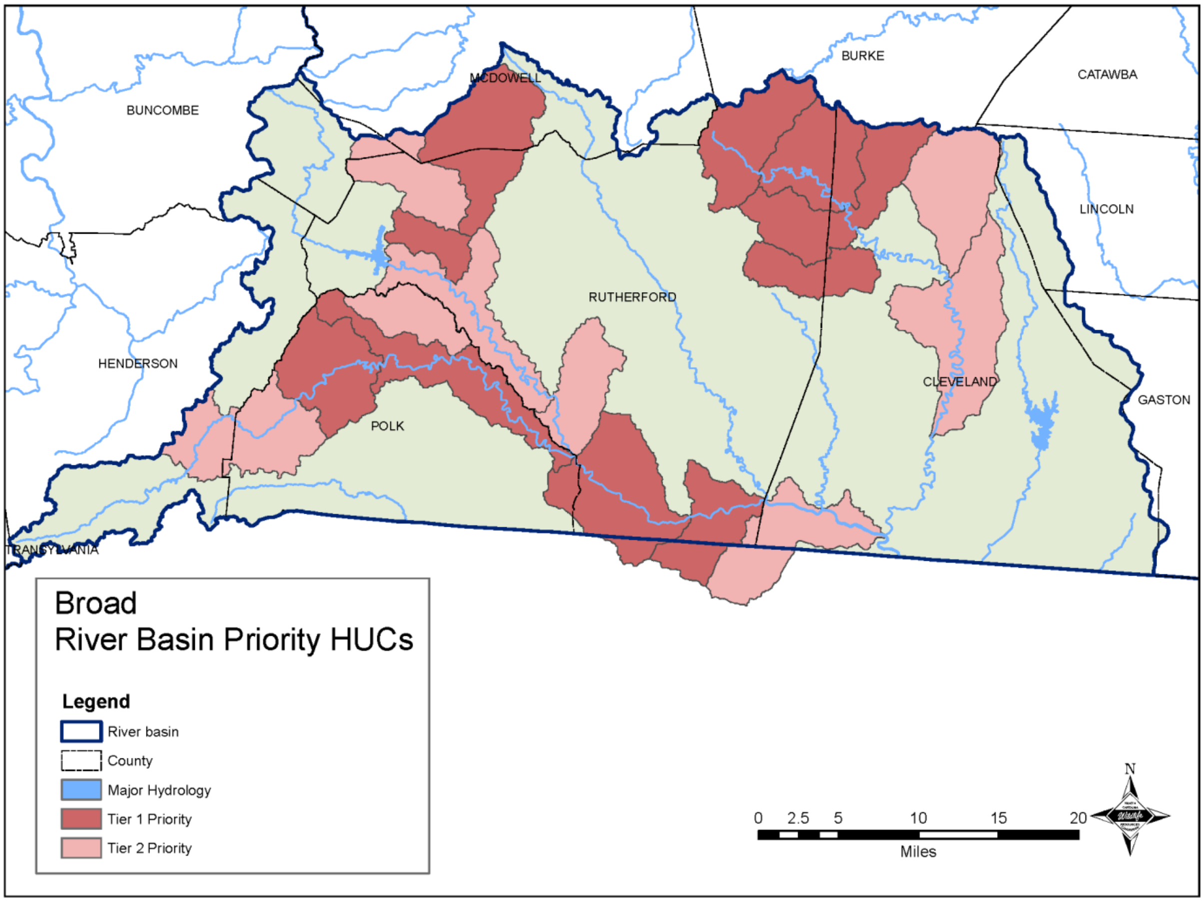
Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Prioritize education and other measures to prevent the introduction or spread of invasive nonnative crayfishes.
• Support measures to remove relict or non-functioning stream barriers where appropriate

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to conserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Support restoration projects and basinwide management initiatives in priority watersheds.
• Maintain partnerships with Foothills Conservancy, Mountain True, and Broad Riverkeeper to conserve and preserve aquatic habitats.

Figure 4.5.4-2 Location of priority watersheds in the Broad River Basin.



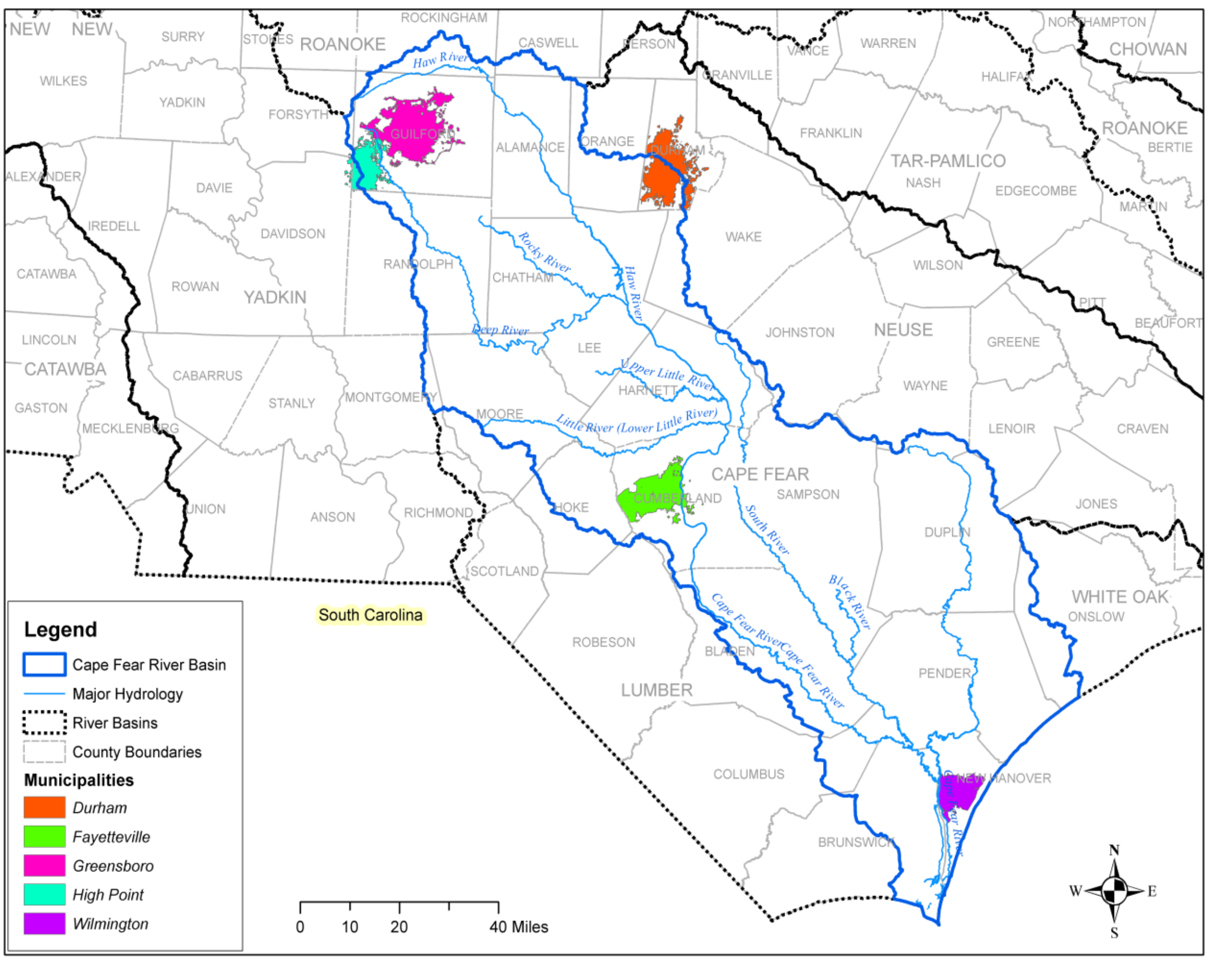
4.5.5 Cape Fear River Basin

4.5.5.1 River Basin Description

The Cape Fear River Basin is the largest river basin in North Carolina and is contained entirely within the state. The Cape Fear River flows southeast through the Piedmont ecoregion into the Coastal Plain before reaching the city of Wilmington and draining into the Atlantic Ocean. The basin covers about 9,164 square miles and has 21,300 miles of freshwater streams, 31,135 acres of freshwater lakes and reservoirs, 31,753 acres of estuarine habitat, and 47 miles of Atlantic coastline (NCDWQ 2005a; NCDWR 2015h). Major drainages in the basin include the Haw River, Deep River, Northeast Cape Fear River, Black River, and the Cape Fear River.

The basin encompasses all or part of 26 counties and includes 115 municipalities of varying population sizes. Sizable cities located in this basin include Durham, Greensboro, High Point, Fayetteville, and Wilmington. Figure 4.5.5-1 depicts the geographic location of the basin.

Figure 4.5.5-1 Location of the Cape Fear River Basin.



The Cape Fear River Basin can be characterized by three general regions:

- the Upper Cape Fear, including the headwaters in the Piedmont;
- the Middle Cape Fear, including the fall line and the Sandhills;
- the Lower Cape Fear, which includes the coastal region with blackwater streams and swamps.

The headwaters include the Deep River, originating near High Point, and the Haw River, originating north of Greensboro, which join to form the Cape Fear River just downstream of the B. Everett Jordan Reservoir dam. Much of the headwater area is located in and flows through highly urbanized areas, which significantly impacts water quality in the basin. Blackwater streams and rivers in the lower Cape Fear include the South River, Black River, and the Northeast Cape Fear River. Species found in the Sandhills and Coastal Plain have a high rate of endemism due to unique habitats in those ecoregions.

Land use in the basin is 42% forested, 18% wetland, 12% urban or developed, 6% grassland, and 21% agricultural (MRLC 2011; Jin et al. 2013). Public lands include approximately 234,381 acres of state and federal lands. Significant public lands include the B. Everett Jordan Reservoir, Bladen Lakes State Park, and numerous game lands managed by the NC Wildlife Resources Commission (NCWRC). The estimated 2010 human population was 2,072,304, which represents about 22% of the state’s total population (USCB 2012; NCDWR 2015h).

4.5.5.2 Aquatic Resource Conditions

Segments of Black River, Deep River, Little River, South River, and several freshwater streams and lakes have supplemental classifications as High-Quality Waters (HQW) or Outstanding Resource Waters (ORW) because they either have excellent water quality or they are a significant resource to humans and/or wildlife (NCDWQ 2015d).The Cape Fear River near the Lilliput Creek, Walden Creek, and Snow’s Cut confluences, Buzzard Bay, Muddy Slough, and other coastal tributaries, and coastal estuarine waters associated with the Intracoastal Waterway also carry an HWQ or ORW classification (NCDWR 2015a).

There are HQW and ORW Special Management Strategy Areas in the basin for the Northeast Cape Fear River, Deep River, Little River, Black and South River Area, Topsail and Middle Sound Area, Masonboro Sound Area, and six additional areas totaling 124,355 ORW acres and 152,786 HQW acres (NCDWR 2015c). These areas require site-specific provisions to protect resource values (e.g., no new discharges or expansion of existing discharges) (see 15A NCAC 02B.0225).

There are 1,829 miles and 18,584 acres of freshwater considered to be nutrient-sensitive waters (NSW) in the Cape Fear River Basin (NCDWR 2015a). The NSW classification applies to all waters in the Haw River and Jordan Reservoir watersheds and is intended for those that need additional nutrient management because of greater vulnerability to excessive aquatic vegetation growth (NCDWQ 2005a).

4.5.5.3 Aquatic Species

Appendix 3 provides lists of SGCN and other priority species for which there are knowledge gaps or management concerns. Appendix 3-18 identifies aquatic SGCN associated with aquatic communities found in this river basin.

In addition to the crayfish, freshwater fish and mussels, and aquatic snails found in the basin, there are also species that have both aquatic and terrestrial stages to their life history. The following list of SGCN are also associated with the aquatic communities in the Cape Fear River Basin

Common Name	Scientific Name	Federal Status	State Status
AMPHIBIANS			
River Frog	*Rana heckscheri*	--	E
REPTILES			
Carolina Swamp Snake	*Seminatrix pygaea paludis*	--	SC
Diamondback Terrapin	*Malaclemys terrapin*	--	SC
Glossy Crayfish Snake	*Liodytes rigida*	--	--
Common Rainbow Snake	*Farancia erytrogramma*	--	--
INSECTS - DRAGONFLIES			
Belle's Sanddragon	*Progomphus bellei*		
Clearlake Clubtail	*Phanogomphus australis*		
Coppery Emerald	*Somatochlora georgiana*		
Rapids Clubtail	*Phanogomphus quadricolor*		
Sandhill Clubtail	*Phanogomphus cavillaris*		
Septima's Clubtail	*Gomphurus septima*	**At-Risk**	
Shining Clubtail	*Stylurus ivae*		
Sweetflag Spreadwing	*Lestes forcipatus*		

4.5.5.4 Threats Affecting Aquatic Species

Development. The Cape Fear River Basin contains multiple areas of high human population density and the most populated areas are located in the Piedmont municipal regions referred to as the Triad and the Triangle (NCDWQ 2005a). The Triad is the area encompassing Winston-Salem, Greensboro, and Highpoint, and the Triangle is the area anchored by Raleigh, Durham, and Chapel Hill. All of the major urban centers in the basin are experiencing fast growth rates. As counties in the upper basin and those along the coast experience high population growth, current capacities for drinking water and wastewater treatment will experience increased demands for service that could require a corresponding increase in utility construction, water withdrawals, and treatment discharges. Comparison of water supply demand projections for municipalities in the basin with percent of projected water supply available for the 2040 planning period indicates demand from growth will utilize from 50% to 99% of available water supplies in the basin (NCDWR 2014b).

Water Quality. The basin has numerous Confined Animal Feeding Operations (CAFOs), primarily swine production, with 1,275 permitted facilities and 2,035 associated waste lagoons (NCDEQ 2024(a)). These facilities, as well as several other impact factors in the basin, result in waters being rated as impaired, due to fecal coliform and *enterococcus* bacterial contamination, ammonia, chlorides, habitat degradation, chlorophyll *a*, low dissolved oxygen (DO), turbidity, nutrients, elevated heavy metal or cyanide levels, and other point and nonpoint pollutants (NCDWQ 2005a). While any one source may only create local impacts, the cumulative effects from multiple sources and impacts occurring throughout the basin have had a severe and long-lasting impact. Sedimentation from agriculture, forestry, and construction practices and stormwater discharge are major issues in the basin.

Impoundments. According to a NC Department of Environment and Natural Resources dam inventory (2014) there are at least 1,290 impoundments in the basin. The mainstem of the Cape Fear is interrupted by three locks and dams in the middle and lower portions of the river. The upper Cape Fear River has large barriers at Buckhorn Dam and Jordan Dam. There are also numerous smaller dams on the tributaries to the Cape Fear. The consequences of these impoundments include blocked migration routes for diadromous and resident native species, reduced recolonization and dispersal potential for multiple aquatic taxa, and unnatural flow regimes below managed dams (Williams et al. 1993; Etnier 1997; Neves et al. 1997; Warren et al. 2000; NCWRC 2005).

Invasive Species. Invasive species (e.g., Flathead Catfish, Blue Catfish, Red Swamp Crayfish) are established in the Cape Fear River Basin and continue to negatively impact native species populations (Fuller et al. 1999; Cooper 2005) via predation and competition. The Striped Shiner is native to other river basins in the state, but has been introduced and occurs as a nonnative species in the Cape Fear River Basin.

4.5.5.5 Basin Specific Recommendations

Conservation priorities that apply statewide to all river basins are presented in Section 4.5.3.3. Priority watersheds identified in the Cape Fear River Basin are shown in Figure 4.5.5-2 (at the end of this section).

Surveys

Surveys need to focus on aquatic snails, crayfish, mussels, and fish believed to be declining or dependent on at-risk or sensitive communities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Conduct distribution and status surveys for SGCN and other priority species.

Atlantic Pigtoe	Greensboro Burrowing Crayfish	Ironcolor Shiner
Triangle Floater	Broadtail Madtom	Flat Bullhead
	Carolina Redhorse	Snail Bullhead

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging in the resilience of organisms to continued impacts to state waters. Studies should include identification of population trends, as well as assessment of conservation or development activities. These efforts will inform species and habitat management decisions. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Conduct monitoring surveys for SGCN mussel species in the Deep and Rocky Rivers and other priority species.

Magnificent Ramshorn	Cape Fear Shiner	Deep River
		Rocky Rivers

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, impacts of climate change and invasive species, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Support species descriptions for undescribed taxa.

Carolina Redhorse	Crayfishes

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Determine the vulnerability of species across all taxa groups to contaminants such as endocrine-disrupting chemicals (EDCs) and other compounds that are present in many of our waterways.		
Broadtail Madtom	Ironcolor Shiner	
• Identify limiting factors of declining species.		
• Identify ways to eradicate or reduce the impacts of nonnative species throughout the basin as well as proactively preventing future introductions.		
Blue Catfish	Mystery snails	Hydrilla
Flathead Catfish		

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. General needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats. In addition, education about, and regulation and prevention of the introduction and spread of exotic or invasive species are vital.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Promote programs to upgrade/increase compliance at wastewater treatment facilities and CAFOs.
• Provide support for land conservation, particularly in riparian areas, through acquisition or easements.
• Support well-planned stream restoration work in collaboration with other organizations.
• Support barrier removal or remediation where appropriate.
• Reintroduce or augment rare mollusk and fish species populations in areas where water quality and stream habitats have recovered sufficiently to support them.
• Continue to identify areas critical to aquatic ecosystem health that can be conserved or restored.

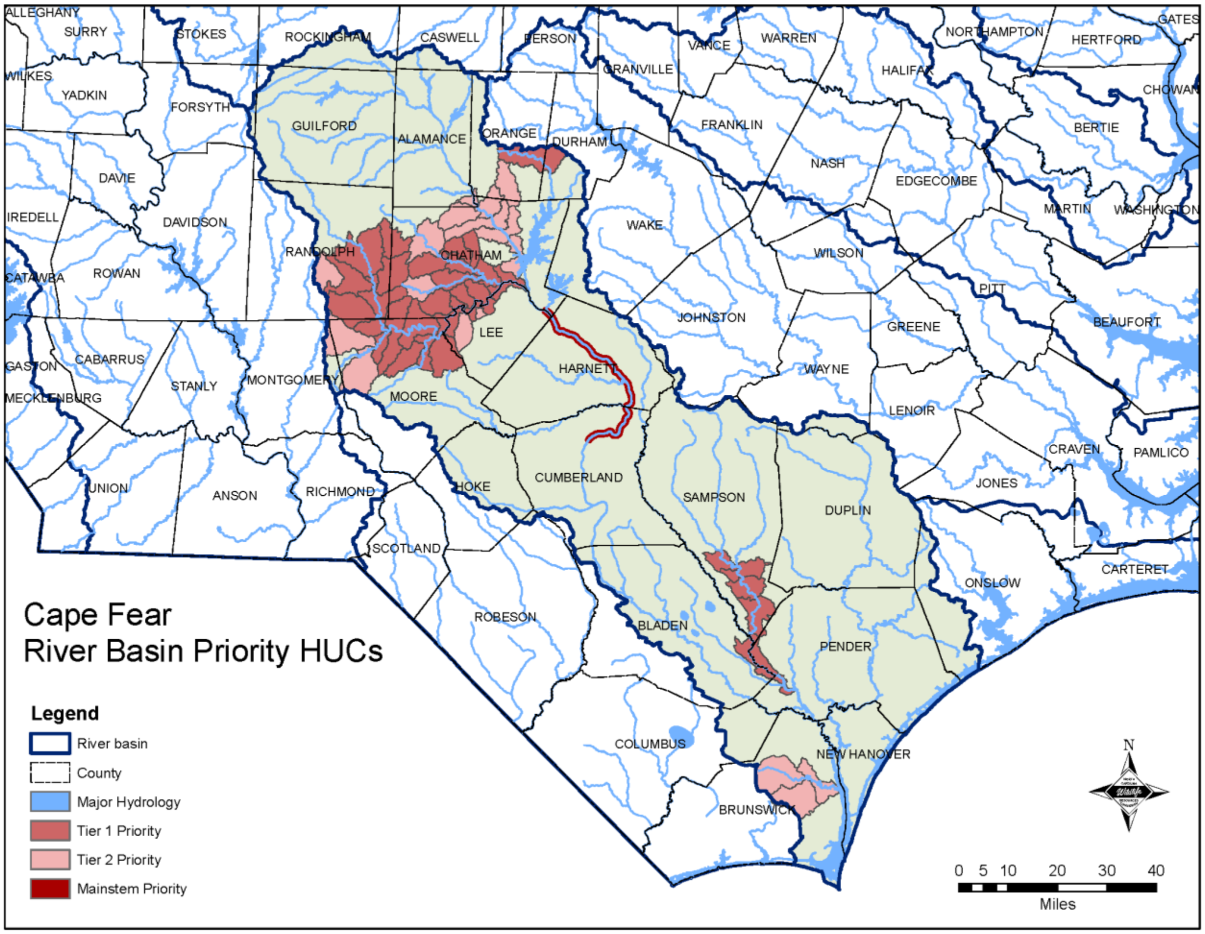
- Promote prevention and awareness of the spread of exotic species and damage to native resources, communities and economic impacts.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Guide academic research projects to help achieve specific conservation goals and objectives.
• Support the application of an aquatic nuisance species management plan with other agencies/groups.
• Address secondary and cumulative impacts upon water quality, buffer ordinances, water supply watershed protection, headwaters protection, etc. (NCDWQ 2000a, NCWRC 2002).
• Work with and promote existing programs that help farmers reduce sedimentation/erosion (e.g., install fences to keep livestock out of streams and improve tilling practices) as well as reduce pesticide and herbicide use.
• Continue work with conservation partners to advance species and habitat recovery goals.

Figure 4.5.5-2 Location of priority HUC12 watersheds in the Cape Fear River Basin.



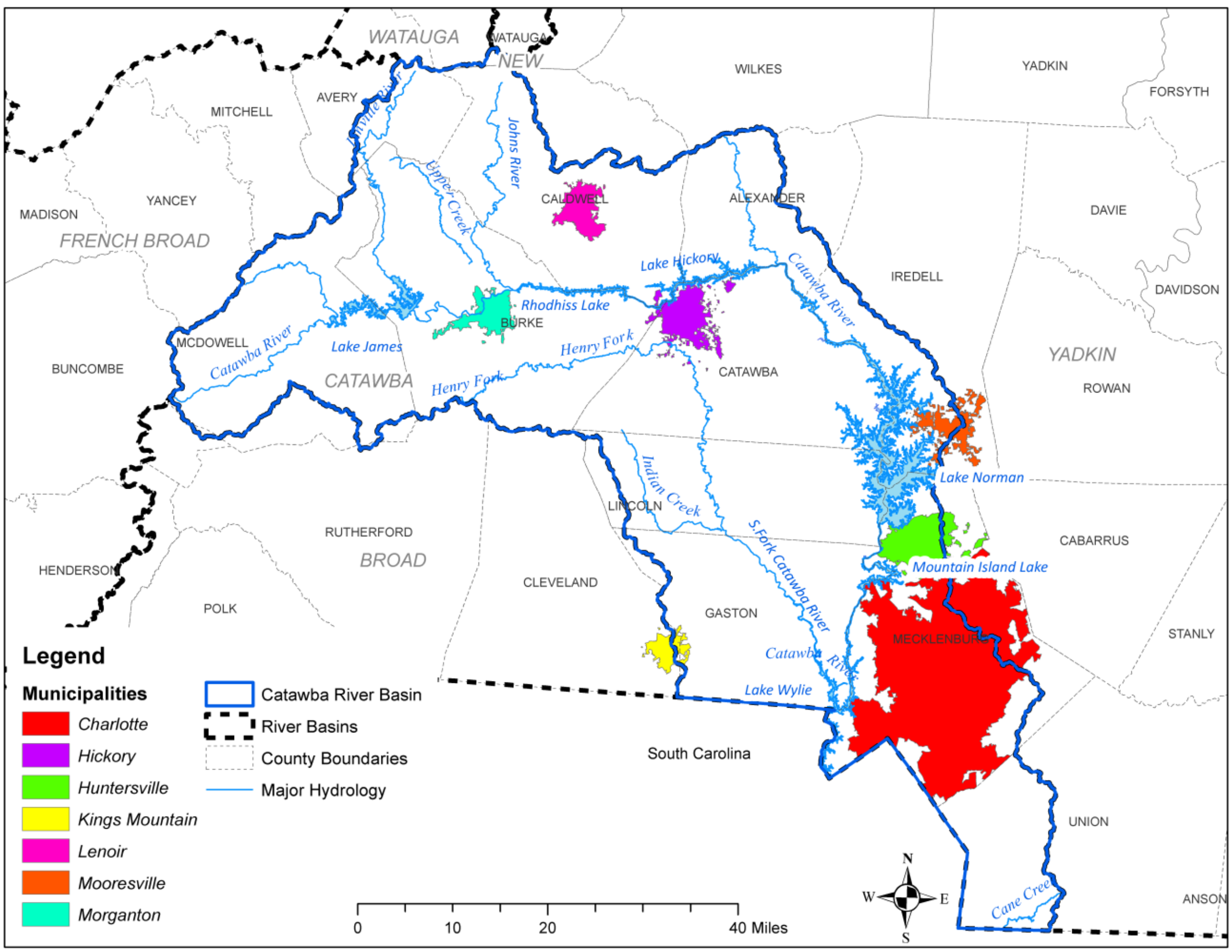
4.5.6 Catawba River Basin

4.5.6.1 River Basin Description

The Catawba River Basin is located in the south central portion of western North Carolina in the Mountain and Piedmont ecoregions. Headwaters begin in the western side of McDowell County and flow eastward into the Piedmont ecoregion before turning southeast and flowing toward the North Carolina/South Carolina border.

The Catawba River Basin encompasses all or portions of 11 counties and 61 municipalities, including the largest municipality in the state (Charlotte). Other large municipalities include Gastonia, Hickory, Huntersville, Lenoir, Mooresville, and Morganton. Figure 4.5.6-1 depicts the geographic location of the basin.

Figure 4.5.6-1 Location of the Catawba River Basin.



The basin covers approximately 3,285 square miles and has more than 7,940 miles of freshwater streams. The Linville River, one of only four rivers in the state designated as a Natural and Scenic River, is located in the Catawba River Basin (USA National Wild and Scenic Rivers System). The Linville River flows through the Pisgah National Forest Wilderness area and into Lake James. Practically all of the Catawba River from Lake James southward is impounded by a chain of dams before entering South Carolina.

This basin, along with the Broad River Basin, forms the headwaters of the Santee-Cooper River system which flows through South Carolina to the Atlantic Ocean. There are three major river drainages in the basin:

- Upper Catawba: major tributaries include Catawba River headwaters, Linville River, North Muddy Creek, Warrior Fork, Johns River, Silver Creek, Lower Creek, Little River, Gunpowder Creek, Muddy Fork, Dutchman's Creek, and Crowders Creek.

- Lower Catawba: major tributaries include Twelve Mile Creek, Six Mile Creek, Waxhaw Branch, Irwin Creek, McAlpine Creek, and Sugar Creek.

- South Fork Catawba: major tributaries include Henry Fork, Jacob Fork, Clark Creek, and Long Creek.

Based on 2011 National Land Cover Dataset information land use in the basin was estimated to be 54% forested, 23% urban or developed, 16% agricultural, 3% grassland, and less than 1% wetland (MRLC 2011; Jin et al. 2013).

4.5.6.2 Aquatic Resource Conditions

There are 3,100 miles of freshwater streams and 54,363 acres of lake and reservoir waters in the basin that have been classified by NCDWR for best uses. There are 11 HQW (108,638 acres) and seven ORW (107,910 acres) Special Management Strategy Areas in the basin (NCDWR 2015c). Notable areas include Armstrong Creek, Wilson Creek area, Linville River, Henry and Jacobs Fork areas, and Upper and Steele Creek areas. These areas require site-specific provisions to protect resource values (no new discharges or expansion of existing discharges) (see 15A NCAC 02B.0225).

Another supplemental classification is NCDWR's trout water (Tr) designation which protects freshwaters for natural propagation of trout and survival of stocked trout on a year-round basis. There are about 632 miles of streams in the Catawba River Basin designated as trout waters. This is not the same as the Commission's designated public Mountain Trout Waters, which is used to designate waters that support trout and are open to public fishing. These waters are classified for NCWRC management purposes as either hatchery-supported (periodically stocked with trout) or wild trout waters (high-quality waters that sustain trout populations by natural reproduction).

4.5.6.3 Aquatic Species

Appendix 3 provides lists of SGCN and other priority species for which there are knowledge gaps or management concerns. Appendix 3-18 identifies aquatic SGCN associated with aquatic communities found in this river basin.

In addition to the crayfish, freshwater fish and mussels, and aquatic snails found in the basin, there are also species that have both aquatic and terrestrial stages to their life history. The following list of SGCN are also associated with the aquatic communities in the Catawba River Basin

Common Name	Scientific Name	Federal Status	State Status
INSECTS - DRAGONFLIES			
American Emerald	*Cordulia shurtleffii*	--	--
Black-tipped Darner	*Aeshna tuberculifera*	--	--
Edmund's Snaketail	*Ophiogomphus edmundo*	**At-Risk**	--
Green-striped Darner	*Aeshna verticalis*	--	--
Harpoon Clubtail	*Phanogomphus descriptus*	--	--
Mountain River Cruiser	*Macromia margarita*	**At-Risk**	--
Ocellated Darner	*Boyeria grafiana*	--	--
Pygmy Snaketail	*Ophiogomphus howei*	--	--
Ski-tipped Emerald	*Somatochlora elongata*	--	--
White-faced Meadowhawk	*Sympetrum obtrusum*	--	--

4.5.6.4 Threats Affecting Aquatic Species

Impoundment. Impoundment is a major factor in the loss and degradation of habitat for priority aquatic species in the Catawba basin. All but the upper headwater reaches of the Catawba River (upstream from Lake James) are either impounded or regulated by hydropower projects (Duke Energy). Coldwater releases degrade the Lake James tailwater for many native species and it is presently managed as a stocked trout fishery. Migration of anadromous and potamodromous fishes are severely limited, if not altogether prevented by dams. The few remaining free-flowing, cool- or warmwater high-quality habitats in larger tributary streams are isolated and fragmented by the impoundment effects on the mainstem Catawba River. The total effect of this habitat fragmentation on priority species populations in not entirely clear; however, some impacts are evident. Habitats may be recovering in some streams where species were extirpated by past habitat loss. Potential recolonization of these recovering habitats may be impossible due to barriers created by dams, impoundments, and/or intervening habitat made unsuitable by other factors.

Several existing impoundments are used for water supply and new impoundments are being proposed within the basin for that purpose. As human population increases, water supply is an increasing burden on surface waters. Water withdrawals, impoundments, and interbasin water transfers can significantly alter habitats for native aquatic species. This is an emerging problem that will likely increase in importance in the near future.

Sedimentation. With the exception of streams located on public lands, streams within the basin are degraded or threatened by a number of factors, including sedimentation, loss of riparian woody vegetation, water withdrawals, channelization and/or relocation, point source pollution, and nutrient loading. Ground disturbance from development activities and poorly managed agriculture are the primary sources of erosion, sedimentation, and nutrient enrichment. Point sources of pollution include wastewater treatment plants and permitted industrial discharges (much of the basin flows through highly urbanized areas). Alterations to stream channels, increased impervious surfaces (resulting in increased flashiness), and loss of riparian vegetation contribute to stream channel and bank erosion, which in turn contribute to sedimentation and other physical habitat degradation.

Water Quality. The basin has 32 permitted Confined Animal Feeding Operations (CAFOs), primarily cattle production, with 60 associated waste lagoons (NCDEQ 2024(a)). These facilities, as well as several other impact factors in the basin, result in waters being rated as impaired, due to fecal coliform and *enterococcus* bacterial contamination, ammonia, chlorides, habitat degradation, chlorophyll *a*, low dissolved oxygen (DO), turbidity, nutrients, elevated heavy metal or cyanide levels, and other point and nonpoint pollutants (NCDWQ 2005a). While any one source may only create local impacts, the cumulative effects from multiple sources and impacts occurring throughout the basin have had a severe and long-lasting impact. Sedimentation from agriculture, forestry, and construction practices and stormwater discharge are major issues in the basin.

Invasives. Nonnative species known in the basin include Asian Clams, Virile Crayfish, Japanese Mystery Snail, Grass Carp, Blue, Channel, and Flathead catfishes, Smallmouth Bass, Muskellunge, White Bass, Yellow Bass, Rainbow and Brown trout, and even the exotic Northern Snakehead. Land-locked Blueback Herring, Alewife, and White Perch are known in several impoundments. In fact, over 33 exotic fish species have been identified in the basin (NCWRC 2005). Nonnative vegetation can also negatively impact native aquatic animal communities. This includes both aquatic and riparian plant species and nonnative plant pathogens that can alter riparian vegetation (e.g., Hemlock Wooly Adelgid). Nonnative aquatic plants are also present in the Catawba River Basin and are a known nuisance, especially in reservoirs. Specific impacts in the Catawba River Basin from these and other introduced species are unclear.

4.5.6.5 Basin Specific Recommendations

Conservation priorities that apply statewide to all river basins are presented in Section 4.5.3.3. Priority watersheds identified in the Catawba River Basin are shown in Figure 4.5.6-2 (at the end of this section).

Surveys

General distribution of most priority species is known; however, surveys are needed to complete distributional status for knowledge gap priority and invasive species.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Fish—survey for SGCN and other priority and state listed species on a routine basis.

Santee Chub Seagreen Darter	Snail Bullhead Thicklip Chub	V-Lip Redhorse

- Mussels – continue to track mussel population health in priority areas such as Johns and Catawba Rivers, and Upper, Mulberry, and Steel creeks, as well as mainstem Catawba reservoirs and tailraces

Johns River Catawba River	Upper Creek Mulberry Creek Steel Creek	Catawba reservoirs and tailraces

- Crayfishes – continue inventories and update status of SGCN and other priority and state listed species.,

Carolina Needlenose Crayfish	Foothills Crayfish Grandfather Mtn Crayfish	South Mountain Crayfish

- Aquatic Snails – inventory primary distribution; determine potential habitats and distribution surveys for SGCN and other priority and state listed species.

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to continued impacts to state waters. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities and invasive species. These efforts will inform species and habitat management decisions. While long-term monitoring sites have been established and baseline data gathered in most areas of the basin for fishes and crayfishes, a comprehensive approach to long-term monitoring is still lacking for mussels. Project-specific monitoring for species restoration in the South Fork Catawba River system and other conservation actions are also needed. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Fish—monitor SGCN and other priority and state listed species on a routine basis.

Brook Trout	Robust Redhorse	Stonecat
Carolina Darter	Santee Chub	Thicklip Chub
	Seagreen Darter	Yellowfin Shiner

- Mussels – monitor SGCN and other priority species in priority areas (Johns and Catawba Rivers, and Upper, Mulberry, and Steel creeks, as well as mainstem Catawba reservoirs and tailraces

Johns River	Upper Creek	Catawba reservoirs and tailraces
Catawba River	Mulberry Creek	
South Fork Catawba River	Steel Creek	

- Crayfishes – monitor priority species.

Carolina Foothills Crayfish	Grandfather Mountain Crayfish

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Resolve taxonomic problems and species descriptions (if required) for mussels in the genera *Elliptio* and *Sagittunio*, and putative undescribed crayfishes in the basin.
- Investigate the impact of habitat fragmentation and invasive species on the basin.
- Investigate aquatic community response to stream restoration projects in priority areas.
- Investigate potential for reintroduction of priority species.
- Support research to improve habitat conditions in regulated rivers.

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats. In addition, education about, and regulation and prevention of the introduction and spread of exotic or invasive species are vital. Specific issues in this basin include high rates of erosion and sedimentation, secondary and cumulative impacts upon water quality, riparian vegetation restoration and conservation, water supply watershed protection, and headwaters protection.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Incorporate management goals for aquatic community conservation and enhancement planning for Johns River and South Mountain Game Lands. South Mountain Game Land
• Continue reintroduction of extirpated mussel species and investigate restoration in other restored or improved habitats as opportunities become available.
• Provide support for land protection, particularly in riparian areas through acquisition or easements.
• Prioritize education and other measures to prevent the introduction or spread of invasive nonnative crayfishes.
• Support measures to remove relict or non-functioning stream barriers where appropriate.

Conservation Programs and Partnerships

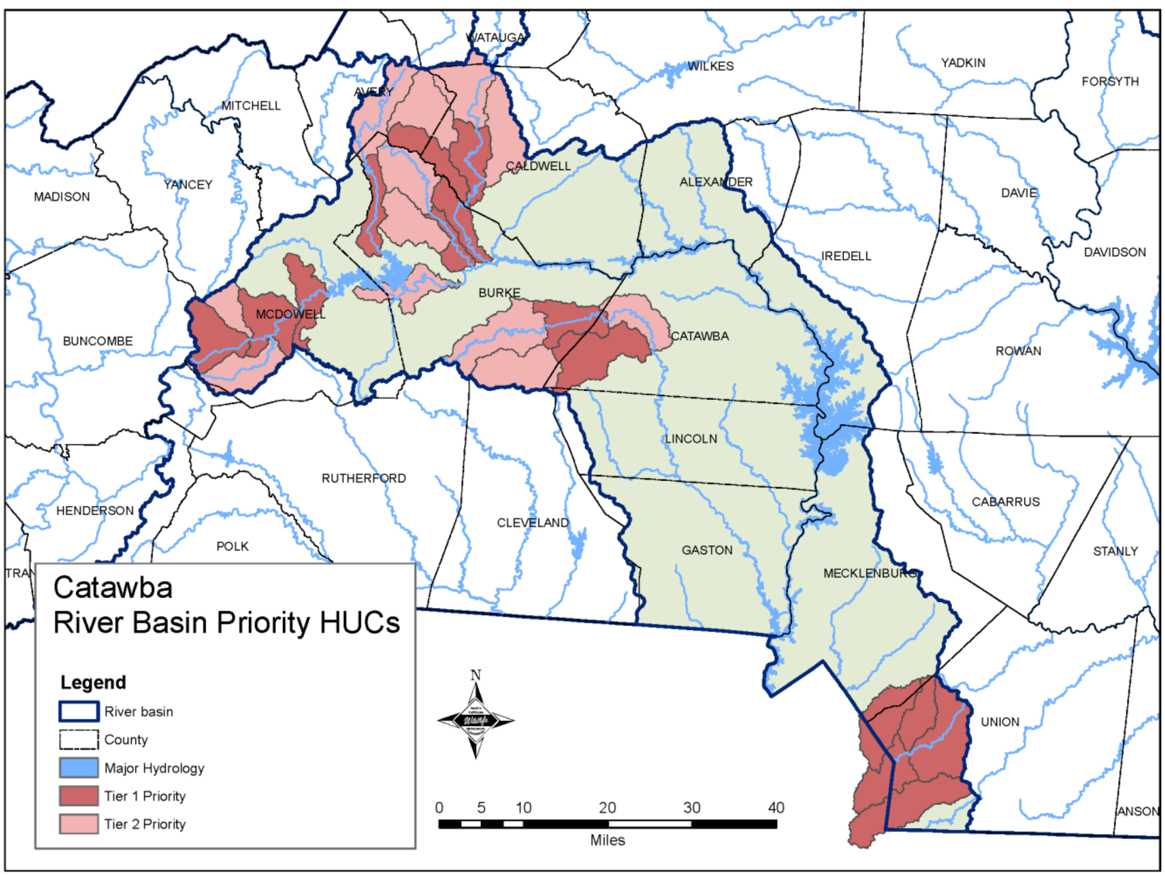
Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

The NCDWR has prepared a Catawba River Basin Water Resources Plan to “determine the water capacity of the Catawba River to serve future populations and at the same time to identify any potential trouble-spots or conflicts related to water supply and its demand (NCDWR

2007). The Catawba-Wateree Basin Advisory Commission helps administer water issues in the basin and is a source for information associated with those issues. Basin Planning documents can be downloaded from the NCDWR website https://www.deq.nc.gov/about/divisions/water-resources/water-planning/basin-planning-branch.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Support restoration projects and basinwide management initiatives in priority watersheds.
• The Catawba River District Partners, the Catawba and Foothills land conservancies, Catawba Riverkeeper, and many other non-governmental organizations (NGOs) are active in the basin and are active partners

Figure 4.5.6-2 Location of priority watersheds in the Catawba River Basin.



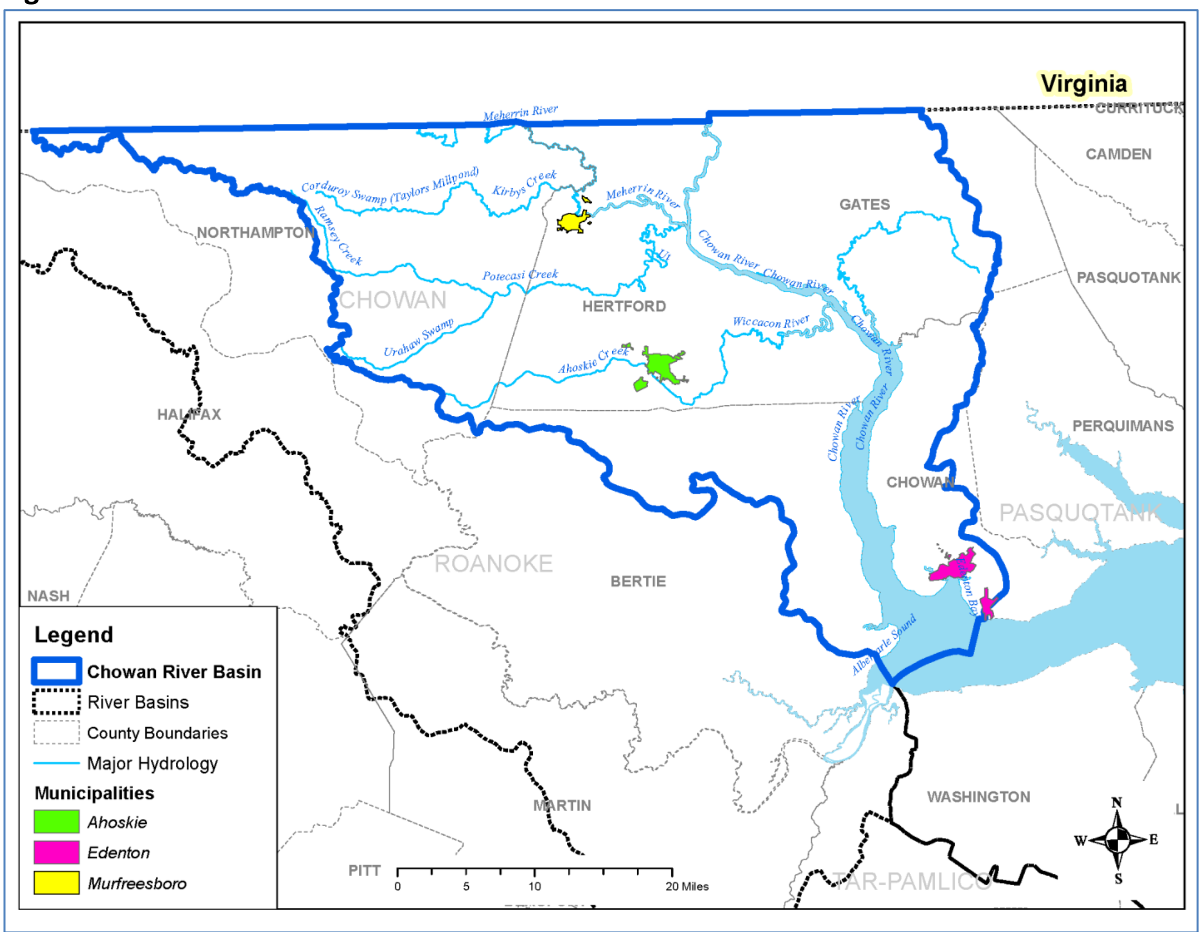
4.5.7 Chowan River Basin

4.5.7.1 River Basin Description

The Chowan River headwaters begin in Virginia; the mainstem river is formed at the confluence of the Nottoway, Meherrin, and Blackwater rivers near the border of Virginia and North Carolina. The waters in the North Carolina portion of the basin flow southeast to the Albemarle Sound. As the twelfth largest river basin in the state, the Chowan River Basin is one of the smaller basins with a watershed of nearly 1,300 square miles in the state (NCDWR 2021). The basin contains about 1,124 miles of freshwater streams, 1,787 acres of lakes and impoundments, and 16,500 acres of estuarine waters (NCDWQ 2007a; NCDWR 2015a, NCDWR 2021).

The North Carolina portion of the basin includes all or part of five counties: Northampton, Hertford, Gates, Bertie and Chowan. There are 19 municipalities in the basin and the largest are Edenton, Ahoskie, and Murfreesboro. The 2010 census estimates the population is just over 95,000 people (NCDWR 2021) Figure 4.5.7-1 depicts the geographic location of the basin.

Figure 4.5.7-1 Location of the Chowan River Basin.



The Chowan River Basin is part of the Albemarle-Pamlico Estuarine system, the second largest estuarine system in the United States. The basin is composed of two major drainages: the Chowan River and the Meherrin River. Major tributaries to the Chowan River include the Meherrin River, Potecasi Creek, Wiccacon River, Bennetts Creek, Indian Creek, and Rockyhock Creek.

The headwaters of the Chowan River begin in the Coastal Plain ecoregion of Virginia, where 75% of the basin is located. The basin enters North Carolina in the northeastern portion of the state. Along with the Roanoke River, the Chowan supplies most of the fresh water supply to the Albemarle Sound. Fishes move between the Chowan, Roanoke and Pasquotank River basins freely as a result of the common connection with the sound (NCDWQ 2007a).

Land use in the basin is 36% forested, 29% agricultural, 20% wetland, 6% grassland, and 4% urban or developed (NCDWR 2021). Land in this area is very flat and the geology consists of alternating layers of sand, silt, clay and limestone. Low flow over the warmest months of the year limits the ability of streams to maintain high DO levels (NCDWQ 2021). The region has slow natural drainage. Many streams are swamp systems, and many man-made ditches have been installed to accommodate drainage for agriculture (NCDWQ 2011b, 2007a). Stream swamp systems periodically have no visible flow or low flow, usually during the summer, but flowing water should be present in swamp streams during the winter.

4.5.7.2 Aquatic Resource Conditions

Approximately 100 miles of the Chowan River are considered an Aquatic Significant Natural Heritage Area by the NCNHP (NCDWR 2021). The Chowan River receives this designation because of the diversity of its freshwater mussel populations, many of which are rare and vulnerable. The Chowan River Basin was the first waterbody in the state to be designated NSW. This designation protects areas with water quality problems associated with excessive plant growth resulting from nutrient enrichment, likely from nonpoint sources (fertilizer in runoff from agriculture and waste from confined animal operations), and nuisance algae blooms associated with excess nutrient loads. Nearly all of the 16,500 acres of estuarine waters in the basin are ranked by NCDWR as supporting aquatic life.

The entire area of the Albemarle Sound is rated impaired (i.e., exceeding criteria) due to a dioxin fish consumption advisory issued by the NC Department of Health and Human Services (NCDHHS 2014). Other factors that contribute to impaired ratings include fecal coliform and *enterroccus* bacteria contamination from confined animal operations and agricultural activities (NCDWQ 2007a).

There are no major reservoirs in the North Carolina portion of the basin but the NC Department of Environment and Natural Resources Dam Inventory (NCDEMLR 2014) reports there are 22 impoundments of varying sizes in the basin. Most were built to provide recreation or irrigation waters and some were constructed as millponds.

4.5.7.3 Aquatic Species

Appendix 3 provides lists of SGCN and other priority species for which there are knowledge gaps or management concerns. Appendix 3-18 identifies aquatic SGCN associated with aquatic communities found in this river basin.

In addition to the crayfish, freshwater fish and mussels, and aquatic snails found in the basin, there are also species that have both aquatic and terrestrial stages to their life history. The following list of SGCN are also associated with the aquatic communities in the Chowan River Basin.

Common Name	Scientific Name	Federal Status	State Status
REPTILES			
Rainbow Snake	*Farancia erytrogramma*	--	--

4.5.7.4 Threats Affecting Aquatic Species

Pollution. In the Chowan River Basin, elevated mercury levels have been measured in long-lived piscivorous (fish-eating) predator fish. The NCDHHS, Division of Public Health has posted a fish consumption advisory for the Chowan River Basin that includes all Largemouth Bass, Black Crappie, Catfish, Chain Pickerel, and Warmouth; Yellow Perch, and Bowfin (or Blackfish) caught east of I-85; and for Black Crappie caught south and east of I-95 for mercury contamination (NCDWQ 2011b). Other fish consumption advisories in the basin include an advisory for dioxin contamination for Catfish and Carp caught in the Albemarle Sound (NCPH 2015) (NCDWR 2021).

Historically, dioxin, a by-product of paper mill bleaching practices, degraded water quality and negatively affected aquatic biota. However, new bleaching technologies have reduced contaminates from paper plant wastewater that enter the basin (NCOEE 2015). Contaminants of emerging concern include microplastics and industrial chemicals GenX and 1,4-dioxane.

Water Quality. There are 43 permitted Confined Animal Feeding Operations (CAFOs) in the Chowan River Basin with 83 waste lagoons associated with the facilities. Waste from these sites contains high levels of nutrients (e.g., nitrogen and phosphorus) in addition to fecal coliform bacteria and any chemical compounds, such as antibiotics or hormone products used in commercial feeding operations (NCDWR 2015b). Animal-waste lagoons and spray fields that discharge near or into aquatic environments through runoff, percolation into groundwater, and volatilization of ammonia and the release of bacterial contamination can significantly degrade water quality and endanger human and animal health (Mallin 2003; Mallin and Cahoon 2003).

Chronic episodes of hypoxia exist in the Chowan River and its tributaries in most years during seasonally hot weather. Dissolved oxygen levels frequently fall below 3.0 mg/l, which negatively affects aquatic biota. Cyclonic events and their accompanying rainfall, storm surge, inundation, and flushing of bottomland swamp habitats have occurred repeatedly within the basin since 1995. These tropical events exacerbate an already fragile summer ecosystem, which leads to lower DO levels that can produce major fish and mussel kills within the basin (NCDWQ 2007a). Soil erosion and runoff of fertilizer and animal waste caused by farming has been a concern within the basin. However, farmers have taken positive steps to reduce runoff effects which have resulted in 123,244 fewer tons of eroding soils each year (NCOEE 2015).

Water Use. There are no interbasin transfers between the Chowan and other river basins. Water withdrawals occur primarily for agricultural purposes (NCDWQ 2007a). Nonpoint pollution sources that degrade water quality include agriculture, animal operations, urban development, forestry operations, stormwater discharge, rural residential development, hydrologic modifications, and septic systems. Point pollution sources in the basin may include municipality wastewater treatment plants, industrial facilities, and urban and industrial stormwater systems.

Development. Two of the five counties in the basin are expected to experience growth rates in excess of 10% by 2020. As the counties in the Chowan River Basin continue to grow along the inner waterways there will likely be a loss of natural areas and an increase in the amount of impervious surface associated with new homes and businesses (NCDWQ 2007a).

Climate Change. Sea level rise has the potential to dramatically alter North Carolina’s coast and estuary systems. Coastal infrastructure, residential properties and industry are threatened and water quality conditions will change (NCDWQ 2007a).

Invasive Species. Invasive species (e.g., Asian Clam, Red Swamp Crawfish, Channel Catfish) have become established in the Chowan River Basin and continue to negatively impact native species populations.

4.5.7.5 Basin Specific Recommendations

Conservation priorities that apply statewide to all river basins are presented in Section 4.5.3.3. Priority 12-digit HUCs identified in the Chowan River Basin are shown in Figure 4.5.7-2 at the end of this section.

Surveys

General surveys are needed to complete primary distributional status for SGCN and other priority species.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Aquatic Snails – conduct baseline distribution surveys for all species. Ridged Lioplax

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Crayfish – Continue to conduct distribution surveys for *Cambarus* sp. C. and Chowanoke Crayfish.		
Chowanoke Crayfish	North Carolina Spiny Crayfish	*Cambarus* sp. C
• Fishes – determine distribution of SGCN and other priority species.		
Blackbanded Sunfish Bridle Shiner	Ironcolor Shiner V-lip Redhorse	Atlantic Sturgeon
• Mussels – determine distribution of SGCN and priority species.		
Alewife Floater Eastern Lampmussel	Eastern Pondmussel Tidewater Mucket	Triangle Floater Yellow Lampmussel

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to a changing climate. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. These efforts will inform future decisions on how to manage species and their habitats. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Identify long-term monitoring sites and develop monitoring protocols for SGCN and other priority species.
Chowanoke Crayfish

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic or evolutionary status of locally variable forms are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Study habitat use and life-history characteristics of SGCN and other priority species.		
Bridle Shiner	Chowanoke Crayfish	V-lip Redhorse
• Determine impacts of nonnative species on priority species.		
Red Swamp Crayfish		
• Support taxonomic research for undescribed and priority species.		
Cambarus sp. C	Lake Phelps Killifish	
• Support genetics research that informs augmentation policy.		
• Support development of captive propagation techniques for priority species.		
Banded Sunfish	Bridle Shiner	Alewife Floater

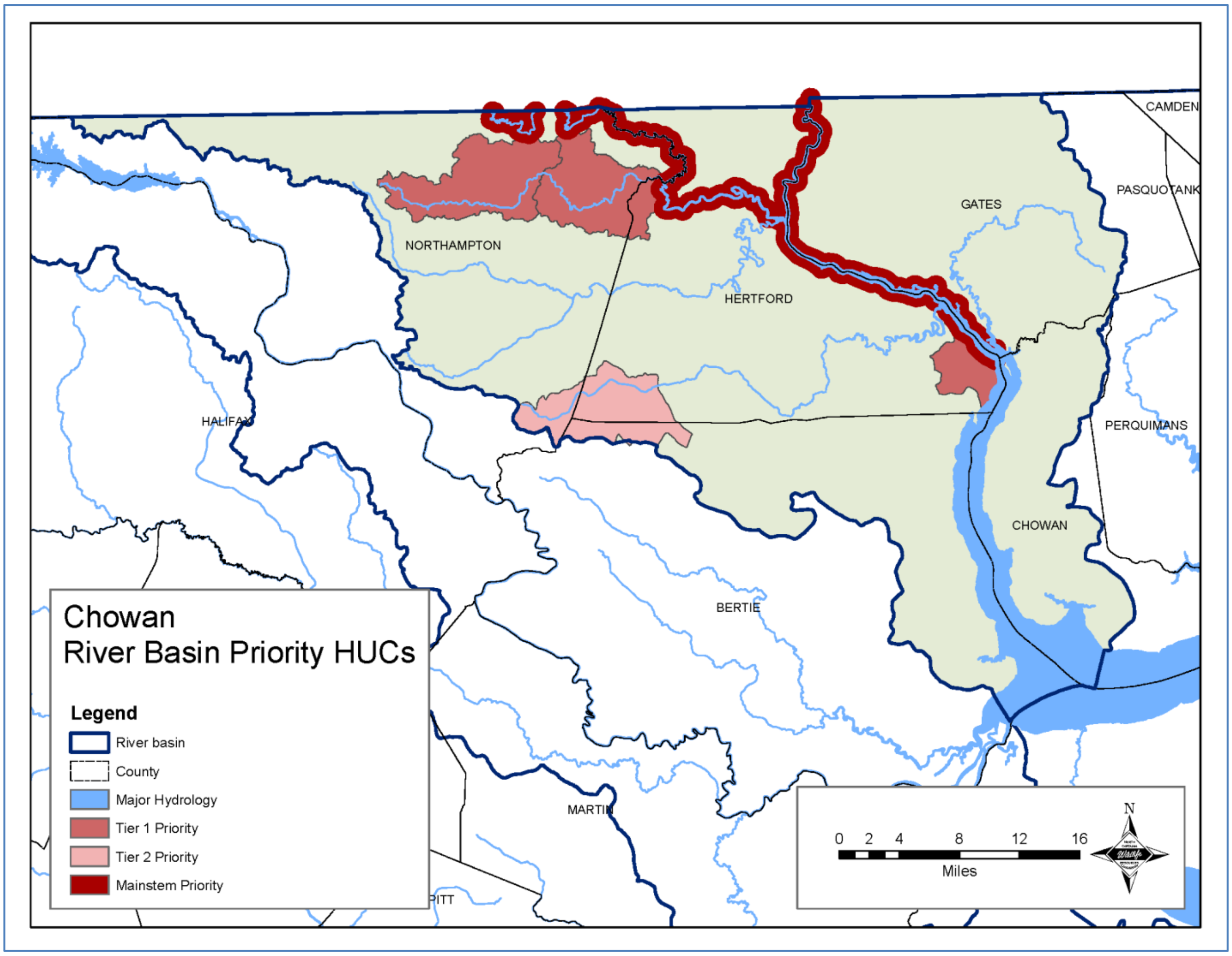
Management Practices
Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Support efforts to restore native aquatic communities (e.g., reintroduction or augmentation).
• Support acquisition of land that is adjacent to current conservation holdings or priority watersheds.
• Support other regulatory agencies to minimize impacts on species and habitats.

Conservation Programs and Partnerships
Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Support the implementation of the Coastal Habitat Protection Plan at all levels of government and amongst citizens (NCDWQ 2007).
• Continue collaborative efforts between natural resource agencies within NC and VA to improve adaptive management and policies on a watershed ecosystem scale (NCDWQ 2021).
• Support restoration projects that promote connectivity.
• Protect SAV in coastal areas (collaborate with Coastal NC SAV Coalition).
• Promote monitoring surveys of SAV and restoration efforts.

Figure 4.5.7-2 Location of priority watersheds in the Chowan River Basin.



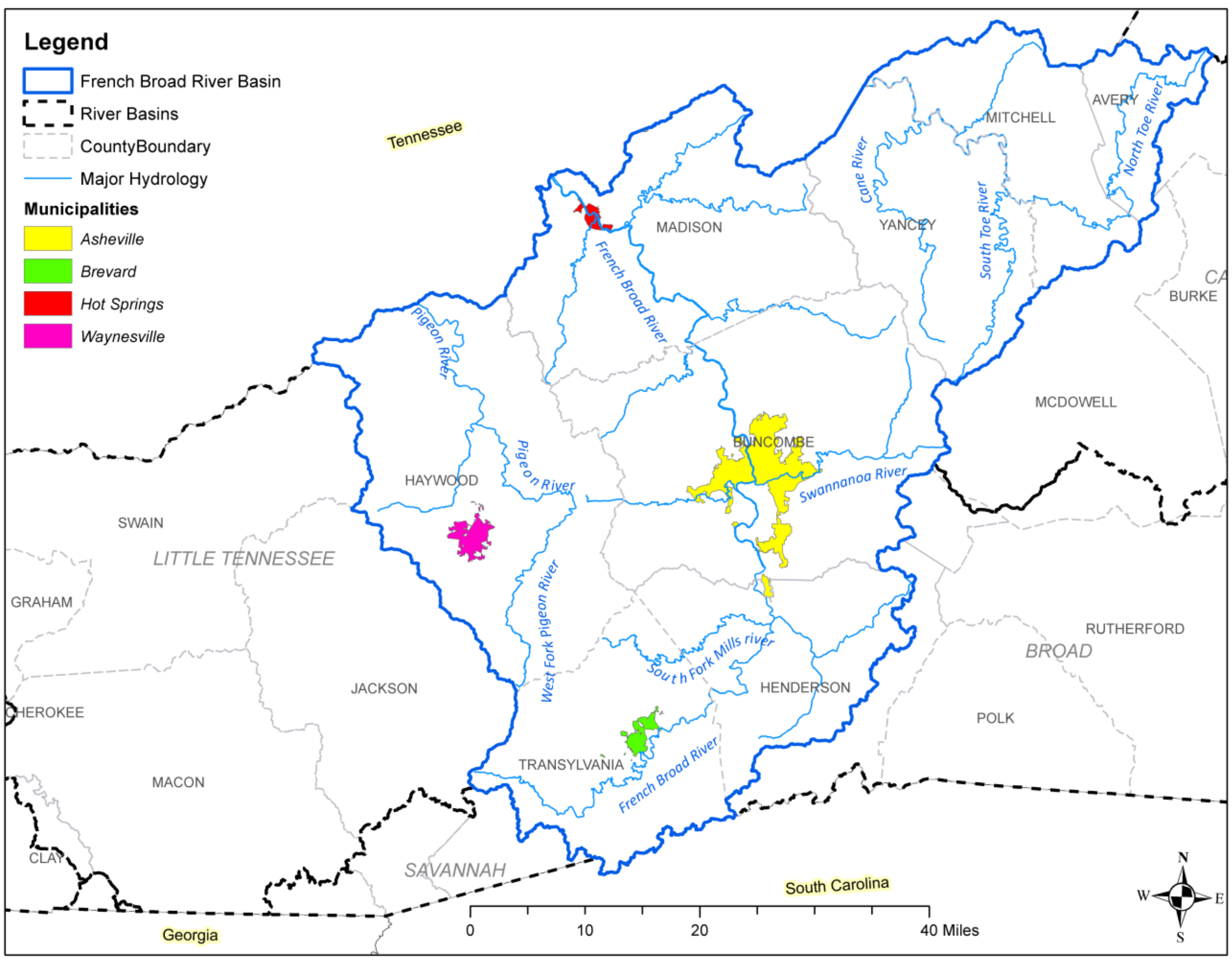
4.5.8 French Broad River Basin

4.5.8.1 River Basin Description

The French Broad River Basin in North Carolina encompasses 2,830 square miles, including 4,136 stream miles, and is entirely within the Mountain ecoregion. The headwaters are entirely within North Carolina. The basin drains from the north and western slopes of the Black Mountains, the highest range in the eastern United States. The upper mainstem French Broad River system drains from the high mountains of the Blue Ridge and flows through the broad, flat valley of the Asheville Basin.

The basin contains all or portions of eight counties (Avery, Buncombe, Haywood, Henderson, Madison, Mitchell, Transylvania, and Yancey), and all or portions of 27 municipalities, including Asheville, Brevard, Hot Springs, and Waynesville. Figure 4.5.8-1 depicts the geographic location of the basin.

Figure 4.5.8-1 Location of the French Broad River Basin.



The French Broad River Basin in North Carolina is composed of three major subbasins, each of which individually flow northwest into Tennessee: French Broad River, Pigeon River, and Nolichucky River.

- Within the Asheville Basin, the French Broad and tributaries are relatively low gradient and share many habitat characteristics with streams in more lowland areas. Consequently, a number of aquatic species more typical of the Valley and Ridge, Piedmont, and even Coastal Plain are known from this part of the French Broad and nowhere else in the Blue Ridge Mountains. Near the city of Asheville, the French Broad flows out of the Asheville Basin and descends a relatively steep, narrow gorge before entering Tennessee. There are no major dams and reservoirs on the mainstem French Broad in North Carolina; however, there are three run-of-river impoundments with small detention pools (Craggy, Capitola, and Redmon). There are multiple small dams and impoundments on larger tributaries (e.g., Lake Julian, Beetree Reservoir, Enka Lake) and many more on smaller streams, especially in the upper portion of the watershed in Henderson and Transylvania counties.

- The topography of the Pigeon River watershed is similar, with high-gradient headwaters, a relatively flat midsection, and a steep gorge near the Tennessee border. Dams and impoundments in the Pigeon River subbasin include Walters Dam/Waterville Lake (with a 12-mile bypassed reach downstream), Lake Junaluska, Allen Creek Reservoir, and Lake Logan.

- The midsection of the Nolichucky River watershed lacks substantial flat areas and remains more high gradient and gorge-like throughout its length in North Carolina. While there are a few small impoundments on minor tributaries, there are no dams on the Nolichucky River and its major tributaries.

Approximately 77% of the basin is forested, 11% is agriculture, 11% is considered developed, 1% is grassland , and less than 1% is wetlands (NLCD 2011; Jin et al. 2013). Much of the forested land is at the higher elevations and lies within the boundaries of Pisgah National Forest, Blue Ridge Parkway, and a portion within the Great Smoky Mountains National Park. Most agricultural and developed lands are concentrated within the river valleys, though residential development is occurring on increasingly steeper slopes.

4.5.8.2 Aquatic Resource Conditions

Water quality is generally good for areas where data are available; however, there are problems (described below) in parts of the basin, and the lack of data for nearly half the basin provides an unclear assessment of overall water quality. It is important to note that all waters in the state are rated as impaired based on a state-wide fish consumption advisory for mercury contamination. There are more than 4,700 miles of freshwater streams in the basin that have been classified by NCDWR for best uses (NCDWR 2015d).

North Carolina Division of Water Resources' trout water designation (Tr) is a supplemental classification that protects freshwaters for natural propagation of trout and survival of stocked trout on a year-round basis. There are about 2,545 miles of streams in the French Broad River Basin designated as trout waters. This is not the same as the Commission's designated public Mountain Trout Waters, which is used to designate waters that support trout and are open to public fishing.

- There are a total of 50,117 acres of HQW Special Management Strategy Areas (SMSAs) in the basin: the East Fork and West Fork of the French Broad River; Crab, Williamson, Laurel, and Catheys creeks; and Rocky, Rockbrook Camp, and Keystone Camp branches (NCDWR 2015c).

- There are 231,580 acres of ORW SMSAs for Big Laurel and Spring creeks, South Toe River and Tributaries Area, Cataloochee Creek Area, South Fork Mills River, and Rough Creek Area.

- There are also 163,614 acres of HQW SMSAs that span the Little Tennessee and French Broad River Basins. The SMSAs require site-specific provisions to protect resource values (e.g., no new discharges or expansion of existing discharges) (see 15A NCAC 02B.0225).

4.5.8.3 Aquatic Species

Appendix 3 provides lists of aquatic SGCN and other priority species for which there are knowledge gaps or management concerns. Appendix 3-18 identifies aquatic SGCN associated with aquatic communities found in this river basin.

In addition to the crayfish, freshwater fish and mussels, and aquatic snails found in the basin, there are also species that have both aquatic and terrestrial stages to their life history. The following list of SGCN are also associated with the aquatic communities in the French Broad River Basin.

Common Name	Scientific Name	Federal Status	State Status
AMPHIBIANS			
Mudpuppy	*Necturus maculosus*	--	**SC**
Eastern Hellbender	*Cryptobranchus alleganiensis alleganiensis*	**PE**	**SC**
Eastern Long-tailed Salamander	*Eurycea longicauda longicauda*	--	**T**

Common Name	Scientific Name	Federal Status	State Status
DRAGONFLIES			
Brook Snaketail	*Ophiogomphus aspersus*	--	--
Green-faced Clubtail	*Hylogomphus viridifrons*	--	--
Harpoon Clubtail	*Phanogomphus descriptus*	--	--
Mountain River Cruiser	*Macromia margarita*	At-**Risk**	--
Mustached Clubtail	*Hylogomphus adelphus*	--	--
Rapids Clubtail	*Phanogomphus quadricolor*	--	--
Superb Jewelwing	*Calopteryx amata*	--	--
REPTILES			
Eastern Spiny Softshell	*Apalone spinifera spinifera*	--	**SC**

4.5.8.4 Threats Affecting Aquatic Species

Water Quality. Habitat degradation resulting from nonpoint source pollution is the most widespread problem throughout the basin. Nutrient enrichment was identified as a greater problem in the French Broad River Basin than in any other interior basin drainage in the region (Hampson et al. 2000). Highway construction and its associated indirect and secondary impacts are also significant concerns in many parts of the basin.

There are 17 permitted Confined Animal Feeding Operations (CAFOs), primarily for cattle, in the basin with 14 waste lagoons associated with the facilities. Waste from these sites is a source of high levels of nutrients (e.g., nitrogen and phosphorus). Animal-waste lagoons and sprayfields that discharge nutrients and bacteria contamination near or into aquatic environments through runoff, percolation into groundwater, and volatilization of ammonia and the release of bacterial contamination can significantly degrade water quality and endanger health (Mallin 2003; Mallin and Cahoon 2003; NCDEQ 2024(a)).

Development. Development is increasing throughout much of this basin and erosion and sedimentation may also be on the rise. Development, urbanization, and agriculture are significant sources of nonpoint source pollution and sedimentation. Poorly managed development on steep slopes and within riparian areas along tributaries apparently contributes much of the sedimentation from development activities. Threats from hydrologic modifications resulting from increased urbanization (i.e., increased impervious surfaces, flood plain development and filling, stream channel alterations) seem to be increasing throughout the basin, with some areas experiencing greater impacts than others.

Habitat for priority aquatic species in the French Broad River subbasin is affected by impacts related to development and urbanization, agriculture, and point sources. Sedimentation and turbidity are more or less chronic problems in most of the larger streams in the lower elevations of the Asheville watershed and surrounding area, including the mainstem French Broad River. Point source pollution, including both present problems and residual effects from much more severe pollution of the past, contributes significantly to habitat degradation and the extirpation of priority species. However, aquatic habitats overall have improved substantially over the past 40 years.

Pollution. Habitat degradation from point sources of pollution, though not as widespread as nonpoint sources, is still a significant problem in portions of the basin. Compared to other basins in the region (e.g., Hiwassee, Little Tennessee, and Catawba), impacts from impoundments are relatively minor in the French Broad River Basin; however, these impacts are an issue for portions of the basin.

Very few high-quality habitats for cool and warmwater priority species in medium to large streams have remained intact through the 20th century. The mainstem French Broad River and tributaries from the confluence of the Davidson River downstream to the Tennessee border have lost a substantial portion of their aquatic species. Habitat continues to remain unsuitable for some of these species; however, recovery of some species may be possible. The Upper French Broad River, Little River, Mills River, and Ivy River have been the primary refuges for most of the priority species that are still extant in this subbasin. However, increased development and chance events are ever-present threats in such fragmented refugia.

High-quality habitat for priority mussels in the Little River is limited to a short reach between Cascade Lake and the confluence of Crab Creek, where sedimentation from agriculture and development in the watershed degrades habitat. Runoff from large-scale agriculture and development, and riparian degradation and bank erosion threaten the lower Mills River.

Historically, sedimentation and pollution from several mining operations throughout the Nolichucky River subbasin (primarily in the North Toe watershed) significantly degraded cool- and warmwater habitats. Encouragingly, improvements that began in the 1970s have helped reduce these impacts. Habitat in the North Toe River between Spruce Pine and the South Toe River confluence continues to be degraded, apparently from discharges and runoff from mining operations and the town of Spruce Pine. Floodplain gravel mining in the Cane River watershed poses a potential threat to long-term channel stability and habitat quality.

The failure of the Burnsville wastewater treatment plant in 2008 had serious impacts on the Cane River, with most of the Appalachian Elktoe population eliminated; however, major renovations and improvements at the treatment plant have restored water quality conditions.

Impoundments. Dams on the mainstem French Broad River are run-of-river and appear to have fewer negative impacts than peaking operation and reservoir impoundment. Barrier effects and population fragmentation (or at least the isolation of upstream populations) impact extant riverine fishes (especially potamadromous species) and the potential for restoration of extirpated species (e.g., Lake Sturgeon, Sauger).

The Pigeon River has experienced significant degradation from point source pollution and impoundment, as well as nonpoint sources. A paper mill at Canton (Blue Ridge Paper Products, formerly Champion Paper) discharged toxic wastes directly into the Pigeon River for several decades. Many priority species were eliminated from the mainstem Pigeon River by this pollution. Improvements in wastewater treatment that began in the early 1990s greatly improved habitat conditions. The paper mill shut down in 2023 and prospects for recovery of many native species are good.

The most significant impacts from impoundment in the French Broad River Basin are at the Walters Dam (Duke Energy) and bypass reach on the Pigeon River. Approximately 5 miles of the river is impounded in Walters Reservoir, and the river 12 miles downstream from Walters Dam is dewatered (except for some leakage at the dam and tributary inflow) by bypassing water from the reservoir through a penstock to a powerhouse near the Tennessee state line. Restoration of minimum flows to the bypassed reach is tied to improvements in upstream water quality (per FERC, Article 414).

The Pigeon River and short reaches of the East Fork and West Fork of the Pigeon, upstream from Canton, have remained a relatively high-quality, cool- and warmwater habitat that has provided refuge for most of the priority species that are still extant in the subbasin. Increasing development could potentially degrade this important habitat. Other tributaries, such as Jonathans Creek, Richland Creek, Fines Creek, and Crabtree Creek are variously degraded by nonpoint source pollution that comes primarily from poorly managed agriculture and increasing development.

Invasive Species. Problems associated with nonnative and invasive species are unclear at present. The White River Crayfish, White Catfish, Flat Bullhead and Snail Bullhead (all native to the Atlantic Slope) are established in the basin. The Red Swamp Crawfish, a native of the lower Mississippi and Gulf Coast drainages, has become established recently in the upper French Broad River subbasin, and could threaten the endemic French Broad Crayfish. The Asian Clam is well established throuhout the entire basin, but threats to native mollusks are not fully understood. The invasive Japanese Knotweed is widespread and expanding in riparian areas throughout the basin. Hydrilla was also recently discovered at mutliple locations in the French Broad River.

4.5.8.5 Basin Specific Recommendations

Conservation priorities that apply statewide to all river basins are presented in Section 4.5.3.3. Priority 12-digit HUCs identified in the French Broad River Basin are shown in Figure 4.5.8-2.

Surveys

Primary distributional surveys for most priority species have been completed; however, more detailed data is needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Snails – inventory primary distribution; determine potential habitats and distribution surveys.
• Crayfishes – complete primary inventories and determine status of undescribed and recently described endemic species.
• Survey seasonal occurrence of potamodromous, or migratory riverine fishes in the lower reaches of French Broad, Pigeon, and Nolichucky rivers.

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to continued impacts to state waters. Studies should include identification of population trends, as well as assessment of impacts from conservation and development activities and invasive species. These efforts will inform species and habitat management decisions. Long-term monitoring sites have been established and baseline data gathered in most areas of the basin for fishes, crayfishes, and mussels, and monitoring strategies have been developed for many priority species, including Appalachian Elktoe. Periodic sampling of species and habitat conditions should continue and be guided by potential for change. More frequent monitoring may be required for specific project assessment.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Conduct special purpose monitoring to assess performance of specific conservation actions, such as Pigeon River species restoration and French Broad reintroduction fish species.		
Buffalo Species	Lake Sturgeon	Redhorse Species
• Monitor distribution and status of nonnative species (e.g., nonnative catfishes and crayfishes).		
• Continue routine monitoring of priority and state listed fish species.		
Blotched Chub	Blotchside Logperch	Stonecat
Brook Trout		
• Continue routine monitoring of priority and state listed mussel species.		

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
Cataloochee Crayfish	French Broad River Crayfish	Grandfather Mountain Crayfish
• Continue routine monitoring of priority and state listed crayfish species.		
Appalachian Elktoe Creeper	Longsolid Slippershell	Tennessee Clubshell

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Long-term habitat improvement trends in the basin may present more opportunities for reintroduction of native species. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Support research projects on improving the success and efficiency of Pigeon River species restoration projects and other species restoration projects in the basin.		
• Investigate impacts to vulnerable from development, habitat fragmentation, point and nonpoint source pollution, and invasive species in the basin.		
French Broad Crayfish	Appalachian Elktoe Longsolid	Slippershell native catfishes
• Study the success of existing reintroduction projects and explore further opportunities for species restoration, especially extirpated priority species. Determine measurable habitat requirements and assess basin conditions for additional reintroduction opportunities.		
Paddlefish	Freshwater mussels	
• Work with partners to resolve taxonomic issues for crayfish in the genus *Cambarus*.		
• Continue to study the success of mussel reintroductions throughout the basin.		

In addition to the SGCN species found in the basin (see Table 4.5.8.2) a list of knowledge-gap priority species is provided in Table 4.5.8.3.

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats. In addition, education about, and regulation and prevention of the introduction and spread of exotic or invasive species are vital. Specific issues in this basin include high rates of development and associated erosion and sedimentation, secondary and cumulative impacts upon water quality, riparian vegetation restoration and conservation, point sources of pollution, water supply watershed protection, and headwaters protection.

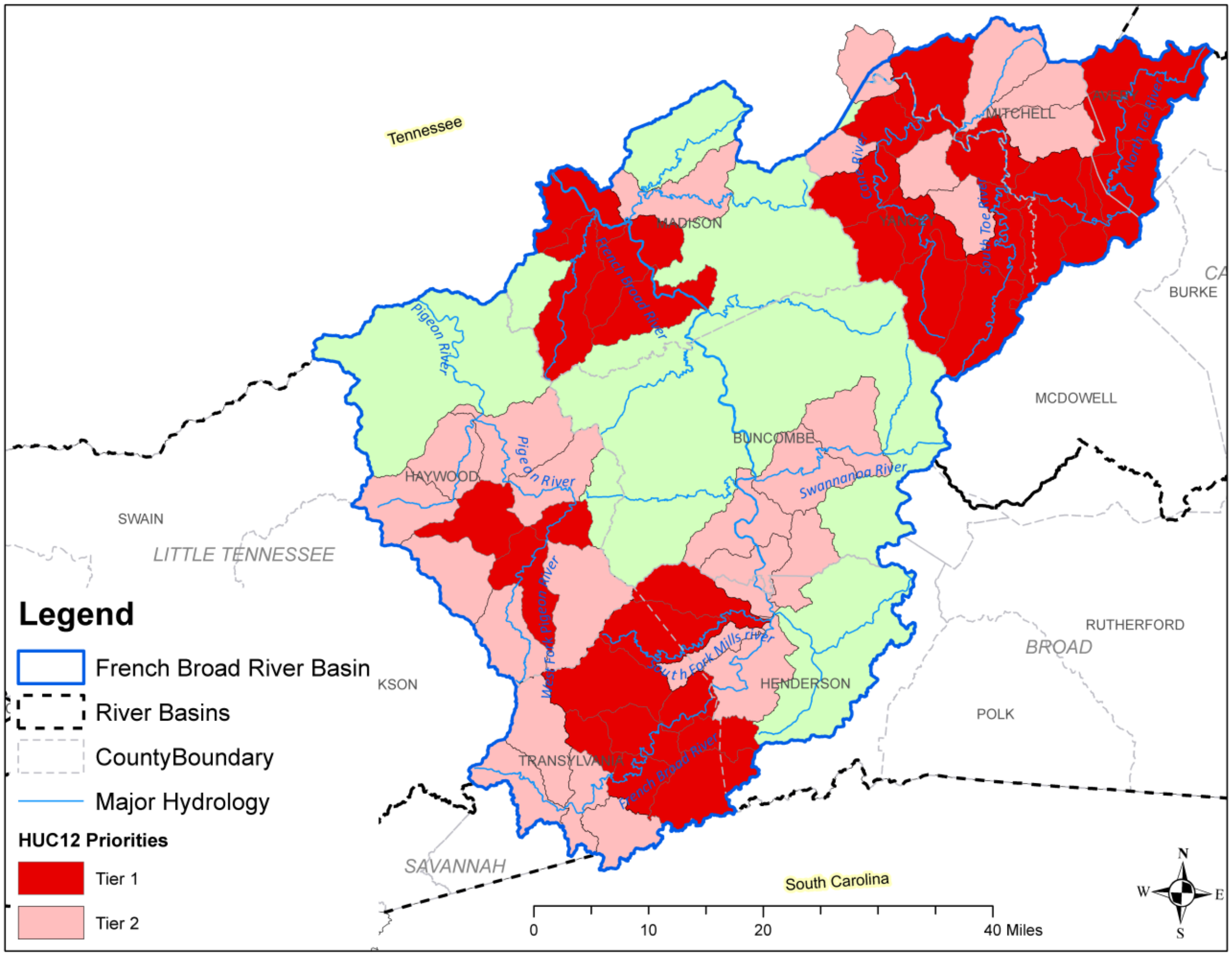
Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Support conservation and restoration of streams and riparian zones in priority areas.
• Incorporate management goals for aquatic community conservation and enhancement planning for Sandymush and Cold Mountain Game Lands. Sandymush Game Lands Cold Mountain Game Lands
• Continue current species restoration efforts in the Pigeon River and reintroduce extirpated species in restored or improved habitats as opportunity allows. Pigeon River
• Continue restoration and augmentation of Appalachian Elktoe and other priority species throughout the basin. Appalachian Elktoe
• Prioritize education and other measures to prevent the introduction or spread of invasive nonnative species, especially crayfishes.
• Support removal of relict dams and enhancement of aquatic organism passage at other barriers.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience. Many overlapping priorities and common objectives, readily available support, and many willing partners provide abundant opportunities in the French Broad River Basin. See NCDWR Basin Plan, chapters 9 and 10, for more information: https://www.deq.nc.gov/about/divisions/water-resources/water-planning/basin-planning/river-basin-plans/french-broad.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Support NCDMS's Watershed Restoration Plan (WRP) and River Basin Restoration Priorities (RBRP) for the French Broad River Basin, and several Local Watershed Plans (LWP) and Project Atlases, including Mud Creek, Bald Creek, South Hominy Creek subbasins (NCWRP 2001b; NCEEP 2003, 2005, 2006). Available online https://www.deq.nc.gov/about/divisions/mitigation-services/planning/watershed-planning-documents.
• Work with multiple agency and non-governmental partners and potential partners to share common goals and objectives, and take advantage of the many opportunities for cooperation throughout the basin.
• Partner with Soil and Water Conservation District and NRCS programs, such as the Agriculture Cost Share Program, as they are also effective partners for conservation in priority areas.
• Continue successful restoration partnerships in the Pigeon River and Richland Creek to restore habitats and species. Pigeon River Richland Creek
• Continue work with Duke Energy, FERC, French Broad EMC, resource agencies, and other cooperators to fulfill relicense settlement agreements and other mitigation for hydropower impacts from Little Tennessee River Basin projects.

Figure 4.5.8-2 Location of priority watersheds in the French Broad River Basin.



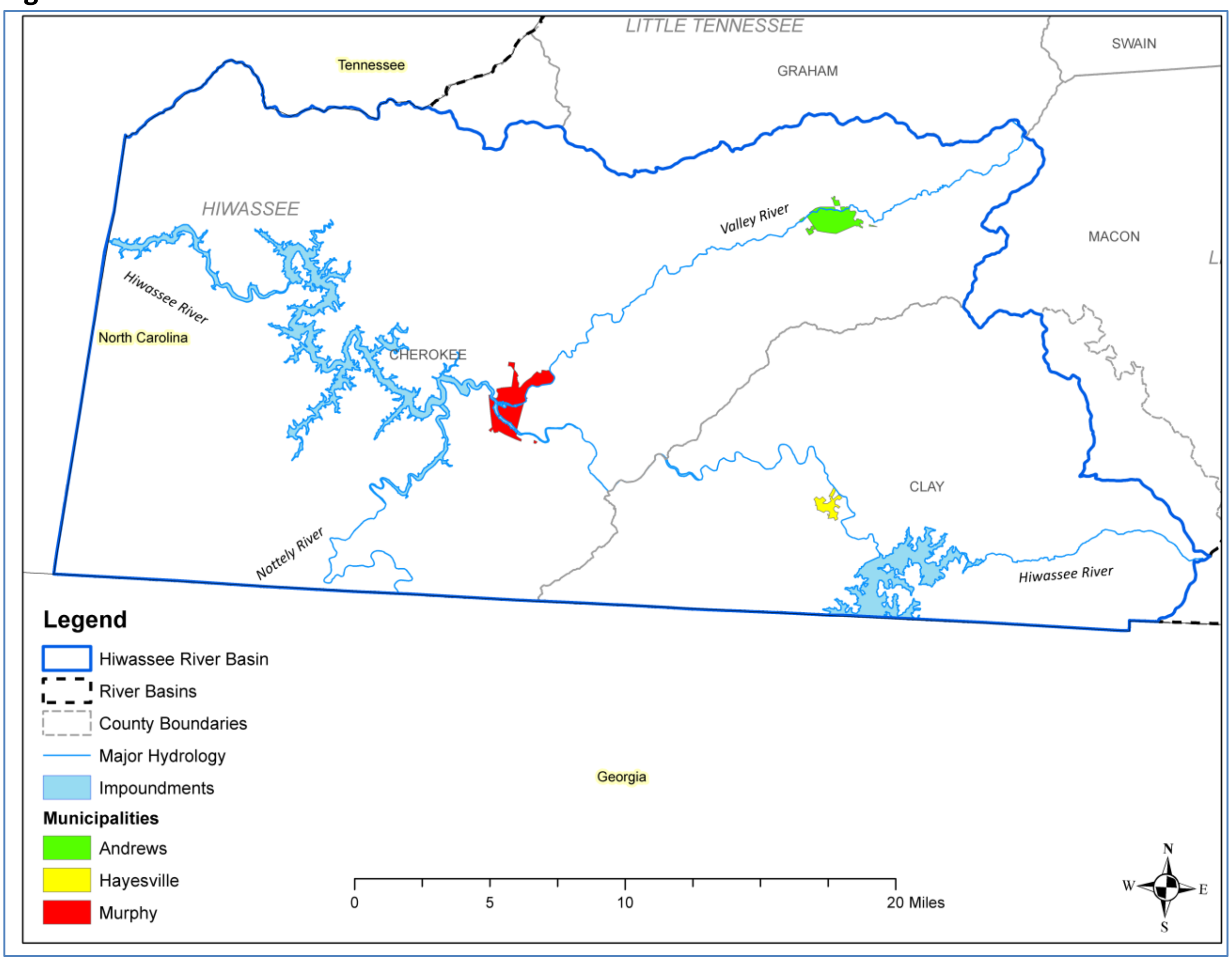
4.5.9 Hiwassee River Basin

4.5.9.1 River Basin Description

The Hiwassee River is part of the Mississippi River System, with headwaters that begin in Georgia. The Hiwassee River flows generally to the northwest through North Carolina and into Tennessee, where it joins the Tennessee River. The North Carolina portion of the basin is located entirely within the Mountain ecoregion. Major tributaries in the basin include the Valley River, Nottely River, Tusquitee Creek, and Brasstown Creek. There are approximately 2,068 miles of freshwater streams and 10,583 acres of impoundments and reservoirs in the basin (NCDWR 2015h; USGSand NHD n.d.).

The Hiwassee River Basin encompasses all or portions of two counties (Cherokee and Clay) and three municipalities (Andrews, Hayesville, and Murphy). Figure 4.5.9-1 depicts the geographic location of the basin.

Figure 4.5.9-1 Location of the Hiwassee River Basin.



The Valley River and Brasstown Creek are the largest streams that are not impounded in the North Carolina portion of the basin (NCDWR 2018). The main stem Hiwassee and Nottely Rivers are regulated by the Tennessee Valley Authority (TVA) for the production of hydroelectric power, with three large impoundments that form the Chatuge, Hiwassee, and Apalachia reservoirs.

- Chatuge Reservoir straddles the North Carolina/Georgia line and impounds the Hiwassee River. The North Carolina portion of the lake is situated in the southwestern portion of the state in Clay County. It provides flood damage reduction, hydroelectric power generation, augmentation of water flows for navigation downstream, and numerous recreational opportunities (TVA 2015). The shoreline is surrounded by development and its proximity to four major cities in four different states likely contributes to its popularity for vacation homes.

- Hiwassee Reservoir impounds the Hiwassee River to create a 22-mile long reservoir in Cherokee County, NC. The reservoir provides hydroelectric power generation and flood damage reduction, as well as several recreational facilities for camping, fishing, and boating (TVA n.d.).

- Apalachia Reservoir is downstream from Hiwassee Reservoir and the powerhouse is operated as run-of-river (little or no water storage provided). Most flow from the dam is diverted through a pipeline from the dam to the Apalachia Powerhouse 8.3 miles downstream in Tennessee before it is returned to the river channel. Minimum flows are released from the dam to the channel downstream, which crosses the state line less than a mile from the dam. The reservoir has very little private shoreline development and no commercial recreational facilities (TVA n.d.).

The Hiwassee River Basin covers approximately 644 square miles, making it one of the smaller basins in the state. Based on 2011 National Land Cover Dataset information, land use in the basin was estimated to be 85% forested, 7% urban or developed, 5% agricultural, 2% grassland, and less than 1% wetland (MRLC 2011). The Nantahala National Forest covers nearly half of the basin and there are substantial private holdings in the middle and higher elevations. Small portions of Eastern Band of Cherokee Indian tribal lands are located within the basin (primarily within the Hanging Dog Creek watershed).

4.5.9.2 Aquatic Resource Conditions

Surface waters of the state are assigned a classification that carries standards for protection of the best uses of that water. Classification categories include aquatic life, recreation, fish consumption, and water supply. There are 1,277 miles of freshwater streams in the basin that have been classified by NCDWR for best intended uses. It is important to note that all waters in the state are rated as impaired based on a state-wide fish consumption advisory for mercury contamination.

Some waterbodies in the basin have supplemental classifications as High Quality Waters (HQW) or Outstanding Resource Waters (ORW) because they either have excellent water quality or they are a significant resource to humans or wildlife (NCDWQ 2015d). There are ORW Special Management Strategy Areas in the basin for Britton Creek (425 acres); Fires Creek area (14,858 acres); Gipp Creek area (1,693 acres); and Tusquitee Creek area (19,561 acres) (NCDWR 2015c). These areas require site-specific provisions to protect resources (e.g., no new discharges or expansion of existing discharges) (see 15A NCAC 02B.0225). Detailed information on water quality parameters in the Hiwassee River Basin is available online from NCDWR Basin Planning Branch (http://portal.ncdenr.org/web/wq/ps/bpu).

Another supplemental classification is NCDWR's trout water designation (Tr), which protects freshwaters for natural propagation of trout and survival of stocked trout on a year-round basis. There are about 306 stream miles in the Hiwassee River Basin designated as trout waters. This is not the same as the Commission's designated public Mountain Trout Waters, which is used to designate waters that are open to public trout fishing.

4.5.9.3 Aquatic Species

Appendix 3 provides lists of SGCN and other priority species for which there are knowledge gaps or management concerns. Appendix 3-18 identifies aquatic SGCN associated with aquatic communities found in this river basin.

In addition to the crayfish, freshwater fish and mussels, and aquatic snails found in the basin, there are also species that have both aquatic and terrestrial stages to their life history. The following list of SGCN are also associated with the aquatic communities in the Hiwassee River Basin.

Common Name	**Scientific Name**	**Federal Status**	**State Status**
AMPHIBIANS			
Eastern Hellbender	*Cryptobranchus alleganiensis alleganiensis*	**PE**	**SC**
REPTILES			
Eastern Spiny Softshell	*Apalone spinifera spinifera*	--	**SC**
Northern Map Turtle	*Graptemys geographica*	--	**SC**

A USFWS assessment of imperiled fishes of the Southern Appalachian ecosystem notes the Hiwassee River is one of the highest priority stream systems in the ecosystem (Butler 2002b). Five highly imperiled taxa were identified for the river system; of these taxa, four are found in North Carolina. The report identified five additional imperiled fishes occurring in the Hiwassee River

Basin in North Carolina. The imperiled species identified in the report that can be found in North Carolina are as follows:

- Sicklefin Redhorse – occurs in clean streams with little sedimentation, generally in swift water over rocky substrata.
- Greenside Darter – occurs in swift riffles with boulders and rubble.
- Redline Darter – occurs in swift, shallow, rocky riffles in clear streams.
- Olive Darter – occurs in fast boulder and bedrock chutes.
- Smoky Dace – occurs in sand and rock pools of small montane streams.

4.5.9.4 Threats Affecting Aquatic Species

Nonpoint source pollution and altered hydrologic regimes are primary impacts on native aquatic communities and their habitats in the Hiwassee basin. Human population growth, and associated residential and commercial development, is one of the most important issues in the basin. Development on steep slopes, and increased impervious surfaces, contribute to increased erosion and sedimentation, as well as increased wastewater and runoff of contaminants, which negatively impacts water quality, hydrology, and aquatic habitat (NCDWQ 2012b). Development is likely to increase substantially in the basin in the coming years.

Impoundments. Including the seven impoundments regulated under FERC licensing or operated by TVA in the basin, an NCDENR dam inventory (NCDEMLR 2014) indicates there are at least 52 impoundments in the basin. Fifty-seven miles of historically free-flowing riverine habitats are now either seasonally or permanently flooded by Chatuge, Mission, Hiwassee, and Appalachia dams and reservoirs, or are indirectly affected by impoundment. The unimpounded reaches of the Nottely and Hiwassee rivers, downstream from dams, are affected by coldwater releases, altered hydrologic regimes, and periodic low levels of DO due to hypolimnetic and peaking power production releases from Chatuge and Nottely dams. Impoundment and thermal alteration may further affect native species by fragmenting available suitable habitat and isolating historically contiguous populations in tributaries.

Water Quality. The NCDWR also monitors state waters to determine if they are supporting their use classification(s) and assigned use-support ratings. The NCDWR reports Lake Chatuge has been consistently oligotrophic (offering little to sustain life) since monitoring first began (2012b) and ecological health has been rated primarily as either poor or at the low end of the fair range in most years (TVA 2015). Periodic higher ecology health ratings have been associated with improved chlorophyll levels, higher levels of DO, timing and amount of rainfall, and changes to runoff and contaminants in sediment (TVA n.d.). The Hiwassee River Watershed Coalition and TVA developed the Lake Chatuge Watershed Action Plan (HRWC 2007) to serve as a restoration guide for returning the lake to good ecological health.

Invasive Species. Nonnative species also pose potential threats to native aquatic species in the Hiwassee River Basin. The Blueback Herring, Asian Clam, Striped Bass, Snail Bullhead, Rainbow Trout, and Brown Trout are established in the basin. Blueback Herring appear to be having an impact on game species (i.e., Walleye) in the Hiwassee Reservoir and Hiwassee River, but impacts to nongame species are unknown at present. Specific impacts from Asian Clam and introduced game fishes are also unclear. Other potential problems are indirect effects from invasive plant species and exotic pathogens that can significantly alter riparian vegetation (e.g., Japanese Knotweed, Hemlock Wooly Adelgid).

4.5.9.5 Basin Specific Recommendations

Conservation priorities that apply statewide to all river basins are presented in Section 4.5.3.3. Priority 12-digit HUCs identified in the Hiwassee River Basin are shown in Figure 4.5.9-2 at the end of this section.

Surveys

While the general distributions of most SGCN species are known, surveys are needed to continually update distributional status for all SGCN and other priority species. Lists of SGCN, knowledge gap, and management priority species are available in Appendix 3. Appendix 3-18 provides a list for all SGCN associated with the Hiwassee River basin.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Fish– complete distribution surveys and support completion of life history studies; identify important spawning areas. Sicklefin Redhorse
• Aquatic snails – inventory primary distribution; determine potential habitats and distribution surveys.
• Determine distribution of nonnative species Blueback Herring

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to continued impacts to state waters. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. These efforts will inform species and habitat management decisions. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

- Create additional ambient monitoring stations or sediment monitoring stations in the basin, especially on Tusquitee Creek (NCDWQ 2012b).
- Continue routine, long-term monitoring to identify population trends for priority and state listed fish species (e.g., Sicklefin Redhorse, Blotched Chub).
- Continue routine surveys for priority and state listed crayfish species.
- Continue routine surveys for priority and state listed mussel and snail species. Monitor Blueback Herring populations to assess impacts on priority species.

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Resolve the taxonomy of mussels and assist partners with species descriptions for.		
Fusconaia sp. *Pleurobema* sp.	*Villosa* sp.	Smoky Dace
• Study early life history, propagation and culture, movement, and habitat use of Sicklefin Redhorse.		
Sicklefin Redhorse		
• Conduct research to improve habitat conditions in regulated reaches of the Hiwassee and Nottely rivers.		
Hiwassee River	Nottely River	
• Work with partners to resolve taxonomic issues for crayfish in the genus *Cambarus*.		
Cambarus sp.		
• Investigate aquatic community response to restoration projects in priority areas.		
• Identify impacts of nonnative species on priority species and habitats.		
Blueback Herring		

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats. In addition, education about, and regulation and prevention of the introduction and spread of exotic or invasive species are vital. Specific issues in this basin include secondary and cumulative impacts upon water quality, riparian vegetation and stream bank restoration and conservation, mitigation of hydropower development impacts, and species restoration opportunities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Support conservation and restoration of streams and native riparian vegetation in priority areas, especially in the Valley River, Brasstown Creek, and the Peachtree-Martins Creek watersheds.

Brasstown Creek	Peachtree-Martins Creek	Valley River

- Enforce erosion control and site-specific stormwater control requirements in order to protect water quality where development is occurring in watersheds with ORW, HQW, and Tr waters, especially Fires Creek and Tusquitee Creek, and the Sweetwater Creek watershed (NCDWQ 2012b).

- Investigate the potential for restoring Christy's Elimia, Sicklefin Redhorse, and priority mussel species in restored or improved habitats.

Christy's Elimia	Sicklefin Redhorse	Freshwater mussels

- Prioritize education and other measures to prevent the introduction or spread of invasive nonnative species, as well as nonnative and invasive aquatic and riparian plants.

Crayfish	Zebra mussels	Alewife Blueback Herring

- Support removal of relict dams and enhancement of aquatic organism passage at other barriers.

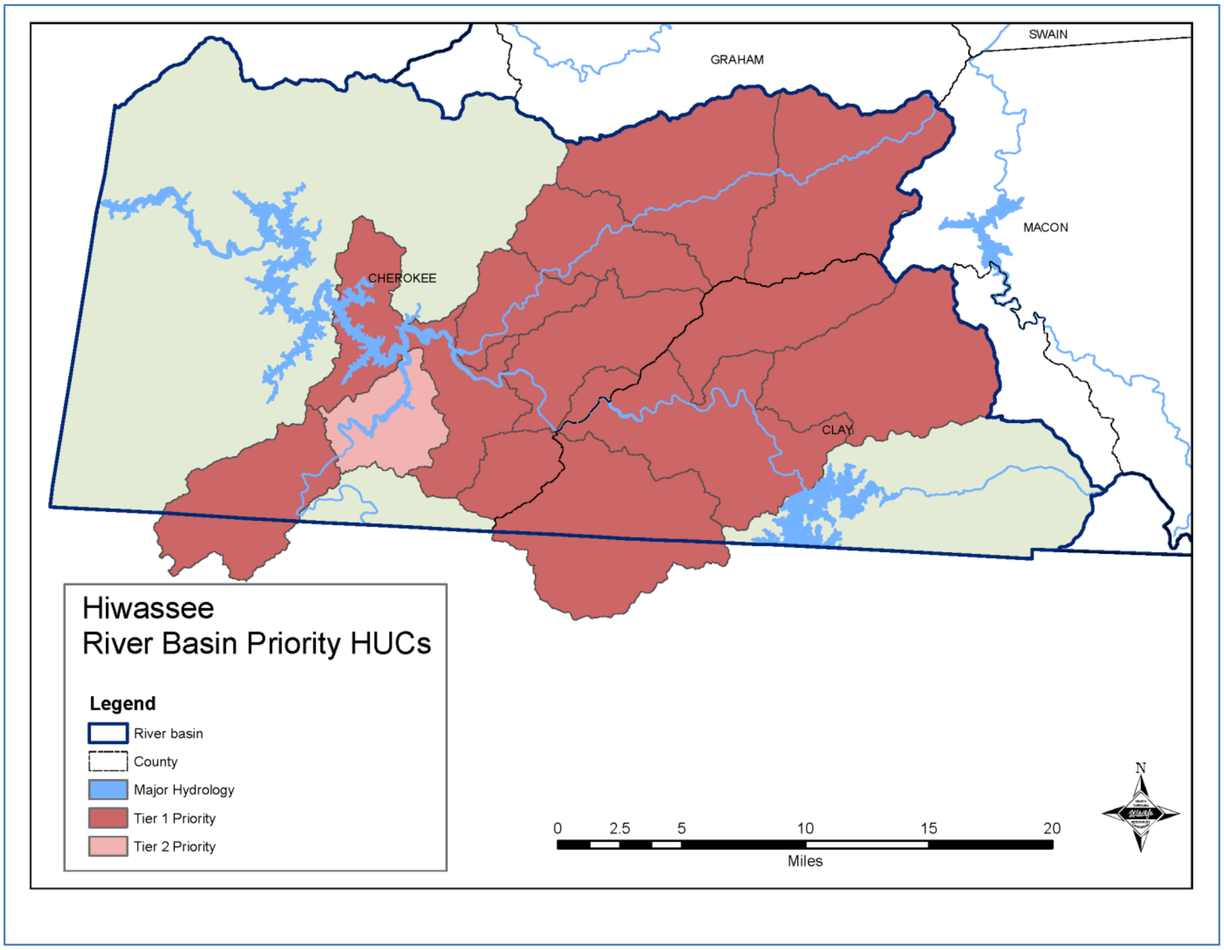
- The NCDMS has identified targeted local watersheds as restoration priorities in most river basins using 14-digit HUCs. Information about these priorities in the Hiwassee River Basin is available online: https://www.deq.nc.gov/about/divisions/mitigation-services/dms-planning/watershed-planning-documents/hiwassee-river-basin-documents.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Continue to cooperate with conservation organizations, resource agencies, and other partners to implement watershed restoration efforts outlined in the Restoration Plan for the Hiwassee River Basin (NCWRP 2001c; NCEEP 2008a, NCDWR 2018), and the Peachtree-Martins Creek Local Watershed Plan (NCEEP 2009c, NCDWR 2018).
• Partner with Soil and Water Conservation District programs, such as the Agriculture Cost Share Program, as they are also effective partners for conservation in priority areas. They can provide technical guidance and assistance to agricultural landowners for planting and maintaining native woody species where fields (e.g., crops, hay, pasture) border riparian corridors (e.g., the Brasstown Creek and Valley River drainage areas) (NCDWQ 2012b).
• Work with partner programs to assist homeowners who have failed to replace septic systems with a new treatment system (a septic tank, dual or recirculation sand filters, disinfection, and step aeration) (NCDWQ 2012b).
• Support watershed restoration and action plans developed for the Valley River and Lake Chatuge (HRWC 2007).
• Continue to work cooperatively as a member of the Candidate Conservation Agreement for Sicklefin Redhorse.

Figure 4.5.9-2 Location of priority watersheds in the Hiwassee River Basin.



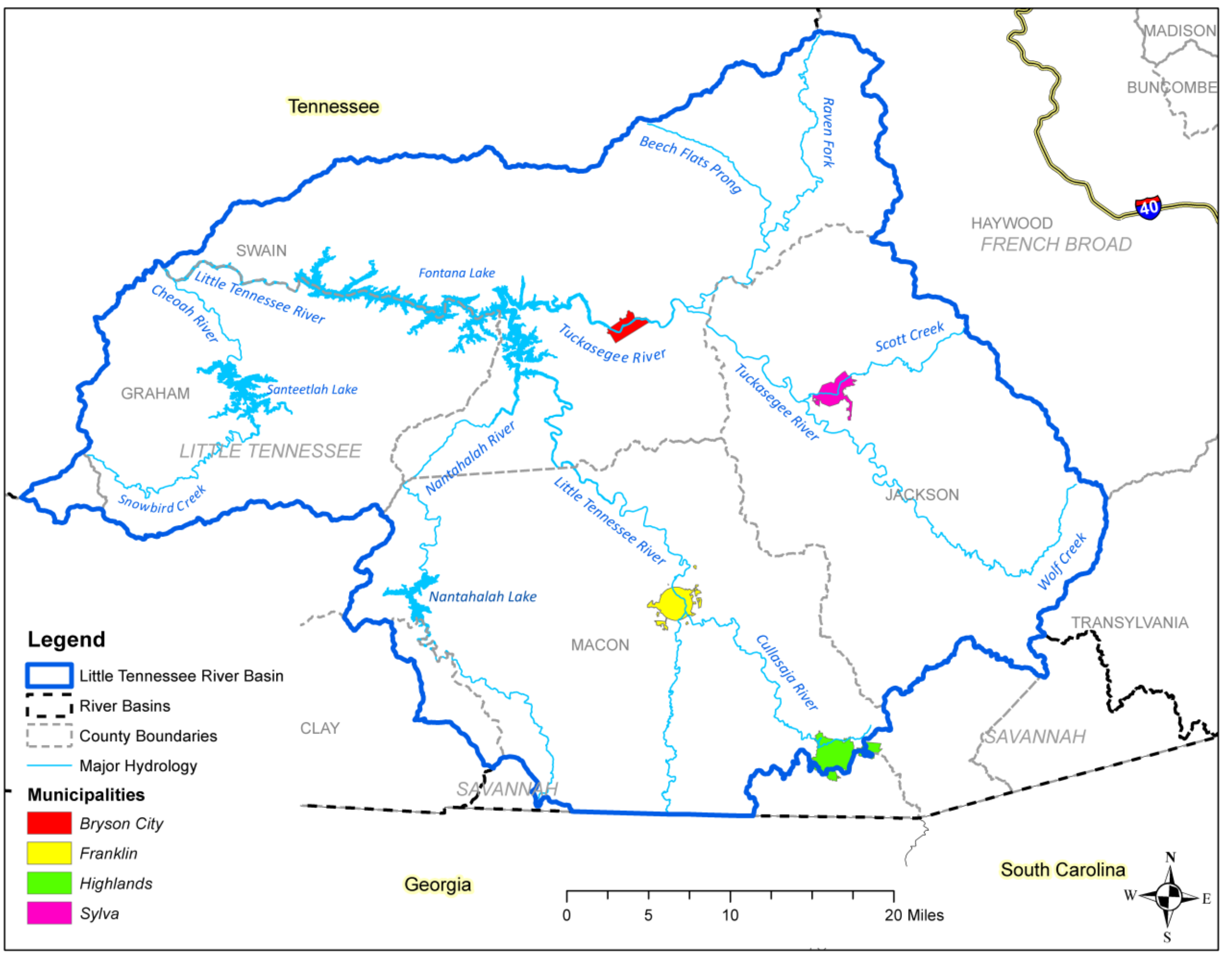
4.5.10 Little Tennessee River Basin

4.5.10.1 River Basin Description

The Little Tennessee River Basin drains part of southwestern North Carolina in Graham, Macon, Swain, Jackson, and Clay counties in the Blue Ridge physiographic province. The headwaters of the Little Tennessee River are in northeastern Georgia, where it flows for seven miles before entering North Carolina. The mainstem Little Tennessee River flows 125 miles through North Carolina before entering Tennessee where it joins the Tennessee River. It is part of the Tennessee/Ohio/Mississippi river system.

The Little Tennessee River Basin encompasses all or portions of six counties and nine municipalities. Sizeable municipalities in this basin include Bryson City, Franklin, Highlands, and Sylva (Figure 4.5.10-1).

Figure 4.5.10-1 Location of the Little Tennessee River Basin.



The basin covers 1,797 square miles in North Carolina and has 2,565 stream miles and 21,158 acres of impoundments. Major tributaries include the Cullasaja, Nantahala, Tuckasegee, Oconaluftee, and Cheoah rivers. Impoundments include Fontana, Nantahala, Calderwood, Cheoah, Santeetlah, Glenville, Bear Creek, Cedar Cliff, Wolf Creek, Tanasee Creek, Ela, Emory, and Sequoyah. Land use in the basin is about 90% forested, 5% urban or developed, 3% agricultural, and less than 1% each of grassland and wetland (MRLC 2011; Jin et al. 2013).

Land ownership in the basin is more than 50% publicly owned, with much of that lying within the boundaries of the Great Smoky Mountains National Park and Nantahala National Forest. The Needmore Game Land (about 4,600 acres) is a recently acquired tract along the Little Tennessee River in Macon and Swain counties and is managed by the NCWRC. The Qualla Boundary Cherokee Indian Reservation covers portions of the Oconaluftee and Tuckasegee watersheds. Much of the higher elevations are within the National Forest and National Park; however, development on private holdings in higher elevations has increased in recent years. Development is presently greatest in the valleys and along the major waterways.

4.5.10.2 Aquatic Resource Conditions

There are more than 3,200 miles of freshwater streams in the basin that have been classified by NCDWR for best uses (NCDWQ 2012c). Water quality is generally good for areas where data are available; however, there are problems in parts of the basin (described below), and the lack of data for nearly half the basin provides an unclear assessment of overall water quality. It is important to note that all waters in the state are rated as impaired based on a state-wide fish consumption advisory for mercury contamination. In addition to the best-use classifications, NCDWR also monitors waters of the state to determine if they are supporting their use classification(s) and assigned use-support ratings. These ratings are published in the most recent 303(d) impaired waterbodies list (NCDWQ 2007b, 2012c).

- The upper headwaters of the East Fork Tuckasegee and Nantahala rivers are designated ORW and multiple higher elevation streams are designated HQW (NCDWR 2015a).

- There are ORW and HQW Special Management Strategy Areas in the basin for the Upper Nantahala River Area (34,397 acres), Tuckaseegee River Area (7,255 acres), North Shore Fontana Lake Area (83,016 acres), Snowbird Creek (10,719 acres), Slickrock Creek (6,648 acres), Flat Creek (2,671 acres), and Oconaluftee River (586 acres) (NCDWR 2015c). These areas require site-specific provisions to protect resource values (e.g., no new discharges or expansion of existing discharges) (see 15A NCAC 02B.0225).

The basin contains some of the highest quality waters in the state, with many high elevation trout streams supporting native Brook Trout. There are approximately 1,727 miles of NCDWR designated trout waters (Tr) in the basin (NCDWR 2015a). This is not the same as the Commission’s designated public Mountain Trout Waters, which is used to designate waters that are open to public trout fishing.

The 24 mile-long reach of the Little Tennessee River between Franklin and Fontana Reservoir supports the greatest diversity and abundance of native aquatic species in the region. Strong populations of Spotfin Chub, Sicklefin Redhorse, and many other priority species generally thrive in the high quality habitat conditions. However, some historically abundant mussels, including Appalachian Elktoe, have declined precipitously throughout the reach. Good habitat conditions and native aquatic communities, including many priority species, also exist in sections of the Tuckasegee River.

4.5.10.3 Aquatic Species

Appendix 3 provides lists of aquatic SGCN and other priority species for which there are knowledge gaps or management concerns. Appendix 3-18 identifies aquatic SGCN associated with the aquatic communities found in this river basin.

In addition to the crayfish, freshwater fish and mussels, and aquatic snails found in the basin, there are also species that have both aquatic and terrestrial stages to their life history. The following list of SGCN are also associated with the aquatic communities in the Little Tennessee River Basin.

Common Name	Scientific Name	Federal Status	State Status
AMPHIBIANS			
Eastern Hellbender	*Cryptobranchus alleganiensis alleganiensis*	**PE**	**SC**
Eastern Long-tailed Salamander	*Eurycea longicauda longicauda*	--	**T**
Mudpuppy	*Necturus maculosus*	--	**SC**
DRAGONFLIES			
Green-faced Clubtail	*Hylogomphus viridifrons*	--	--
Mountain River Cruiser	*Macromia margarita*	**At-Risk**	--
Ocellated Darner	*Boyeria grafiana*	--	--
Ski-tipped Emerald	*Somatochlora elongata*	--	--
Stygian Shadowdragon	*Neurocordulia yamaskanensis*	--	--
Superb Jewelwing	*Calopteryx amata*	--	--
Zebra Clubtail	*Stylurus scudderi*	--	--
REPTILES			
Eastern Spiny Softshell	*Apalone spinifera spinifera*	--	**SC**

4.5.10.4 Threats Affecting Aquatic Species

Impoundment. The major problems affecting species and habitats in the Little Tennessee River Basin are impoundments (dams) and their associated impacts, and excess erosion and stream sedimentation. Of the entire 144 miles of the mainstem Little Tennessee River (in Georgia, North Carolina, and Tennessee), only 47 miles in Georgia and North Carolina remain unimpounded. Habitat alteration from impoundment, coldwater releases, and peaking flow regulation from dams also substantially impair and limit native aquatic communities in the upper Tuckasegee, Nantahala, and Cheoah river systems. Populations of aquatic animals are also fragmented and isolated by dams and other barriers throughout the basin.

Pollution. Potentially high-quality habitats are further degraded from nonpoint source pollution, primarily from erosion and sedimentation from disturbance related to development and agriculture. Water and habitat quality upstream from Lake Emory at Franklin (upper Little Tennessee River, Cullasaja River, Cartoogechaye Creek, and tributaries) varies considerably (LTLT 2011; NCDWQ 2012c for further information). Instream habitat conditions in the upper Little Tennessee River are impaired by excessive sedimentation. Habitat for sensitive aquatic species within this reach is presently marginal to totally lacking. Portions of the Cullasaja River and Cartoogechaye Creek are presently in relatively good shape. While some tributaries in this area contribute significantly, substantial amounts of sediment result from bank erosion along the upper Little Tennessee mainstem. Erosion and sedimentation are also problems in the Tuckasegee River watershed, especially in the larger tributaries between Cullowhee and Bryson City (Cullowhee, Savannah, and Scott creeks).

Invasve Species. Invasive, nonnative species are a potential problem. The Yellowfin Shiner has apparently been introduced to the upper Little Tennessee River and is expanding downstream from Franklin. Other nonnative fish species (e.g., Flat Bullhead, Bluehead Chub, and Yellow Perch) also inhabit portions of the basin. The Asian Clam is established in the Little Tennessee and Tuckasegee rivers. Chinese Mystery Snails have been found in Cowee Creek and Little Tennessee River. The Rusty Crayfish was previously thought to be established in the basin (Cooper 2005; Simmons and Fraley 2010), but recent molecular studies have identified these nonnatives as Kentucky River Crayfish (Kessler et al. 2015). Zebra Mussels are not yet known to be established in North Carolina waters, but are known to exist in the Tellico Reservoir (Little Tennessee River) downstream, in Tennessee.

Nonnative vegetation can also negatively impact native aquatic animal communities. This includes both nonnative aquatic and riparian plant species and nonnative plant pathogens that can alter riparian vegetation and affect aquatic habitats (e.g., Hemlock Wooly Adelgid). Monoecious Hydrilla has invaded the Santeetlah Reservoir, Cheoah River, and Little Tennessee River since 2005.

4.5.10.5 Basin Specific Recommendations

Conservation priorities that apply statewide to all river basins are presented.3.3. Priority 12-digit HUCs identified in the Little Tennessee River Basin are shown in Figure 4.5.10-2 at the end of this section.

Surveys

General distribution of most priority species is know; however, surveys are needed to continually update distributional status for SGCN and other priority species. Lists of SGCN, knowledge gap, and management priority species are available in Appendix 3. Appendix 3-18 provides a list for all SGCN associated with the Little Tennessee River basin.

Priority Conservation Action, Examples of Focal Species or Focal Habitats	
• Snails – complete primary distribution inventories; determine potential habitats and distribution surveys.	
• Fish – identify important spawning areas, potential seasonal tributary use, and early juvenile habitats.	
Sicklefin Redhorse	Spotfin Chub
• Crayfish – complete distribution surveys for burrowing crayfish in areas where data is lacking.	

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to continued impacts to state waters. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. These efforts will inform species and habitat management decisions. Several long-term monitoring strategies are in place for priority areas and species, including Spotfin Chub and Appalachian Elktoe. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Continue routine monitoring of SGCN and other priority and state listed fish species
• Continue routine monitoring of priority and state listed crayfish species.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Continue routine monitoring of priority and state listed mussel species.
• Continue monitoring aquatic community response to remediation of hydropower impacts and species restoration in Cheoah River.

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Resolve the taxonomy of mussels in the genus *Villosa* and species descriptions for Smoky Dace and undescribed crayfish in the genus *Cambarus*.		
Villosa sp.	Smoky Dace	*Cambarus* sp.
• Study the early life history, propagation and culture, movement, and habitat use of Sicklefin Redhorse.		
Sicklefin Redhorse		
• Continue research into potential causes for the decline of Appalachian Elktoe and Slippershell in the Little Tennessee River.		
Appalachian Elktoe	Slippershell	
• Research to improve habitat conditions in regulated reaches of the Cheoah, Nantahala, and Tuckasegee rivers.		
Cheoah River	Nantahala River	Tuckasegee River
• Investigate aquatic community response to restoration projects in priority areas.		
• Identify impacts of nonnative species on priority species and habitats.		
Basket Clam	Kentucky River Crayfish	Hydrilla
• Work with partners to monitor impacts on aquatic species from potential dam removals.		
Ela Dam	Emory Dam	

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Continue to study the success of stocked mussels throughout the basin.

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats. In addition, education about, and regulation and prevention of the introduction and spread of exotic or invasive species are vital. Specific issues in this basin include secondary and cumulative impacts upon water quality, riparian vegetation and stream bank restoration and conservation, mitigation of hydropower development impacts, and species restoration opportunities.

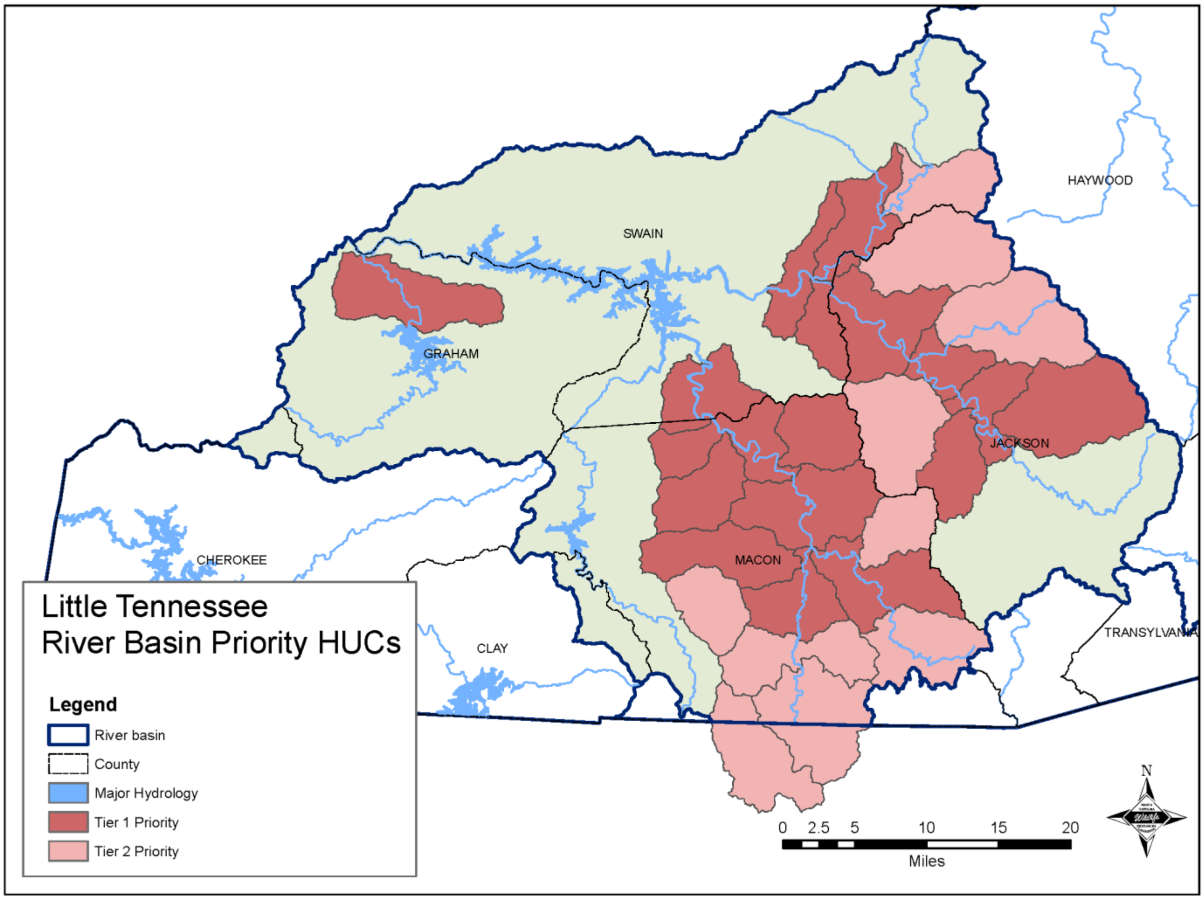
Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Support conservation and restoration of streams and riparian zones in priority areas.		
• Incorporate management goals for aquatic community conservation and enhancement planning and new land acquisitions for Needmore Game Lands.		
Needmore Game Lands		
• Continue reintroduction of extirpated priority and other species in the Cheoah River and other restored or improved habitats as opportunity allows.		
• Continue restoration and augmentation of Sicklefin Redhorse and evaluate potential for the restoration of other target priority species in the upper Tuckasegee, Little Tennessee, and Oconaluftee rivers.		
Sicklefin Redhorse	Oconaluftee River Tuckasegee River	Little Tennessee River
• Prioritize education and other measures to prevent the introduction or spread of invasive nonnative species..		
Crayfish	Zebra Mussels	Alewife Blueback Herring
• Support removal of relict dams and enhancement of aquatic organism passage at other barriers.		

Conservation Programs and Partnerships

Conservation programs, incentives and partnerships should be utilized to the extent possible to conserve high quality resources and important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience. Many overlapping priorities and common objectives, the relative availability of funding and support, and many willing partners provide abundant opportunities in the Little Tennessee River Basin.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Support NCDMS's Watershed Restoration Plan (WRP) and River Basin Restoration Priorities (RBRP) for the Little Tennessee River Basin and Local Watershed Plans (LWPs) and a Project Atlas for the Franklin to Fontana Reservoir reach (NCWRP 2002a; NCEEP 2008b, 2011).
• Work with the Little Tennessee Native Fish Conservation Partnership, a consortium of state and federal resource management agencies, Mainspring Conservation Trust, Watershed Association for the Tuckasegee River, and other stakeholders that identify and address issues common across the watershed in North Carolina. Current projects include finding solutions for construction contractor training in erosion prevention BMPs, land acquisition, and planting riparian vegetation on private land.
• Partner with Soil and Water Conservation District programs, such as the Agriculture Cost Share Program, as they are also effective partner programs for conservation in priority areas.
• Continue working with Duke Energy, Brookfield Energy, Northbrook Energy, FERC, and other resource agencies and cooperators to fulfill relicense settlement agreements and other mitigation for hydropower impacts from Little Tennessee Basin projects.
• Investigate, implement, and support (as appropriate) programs that are directed at candidate or listed species recovery (e.g., Candidate Conservation Agreements, Habitat Conservation Planning, Safe Harbor agreements).
• The entire Little Tennessee River Basin across North Carolina, Georgia, and Tennessee state boundaries has been designated a Native Fish Conservation Area by the Fisheries Conservation Foundation, and an interstate and multi-partner steering committee with topical work groups has been established to identify and cooperatively address basinwide issues. More information is available online https://www.littlet.org.

Figure 4.5.10-2 Location of priority watersheds in the Little Tennessee River Basin.



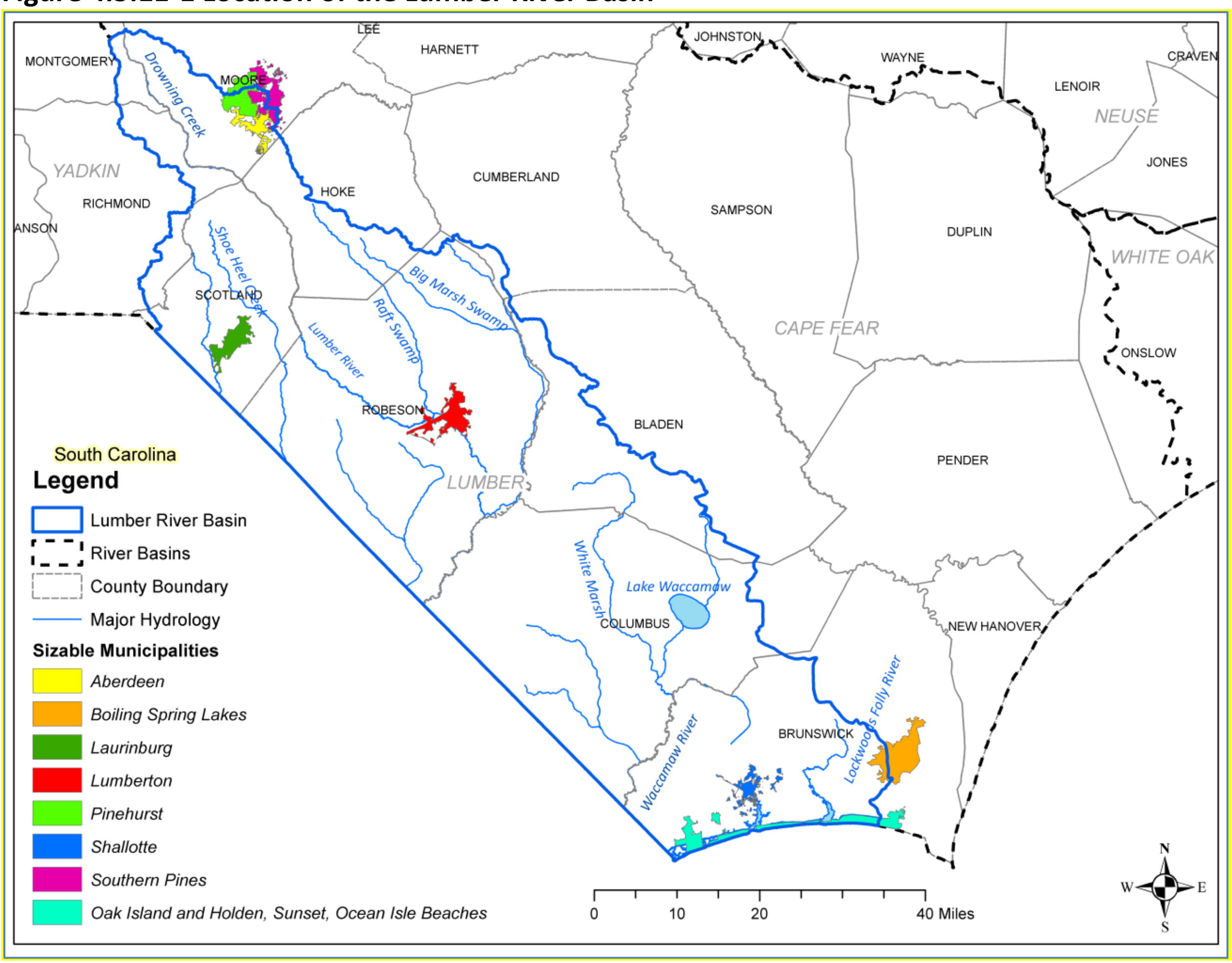
4.5.11 Lumber River Basin

4.5.11.1 River Basin Description

The Lumber River Basin is located in the southeastern corner of North Carolina and the northeastern corner of South Carolina. The headwaters of the Lumber River originate in the Sandhills ecoregion (a notable center of species endemism) in the northwest corner of the basin. The remaining portion of the basin occurs in the Coastal Plain ecoregion. The basin covers approximately 3,329 square miles, making it the seventh largest river basin, and has nearly 26 miles of Atlantic coastline.

The Lumber River Basin encompasses all or portions of 10 counties and 51 municipalities. Sizeable municipalities in this basin include Aberdeen, Boiling Spring Lakes, Laurinburg, Lumberton, Pinehurst, Shallotte, and Southern Pines (Figure 4.5.11-1).

Figure 4.5.11-1 Location of the Lumber River Basin



There are approximately 2,222 miles of freshwater streams, 9,865 acres of freshwater lakes, and 4,680 acres of estuarine or saline waterbodies. All but two rivers in the basin flow into the Great Pee Dee River in South Carolina: the Shallotte and Lockwoods Folly rivers drain directly to the Atlantic Ocean. A total of 115 miles have been designated as State Natural and Scenic Water and 81 miles have been designated as National Wildlife and Scenic Water (NCEEP 2008c; NCGS n.d.; NWSRS n.d.).

Waterbodies in the Sandhills ecoregion are typified by flowing sand-bottomed streams, with acidic water, and are primarily located in the northwestern one-third of the basin. Soils in the Sandhills are well drained and provide a reliable source of groundwater recharge to the streams that run through this part of the basin. Coastal Plain waterbodies are typically meandering and have low flow conditions that contribute to the basin being dominated by blackwater systems. Streams are often braided systems, have wide floodplains, and have natural communities that are often hardwood bottomlands or pocosin wetlands (NCDWQ 2010b,c). Natural Carolina bays can be found throughout much of the basin, with smaller bays that are often ephemeral and ideal habitat for amphibians.

Based on the 2011 National Land Cover Dataset, land use in the basin was estimated to be 29% forested, 2% grassland, 26% agricultural, 32% wetland, and 7.3% urban or developed (NLCD 2011). There are six game lands in the basin covering 109,134 acres, including a portion of the Green Swamp Game Lands. Rapid population growth in the upper end of the basin (Moore and Hoke counties) is associated with recreation activities (golf communities) and Department of Defense (DOD) facilities, while growth along the coast (Brunswick County) is associated with development for tourism. This growth contrasts with other areas in the basin where growth rates are much lower (NCDWR 2010c).

4.5.10.2 Aquatic Resource Conditions

Segments of the Lumber River, Naked Creek, Drowning Creek, and Lake Waccamaw have supplemental classifications as High-Quality Waters (HQW) or Outstanding Resource Waters (ORW) because they either have excellent water quality or they are a significant resource to humans and/or wildlife (NCDWQ 2010b).

Coastal estuarine waters and waters at the mouth of the Lockwoods Folly and Shallotte rivers and their tributaries carry either an HWQ or ORW classification (NCDWR 2015a).There are ORW Special Management Strategy Areas in the basin for the Lumber River (65,169 acres), Naked Creek (25,189 acres), and Lake Waccamaw (9,760 acres) (NCDWR 2015c). These areas require site-specific provisions to protect resource values (e.g., no new discharges or expansion of existing discharges) (see 15A NCAC 02B.0225).

4.5.11.3 Aquatic Species

Appendix 3 provides lists of aquatic SGCN and other priority species for which there are knowledge gaps or management concerns. Appendix 3-18 identifies aquatic SGCN associated with aquatic communities found in this river basin.

In addition to the crayfish, freshwater fish and mussels, and aquatic snails found in the basin, there are also species that have both aquatic and terrestrial stages to their life history. The following list of SGCN are also associated with the aquatic communities in the Lumber River Basin.

Common Name	Scientific Name	Federal Status	State Status
AMPHIBIANS			
River Frog	*Rana [Lithobates] heckscheri*	--	**E**
DRAGONFLIES			
Clearlake Clubtail	*Phanogomphus australis*	--	--
Shining Clubtail	*Stylurus ivae*	--	--
Townes' Clubtail	*Stylurus townesi*	--	--
REPTILES			
Carolina Swamp Snake	*Liodytes pygaea paludis*	--	**SC**
Diamondback Terrapin	*Malaclemys terrapin*	--	**SC**
Glossy Crayfish Snake	*Liodytes rigida*	--	--
Rainbow Snake	*Farancia erytrogramma*	--	--

4.5.11.4 Threats Affecting Aquatic Species

Pollution. Impacts affecting species and their habitats within the Lumber River Basin include nonpoint sources of pollution resulting from inadequate management practices related to agriculture, forestry, construction, and stormwater discharges. Sedimentation due to erosion is one of the major causes of habitat loss in this basin.

Water Quality. In addition, the Lumber River Basin has a dense concentration of swine production facilities. There are 208 permitted Confined Animal Feeding Operations (CAFOs) in the Lumber River Basin with 299 waste lagoons associated with the facilities (NCDEQ 2024(a)). Waste from these sites contains high levels of nutrients (e.g., nitrogen and phosphorus) in addition to fecal coliform bacteria and any chemical compounds, such as antibiotics or hormone products used in commercial feeding operations (NCDWR 2015b). Animal-waste lagoons and spray fields that discharge near or into aquatic environments through runoff, percolation into groundwater, and volatilization of ammonia and the release of bacterial contamination can significantly degrade water quality and endanger human and animal health (Mallin 2003; Mallin and Cahoon 2003).

Impoundments. According to a NCDENR dam inventory (NCDEMLR 2014), there are at least 145 impoundments in the basin, most of which are small impoundments. The consequences of these dams include blocked migration routes for diadromous and resident native species, and reduced recolonization and dispersal potential for multiple aquatic taxa (Williams et al. 1993; Etnier 1997; Neves et al. 1997; Warren et al. 2000; NCWRC 2005). Water withdrawals for irrigation and similar uses further change flow patterns and reduce the quality/quantity of available habitat for aquatic species (NCDWQ 2010b). Invasive species (e.g., Flathead Catfish and Red Swamp Crayfish) are established in the Lumber River Basin and continue to negatively impact native species populations (Fuller et al. 1999; Cooper 2005) via predation and competition.

4.5.11.5 Basin Specific Recommendations

Conservation priorities that apply statewide to all river basins are presented in Section 4.5.3.3. Priority 12-digit HUCs identified in the Lumber River Basin are shown in Figure 4.5.11-2 at the end of this section.

Surveys

Priorities for distribution and status surveys need to focus on aquatic snails, crayfish, mussels, and fish believed to be declining or dependent on at-risk or sensitive communities, as well as poorly understood or newly discovered species.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Conduct distributional and status surveys on basin-specific priorities

Coastal Plain crayfishes	Broadtail Madtom	Banded Sunfish
Pygmy Sunfish species	Sandhills Chub	Ironcolor Shiner

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to continued impacts to state waters. Studies should include identification of population trends, as well as assessment of conservation or development activities. These efforts will inform species and habitat management decisions. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Monitor populations of endemic fishes and mussels occurring in Lake Waccamaw to assess the effect of land use changes and practices in the surrounding watershed and the introduction of nonnative plants and animals. Lake Waccamaw

Research
Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, the impacts of climate change and invasive species, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. Studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Support species descriptions for undescribed taxa.		
Broadtail Madtom		
• Determine vulnerability of species across all taxa groups to contaminants such as endocrine-disrupting chemicals (EDCs), microplastics, and other compounds that are present in many of the waterways of the Lumber River Basin.		
• Identify ways to eradicate or reduce the impacts of nonnative species throughout the basin as well as proactively preventing future introductions.		
Blue Catfish	Flathead Catfish	Apple Snails

Management Practices
Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. General needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats. In addition, education about, and prevention of the introduction and spread of exotic or invasive species are vital. Specific issues that need to be addressed in this basin include secondary and cumulative impacts upon water quality, buffer protection, water supply watershed protection, and protection of headwaters.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Promote programs to upgrade/increase compliance at wastewater treatment facilities and CAFOs.
• Promote prevention and awareness of the spread of exotic species and damage to native resources, communities and economic impacts.
• Provide support for land conservation, particularly in riparian areas (acquisition, easements, restoration).
• Support well-planned stream habitat, hydrology, and connectivity restoration work in collaboration with other organizations, where appropriate.
• Continue to identify areas critical to aquatic ecosystem health that can be conserved or restored.
• Coordinate and provide management guidance on managed properties, such as NCWRC game lands, to maximize effective conservation and restoration activities on these public lands.
• Pursue propagation, augmentation, and reintroduction of rare native species into appropriate habitat.

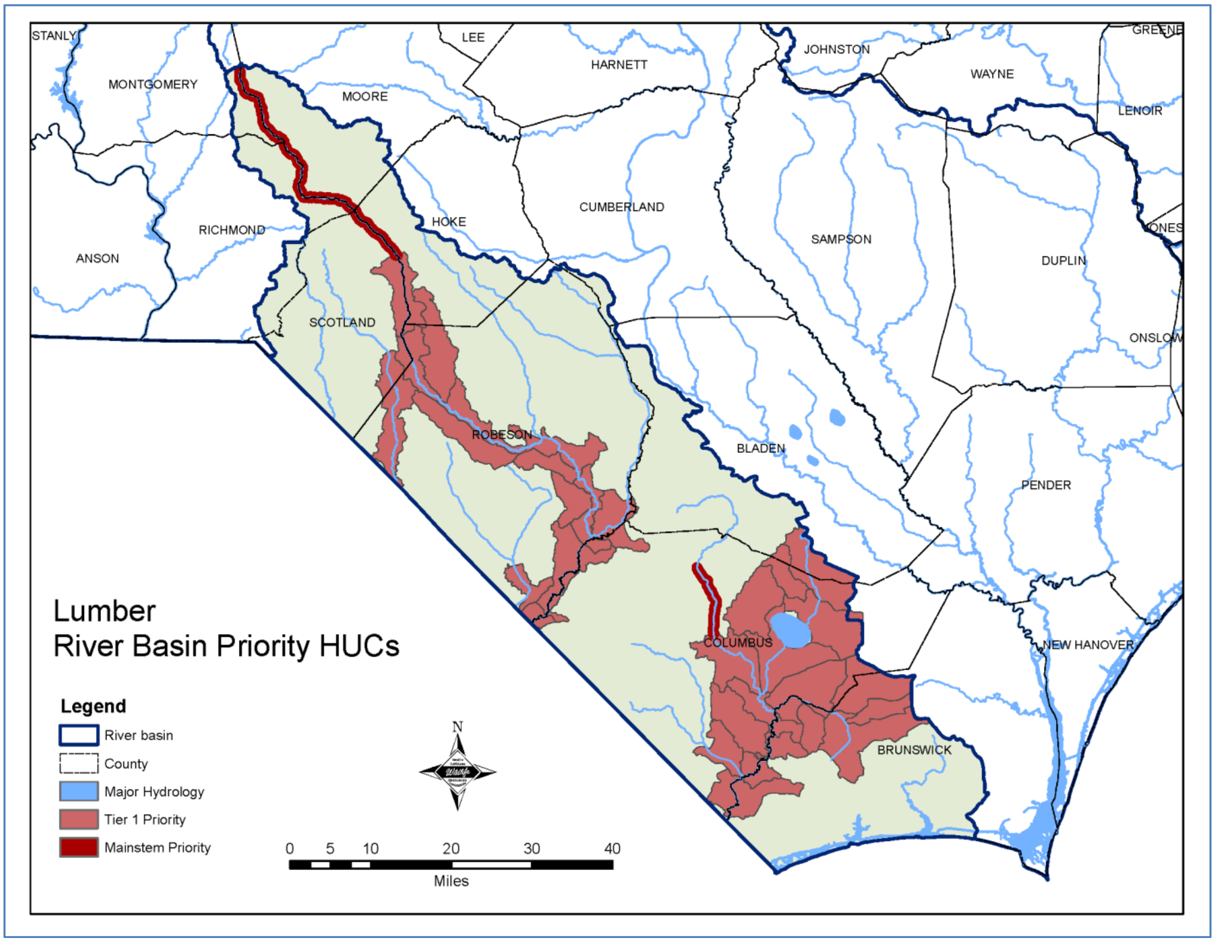
Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to conserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Guide academic research projects to help achieve specific conservation goals and objectives.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Work with conservation partners to advance conservation and habitat protection/restoration goals.
• Support the development and application of an aquatic nuisance species management plan with other agencies/groups.
• Address secondary and cumulative impacts upon water quality, buffer ordinances, water supply watershed protection, headwaters protection, etc. (NCDWQ 2000a, NCWRC 2002).
• Work with and promote existing programs that help farmers reduce sedimentation/erosion (e.g., install fences to keep livestock out of streams) as well as reduce pesticide and herbicide use.
• Provide landowners, developers, and municipal planners with education and guidance on how to protect aquatic habitats and water quality.

Figure 4.5.11-2 Location of priority watersheds in the Lumber River Basin.



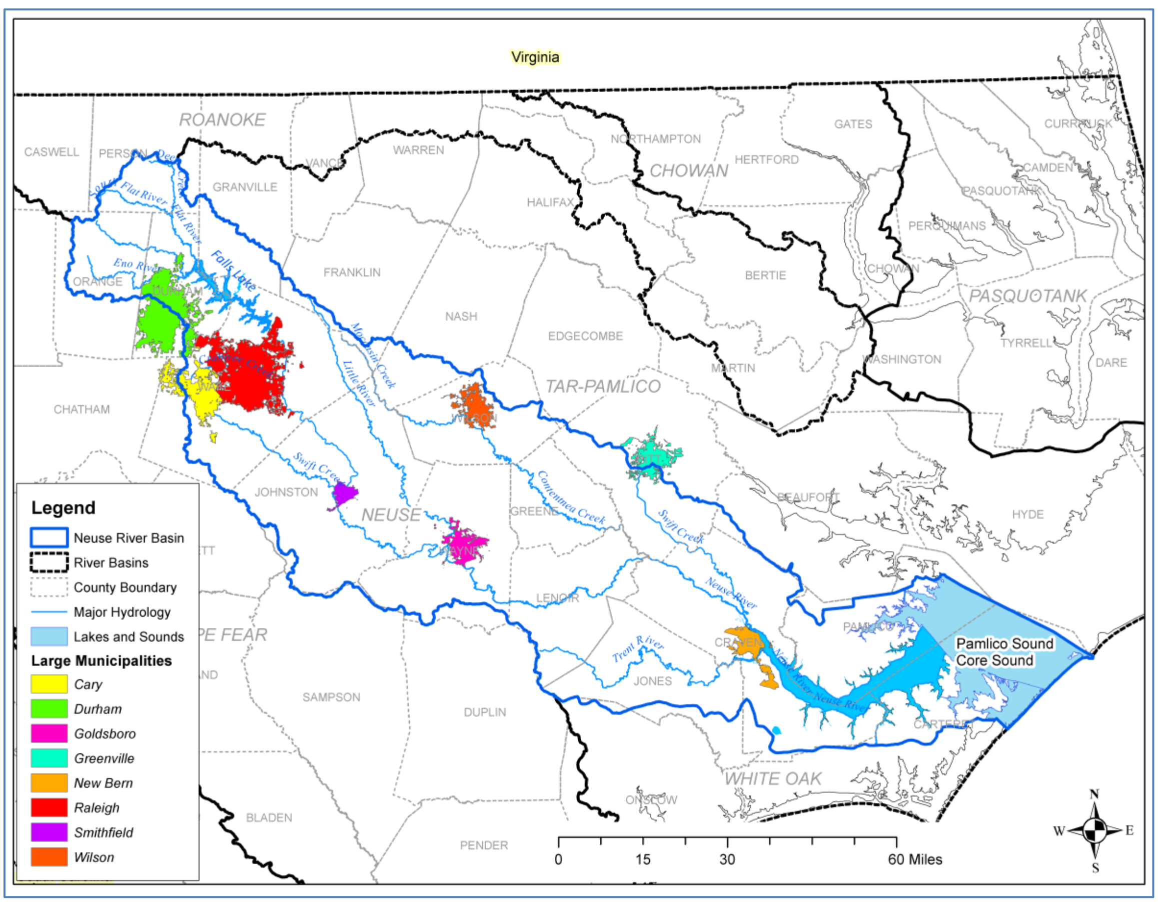
4.5.12 Neuse River Basin

4.5.12.1 River Basin Description

The Neuse River Basin is an Atlantic Slope drainage with headwaters originating in the north-central Piedmont ecoregion in Person and Orange counties. The uppermost 22 miles of the river's main stem is impounded by Falls of the Neuse Reservoir dam just northeast of the city of Raleigh. Downstream of the dam, the river continues its course for approximately 185 miles southeast past the cities of Raleigh, Smithfield, Goldsboro, and Kinston (NCDWQ 2009; 2012d; 2015e, 2018). It flows southeast until it reaches tidal waters near Streets Ferry, upstream of New Bern. At New Bern, the river broadens dramatically and turns into a 40-mile long brackish tidal estuary that eventually flows into the Pamlico Sound.

The Neuse River Basin encompasses all or portions of 23 counties and 84 municipalities (NCDEQ 2023). Large cities located in this basin include several of the fastest growing urban and suburban areas in the state, Cary, Durham, Goldsboro, Greenville, New Bern, Raleigh, Smithfield, and Wilson. Figure 4.5.12-1 depicts the geographic location of the basin.

Figure 4.5.12-1 Location of the Neuse River Basin.



The Neuse River Basin is the third largest basin in North Carolina with 6,235 square miles drainage area and is one of only four major river basins whose boundaries are located entirely within the state (NCDWR 2015d,h, NCDWR 2021).

There are two distinct portions of the Neuse River Basin: the upper one-third in the Piedmont and the lower two-thirds in the Coastal Plain. Streams in the Piedmont portion typically are low gradient, with sluggish pools separated by riffles and occasional small rapids. Soils are highly erodible in the Piedmont and are underlain by fractured rock formations that have a limited water storage capacity. This portion of the basin tends to have low summer flows and limited ability to assimilate oxygen-consuming wastes, which contributes to hypoxia.

The Coastal Plain portion features slow-moving blackwater streams, low-lying swamps, and productive estuarine waters. The larger waterbodies in the basin are meandering, often lined with swamps and bottomland hardwoods, and often have naturally low DO and pH. Soils are deep sands that have a high groundwater storage capacity. Natural lakes include the remnants of bay lakes in the lower Coastal Plain (NCDWQ 2012a).

There are several areas of rapidly expanding urban land use; however, much of the land use in the basin is agriculture or forest. Protected forested land in the basin includes Eno River State Park and seven game lands covering 236,330 acres (e.g., portions of the Croatan National Forest, Butner-Falls of Neuse, Neuse River) (NCDWQ 2012a). Based on 2011 National Land Cover Dataset information, land use in the basin was estimated to be 29.4% forested, 4.4% grassland, 26.2% agricultural, 19.3% wetland, and 12.4% urban or developed (MRLC 2011; Jin et al. 2013).

4.5.12.2 Aquatic Resources

The Neuse River basin is subject to state protection of riparian buffers as part of a nutrient sensitive water (NSW) management strategy (15A NCAC 02B.0714). All waters in the Neuse River basin are classified as NSW. This classification is intended for waters that need additional nutrient management due to greater vulnerability to excessive aquatic vegetation growth (NCDWQ 2015d).

Major tributaries include the Eno, Flat, Little, and Trent rivers and Crabtree, Swift, and Contentnea creeks. The basin contains:

- 17,901 acres and 3,389 miles of freshwater streams,
- 370,779 acres and 143 miles of saltwaters in the basin,
- 16,414 acres of freshwater reservoirs and lakes,
- 369,977 estuarine acres, and
- 21 miles of Atlantic coastline.

There are 284 different stream reaches that have supplemental classifications as High Quality Waters (HQW) (NCDEQ 2025) representing about 265 stream miles in the basin because they have excellent water quality (NCDWQ 2025). This includes freshwater segments of the Neuse, Eno, Little, and South rivers. Coastal estuarine waters of the Intracoastal Waterway, Core and Pamlico Sounds, and their bays carry a HWQ classification (NCDWR 2025). The Neuse River Estuary is made up of the Pamlico Sound, upper Core Sound, West Bay, Barry Bay, Rumley Bay, Cedar Island Bay, Back Bay, and other estuarine embayments and tributaries. The HQW classification includes NSW and ORW classifications (NCDWQ 2009).

Deep Creek and Rocky Fork Branch in the Flat River watershed have been classified as Outstanding Resource Waters (ORW) to protect the exceptional water quality in the watershed (NCDWQ 2009). There are 63,513 acres of saltwater ORW in the Neuse River basin (NCDWQ 2009). There are ORW Special Management Strategy Areas in the basin for Deep Creek (23,660 acres and 22 stream miles). The Neuse-Southeast Pamlico Sound, Core Sound, Thorofare Bay, with Pamlico and Back Sound Areas (126,940 acres) (NCDWR 2015c). These areas require site-specific provisions to protect resource values (no new discharges or expansion of existing discharges) (see 15A NCAC 02B.0225).

A statewide fish consumption advisory from the North Carolina Department of Health and Human Resources, Division of Public Health is in place due to mercury contamination (http://epi.publichealth.nc.gov/oee/programs/fish.html.) Fish such as blackfish (bowfin), largemouth bass and chained pickerel (jack fish) have been found to have high mercury levels (NCDWR 2021).

4.5.12.3 Aquatic Species

Appendix 3 provides lists of aquatic SGCN and other priority species for which there are knowledge gaps or management concerns. Appendix 3-18 identifies aquatic SGCN associated with the aquatic communities found in this river basin.

In addition to the crayfish, freshwater fish and mussels, and aquatic snails found in the basin, there are also species that have both aquatic and terrestrial stages to their life history. The following list of SGCN are also associated with the aquatic communities in the Neuse River Basin.

Common Name	Scientific Name	Federal Status	State Status
AMPHIBIANS			
Neuse River Waterdog	*Necturus lewisi*	**T**	**T**
DRAGONFLIES			
Coppery Emerald	*Somatochlora georgiana*	--	**--**

Septima's Clubtail	*Gomphurus septima*	**At-Risk**	**--**
Shining Clubtail	*Stylurus ivae*	--	**--**
Skillet Clubtail	*Gomphurus ventricosus*	--	**--**
Splendid Clubtail	*Gomphurus lineatifrons*	--	**--**
Sweetflag Spreadwing	*Lestes forcipatus*	--	**--**
REPTILES			
Carolina Saltmarsh Snake	*Nerodia sipedon williamengelsi*	--	**SC**
Diamondback Terrapin	*Malaclemys terrapin*	--	**SC**
Glossy Crayfish Snake	*Liodytes rigida*	--	--
Rainbow Snake	*Farancia erytrogramma*	--	--

4.5.12.4 Threats Affecting Aquatic Species

Pollution. It is important to note that all waters in the state are rated as impaired based on a statewide fish consumption advisory for mercury contamination. In the Wake County portion of the basin, Brier Creek, Little Brier Creek, Crabtree Creek, Lake Crabtree, Rocky Branch, Walnut Creek, and the Neuse River (from Crabtree Creek to Auburn-Knightdale Road) all carry a health advisory against eating any fish from these waters because of contamination by polychlorinated biphenyls (PCBs) (NCDPH 2014).

Emerging compounds of concern include per- and polyfluoroalkyl substances (PFAS) and 1,4-dioxane that have been found in public drinking water supply reservoirs in the Neuse River Basin (NCDEQ 2021). PFAS are a class of synthetic chemicals used in the production of a wide variety of manufactured goods including non-stick cookware, water-repellent clothing, stain resistant fabrics, cosmetics, food packaging materials, and fire-retardant foams. These compounds are composed of fluorinated carbon chains that readily transport in the environment and are highly resistant to degradation. The synthetic industrial organic compound 1,4-dioxane is used as an industrial solvent and is formed as a byproduct of some industrial processes. It persistent in the environment and is difficult to remove through standard water and wastewater treatment processes. The USEPA has characterized the compound as likely to be carcinogenic to humans (NCDEQ 2021).

In 2007, the Neuse River was listed as one of the most endangered rivers in the United States because of eutrophication caused by high waste loads attributed to development and agriculture (American Rivers 2007; Ferrell et al. 2014). Nonpoint source pollution from agriculture and forestry has degraded aquatic habitats within the basin. For example, animal waste byproducts cause increased levels of nitrates and phosphates, which can lead to excess growth of algae and aquatic plants and to decreased DO levels (especially during summer months) that result in fish kills.

Atmospheric deposition of nitrogen from cars and factories can lead to decreased water quality. Large quantities of nutrients, especially nitrogen, from nonpoint sources are considered the greatest threat to water quality of the Neuse River Estuary. There are over 400 point source waste discharge permits for the basin from municipal wastewater treatment plants, industrial facilities, small package treatment plants, and large urban and industrial stormwater. Municipal point source waste pollution also contributes nitrogen, phosphorus, and other contaminants to waters in the basin.

Water Quality. There are 509 permitted Confined Animal Feeding Operations (CAFOs) in the Neuse River Basin with 848 waste lagoons associated with the facilities (NCDEQ 2024(a)). Waste from these sites is a source of high levels of nutrients (e.g., nitrogen and phosphorus) (NCDWR 2015b). Animal-waste lagoons and sprayfields that discharge nutrients and bacteria contamination near or into aquatic environments through runoff, percolation into groundwater, and volatilization of ammonia and the release of bacterial contamination can significantly degrade water quality and endanger health (Mallin 2003; Mallin and Cahoon 2003).

Impoundments. According to A Southeast Aquatic Resources Partnership (SARP) dam inventory (SARP 2024), there are over 4,500 impoundments in the basin, most of which are mill or farm ponds. Impoundments in the basin have affected aquatic species by physically altering habitat, reducing flows and DO, and causing erosion. Modification of flow regimes by upstream impoundments affects various life history characteristics of downstream migratory fishes and other aquatic fauna by limiting dispersal and recolonization. Additionally, water withdrawals for irrigation reduce the amount of habitat available for aquatic species (NCDWQ 2009).

The upper 22 miles of the Neuse River proper are impounded by the Falls of the Neuse Reservoir dam which was built by the US Army Corps of Engineers to provide drinking water, flood control, and recreation opportunities. Other major reservoirs in the Neuse River Basin include Little River Reservoir, Lake Michie, Lake Orange, Corporation Lake, Lake Ben Johnson, Lake Butner, Lake Rogers, Lake Wheeler, Lake Benson, and Buckhorn Reservoir. The Milburnie Dam was removed in 2017 which opened 15 miles of the Neuse River and tributaries for migration and spawning of American Shad, Striped Bass, and other anadromous fish as well as restoration of free-flowing stream habitat for many priority aquatic species (American Rivers 2017).

The Falls of the Neuse Reservoir (Falls Lake) and Lake Johnson are rated as impaired based on turbidity, failure to meet water quality standards for nutrient enrichment, and PCB contamination in fish tissue samples. Eutrophic conditions have been present in Falls Lake since it was impounded in the early 1980s (NCOEE 2007, 2009, n.d.; NCDWR 2015b) and high levels of chlorophyll *a*, low DO, turbidity, and contamination are persistent problems. Other examples of impaired impoundments include Big Lake and Reedy Creek Lake in Umstead State Park (Wake County).

Development. United States Census Bureau (USCB) data shows that five of the fastest-growing cities in the United States are located in the Neuse River Basin. According to the 2020 Census, the state's population is nearly 10.5 million people. The population is projected to grow ato 15.3 million by 2060. The Raleigh-Cary area in the basin was ranked 20th for growing metropolitan areas nationwide (US Census 2025). North Carolina's Office of State Budget and Management has reported the state is the 3rd fastest growing state when compared to the rest of the nation (NCOSBM 2024).

Urban centers in the Piedmont rely on surface water withdrawn from reservoirs or directly from the Neuse River (about two-thirds of the total demand on the basin), while rural areas and communities in the Coastal Plain rely more on ground water (NCDWR 2015c). As is the case in the Cape Fear River Basin, current drinking water supplies and wastewater treatment capacities may not be sufficient to meet demands caused by population growth, and new infrastructure will be needed to meet these demands. Development and the related need for additional infrastructure will result in increased stresses on already impaired aquatic resources. The loss of natural areas and increase in impervious surfaces that result from rapid population growth cause increased sediment runoff from construction. More homes mean an increase in lawn fertilizer runoff. Heavy metal runoff contributes to elevated mercury levels in fish tissue. These point and nonpoint runoff sources accumulate in the Pamlico Sound, where researchers at the University of North Carolina at Wilmington found one-third of the sediments contaminated with chemicals and toxic metals (Powell 1999).

Invasive Species. Hydrilla was a problem in the Eno River watershed in the upper Neuse River basin. The Eno River Hydrilla Management Task Force was formed in 2013 and the partnership determined herbicides would be the best control agent against hydrilla. Treatment applied from 2015 to 2019 was largely successful for the treated section of the Eno River. However, infested areas downstream from Falls Lake continues to be an issue (NCDEQ 2024).

4.5.12.5 Basic Specific Recommendations

Conservation priorities that apply statewide to all river basins are presented in Section 4.5.3.3. Priority 12-digit HUCs identified in the Neuse River Basin are shown in Figure 4.5.12-2 at the end of this section.

Surveys

General surveys are needed to complete primary distributional status for SGCN and other priority species (see Appendix 3).

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Fishes – Continue surveys to determine distribution and status of SGCN and other priority species.

Banded Sunfish	Bridle Shiner	Least Brook Lamprey
Black Banded Sunfish	Ironcolor Shiner	Mimic Shiner
		V-lip Redhorse

- Mussels – determine distribution and status of SGCN and other priority species.

Chameleon Lampmussel	Green Floater	Yellow Lampmussel
Creeper	Triangle Floater	

- Crayfishes – determine distribution and status of SGCN and other priority species.

Carolina Ladle Crayfish	Croatan Crayfish	Pamlico Crayfish

- Snails – conduct baseline distribution surveys for all species that occur in the basin.

- Exploratory surveys on the Neuse River to document suspected populations of Tidewater Mucket.

  Tidewater Mucket

Monitoring
Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to continued impacts to state waters. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. These efforts will inform species and habitat management decisions. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species.

Research
Research to facilitate appropriate conservation actions includes investigation of habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Study habitat use and life history characteristics of SGCN and other priority species.		
Carolina Ladle Crayfish	Least Brook Lamprey	V-lip Redhorse
Green Floater	Triangle Floater	
• Support taxonomic research for SGCN and other priority species.		
Cambarus sp. C complex	Coastal Plain crayfish	Mimic Shiner
Chameleon Lampmussel	Creeper	Panhandle Pebblesnail
	mussel genus *Elliptio*	
• Support development of captive propagation techniques for SGCN and other priority species.		
Green Floater	Ironcolor Shiner	Triangle Floater
• Support genetics research that informs augmentation policy for priority species		
Bridle Shiner	Green Floater	Triangle Floater
Chameleon Lampmussel	Ironcolor Shiner	
• Determine impacts of nonnative species on SGCN and other priority species.		
Japanese Mystery Snail	Red Swamp Crawfish	Flathead Catfish

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats. In addition, education about, and regulation and prevention of the introduction and spread of exotic or invasive species are vital.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Support efforts to restore the native aquatic community through reintroduction or augmentation.
• Support acquisition of land that is adjacent to current conservation holdings or priority watersheds.
• Support other regulatory agencies to minimize impacts on species and habitats.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Where appropriate, support dam removal and habitat restoration.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

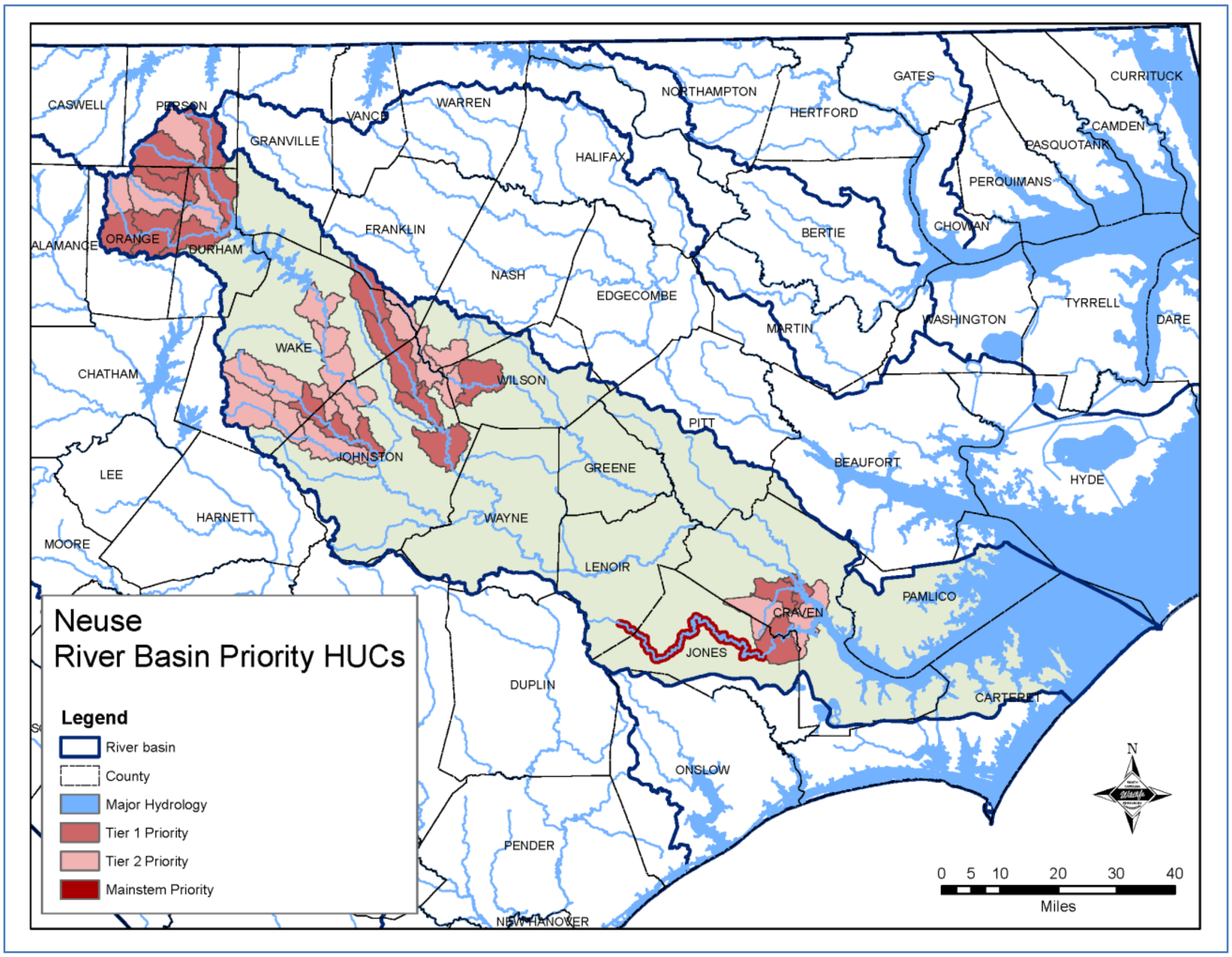
Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Guide academic research projects to help achieve specific conservation goals and objectives.
- Support the application of an aquatic nuisance species management plan with other agencies/groups.
- Address secondary and cumulative impacts upon water quality (buffer ordinances, water supply watershed protection, headwaters protection).
- Work with and promote existing programs that help farmers reduce sedimentation/erosion (e.g., installing fences to keep livestock out of streams and improving tilling practices), as well as reduce pesticide and herbicide use.
- Support stormwater management and wastewater treatment plant improvements and upgrades.
- Develop and disseminate educational and newsprint media, including stand-alone documents, press releases, newspaper and magazine articles, and displays.
- Improve and maintain existing web resources (mussel, crayfish, and fish atlases, etc.)

- Continue to seek opportunities for direct outreach throughout the basin.

- Continue to work with land conservancies to protect aquatic habitats.

Figure 4.5.12-2 Location of priority watersheds in the Neuse River Basin.



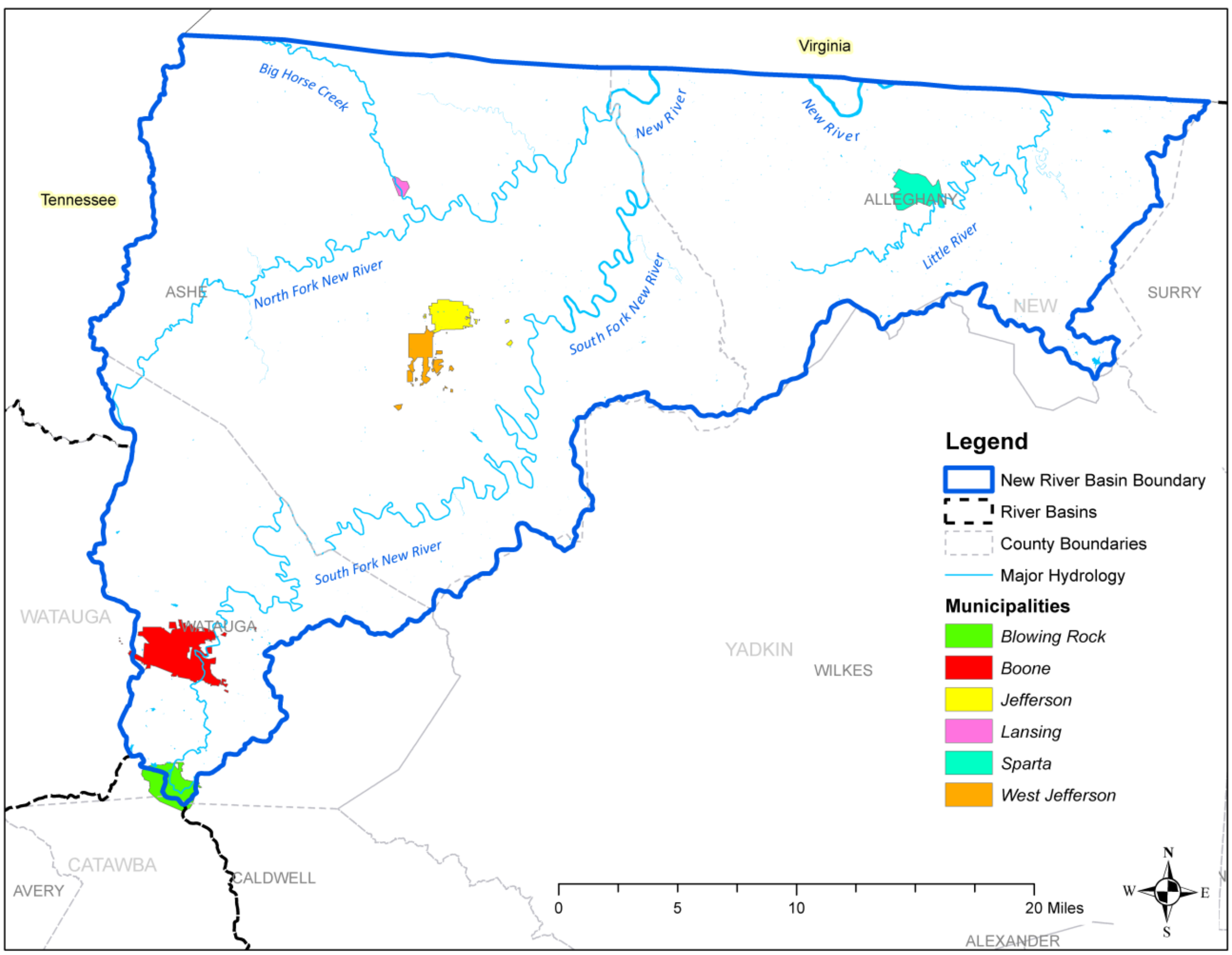
4.5.13 New River Basin

4.5.13.1 River Basin Description

The New River Basin in North Carolina is located in the northwest corner of the state and is part of the Kanawha/Ohio/Mississippi River system. The basin drains 765 square miles in North Carolina and includes approximately 2,071 stream miles. It begins as two streams on the western side of the Blue Ridge Mountains in Watauga County. The North Fork and South Fork converge along the Ashe-Alleghany County line as the New River, which flows northward into Virginia and loops back southward into North Carolina twice before continuing north into Virginia. It eventually flows into the Kanawha River in Virginia.

The New River Basin encompasses all or portions of three counties (Ashe, Alleghany, and Watauga) and has six municipalities, with Boone being the largest. Figure 4.5.13-1 depicts the geographic location of the basin.

Figure 4.5.13-1 Location of the New River Basin.



The New River Basin is entirely within the Mountain ecoregion and is comprised of three subbasins: the North Fork New River, the South Fork New River, and the Little River. Major tributaries include the Little River, Chestnut Creek, and Big Laurel Creek.

The North Carolina portion of the New River Basin is mountainous and rural. Based on 2011 National Land Cover Dataset information (MRLC 2011), land use in the basin is 69% forested, 22% agricultural, 7% developed or urban, 1% grassland, and less than 1% wetland (MRLC 2011; Jin et al. 2013). Most land in the basin is privately owned. Public land ownership includes the New River State Park (1,300 acres along the South Fork New River), Mount Jefferson State Natural Area, Elk Knob State Park, five NCWRC game lands covering about 8,203 acres (including Three Top Mountain, Pond Mountain, and Mitchell River), and relatively small areas within the Blue Ridge Parkway (Blue Ridge National Heritage Area 2015).

The USFWS established the Mountain Bogs National Wildlife Refuge (39 acres) in Ashe County for conservation of Appalachian mountain bog habitats and protection of federal listed endangered and threatened species (USFWS 2015). NCWRC established the Watson-Old Man's Bog Tract (about 10 acres) in Alleghany County to protect rare species.

4.5.13.2 Aquatic Resource Conditions

The entire North Carolina portion of the New River and the lower South Fork New River (26 miles) are designated as both a USA National Wild and Scenic River (NWSRS 2015) and a state Natural and Scenic River (NCDPR 2015). The entire Wild and Scenic-designated reach of the New River and South Fork New River reach is classified as Outstanding Resource Waters (ORW). The entire New River was named an American Heritage River (NPS 2015) in 1998. This designation brings with it federally funded, community-driven initiatives for protecting the river and for guiding sustainable growth in the basin.

The basin contains some of the highest quality waters in the state, with many high-elevation trout streams supporting native Brook Trout. There are 569 miles of NCDWR-designated trout waters (Tr) in the basin representing 171 stream segments classified as trout (Tr) waters. The Tr designation is a supplemental classification intended to protect freshwaters that have conditions that sustain and allow for natural trout propagation as well as survival of stocked trout. This classification is not the same as the Public Mountain Trout Waters (PMTW) designation used by NCWRC. The PMTW is a state fishery management designation administered by NCWRC that designates public access to streams for fishing of hatchery stocked trout on private and public lands.

There are numerous streams in the basin that carry the ORW classification, including the North Fork New River and most of its tributaries, Big Laurel Creek and its tributaries, Three Top Creek and its tributaries, and South Fork New River and its tributaries. The requirements for classification as ORW are more stringent than those for HQW and in some circumstances, the unique characteristics of the resources require that a specialized management strategy be developed (NCDWQ 2011c).

There are four HQW (51,463 acres) and six ORW (160,697 acres) Special Management Strategy Areas in the basin for North Fork and South Fork New River areas, Little River, Howard Creek, and Old Field Creek and Call Creek areas (see 15A NCAC 02B.0100 to 02B.0317, updated in 2019). These areas require site-specific provisions to protect resource values (no new discharges or expansion of existing discharges).

Critical Area (CA) is the area adjacent to a water supply intake or reservoir where risk associated with pollution is greater than other parts of the watershed. Doe Fork, East Fork South Fork New River, Flannery Fork, Flattop Branch, Howard Creek, Middle Fork South Fork New River, Norris Branch including the reservoir, and Roan Creek are designated CA for water quality protection.

4.5.13.3 Aquatic Species

Appendix 3 provides lists of aquatic SGCN and other priority species for which there are knowledge gaps or management concerns. Appendix 3-18 identifies aquatic SGCN associated with the aquatic communities found in this river basin.

In addition to the crayfish, freshwater fish and mussels, and aquatic snails found in the basin, there are also species that have both aquatic and terrestrial stages to their life history. The following list of SGCN are also associated with the aquatic communities in the New River Basin.

Common Name	Scientific Name	Federal Status	State Status
AMPHIBIANS			
Eastern Hellbender	*Cryptobranchus alleganiensis alleganiensis*	**PE**	**SC**
Eastern Long-tailed Salamander	*Eurycea longicauda longicauda*	**--**	**T**
Mudpuppy	*Necturus maculosus*	**--**	**SC**
DRAGONFLIES			
American Emerald	*Cordulia shurtleffii*	--	**--**
Black-tipped Darner	*Aeshna tuberculifera*	--	**--**
Brook Snaketail	*Ophiogomphus aspersus*	--	**--**
Green-faced Clubtail	*Hylogomphus viridifrons*	--	**--**
Mustached Clubtail	*Hylogomphus adelphus*	--	**--**
Ocellated Darner	*Boyeria grafiana*	--	**--**

Common Name	Scientific Name	Federal Status	State Status
Pygmy Snaketail	*Ophiogomphus howei*	--	--
Rusty Snaketail	*Ophiogomphus rupinsulensis*	--	--
Ski-tipped Emerald	*Somatochlora elongata*	--	--
Splendid Clubtail	*Gomphurus lineatifrons*	--	--
Spotted Spreadwing	*Lestes congener*	--	--
Stygian Shadowdragon	*Neurocordulia yamaskanensis*	--	--
Sweetflag Spreadwing	*Lestes forcipatus*	--	--
White-faced Meadowhawk	*Sympetrum obtrusum*	--	--
Zebra Clubtail	*Stylurus scudderi*	--	--

4.5.13.4 Threats Affecting Aquatic Species

There are localized problems and general habitat degradation in many cool-and warmwater habitats for priority species throughout the basin. Development and land clearing, poorly managed livestock grazing (which causes runoff and stream bank degradation), unpaved rural roads along streams, and loss of riparian vegetation are some of the primary sources.

Pollution. Water quality is generally good in the New River Basin. However, impaired waters within the basin include Naked Creek, Little Buffalo Creek (due to wastewater treatment plant discharge, nonpoint sources-sedimentation), Peak Creek, Ore Knob Branch, and Little Peak Creek (due to acid mine drainage).

Water Quality. There are eight permitted Confined Animal Feeding Operations (CAFOs) for cattle in the basin with 11 waste lagoons associated with the facilities (NCDEQ 2024(a)). Waste from these sites contains high levels of nutrients (e.g., nitrogen and phosphorus) in addition to fecal coliform bacteria and chemical compounds, such as antibiotics or hormone products used in commercial feeding operations (NCDWR 2015b). Animal-waste lagoons and spray fields that discharge associated wastewater near aquatic environments are a source of contamination from runoff, percolation into groundwater, and volatilization of ammonia and the release of bacterial contamination. These sources can significantly degrade water quality and endanger human and animal health (Mallin 2003; Mallin and Cahoon 2003).

Land Use. Water quality is variously degraded by acid mine drainage, impacts from urban runoff, and wastewater treatment plant discharge. Erosion and sedimentation have widespread impacts on aquatic habitats. Impacts from sedimentation appear to be quite severe in some localized areas and generally degrade habitats in larger tributaries and in the mainstem New River. Habitats in the same reaches also appear to suffer from over-widened channels with more uniform depth and substrate coarseness. Increasing human population places greater demand on drinking water supplies. Increased water withdrawals from streams, primarily in the upper South Fork New River subbasin, are a potential trend.

Most agriculture and development is concentrated in the valleys with the exception of Christmas tree farms, although development on steeper slopes is increasing. Christmas tree production is a major agricultural enterprise in the basin and large amounts of pesticides and herbicides are used. Impacts from this on aquatic systems are largely unknown.

Impoundments. Impoundment is not a significant issue in the basin. According to an NCDENR dam inventory (NCDEMLR 2014), there are 46 impoundments in the basin. Most are small privately owned lakes used for recreation. There is one run-of-river hydroelectric facility at Sharpe Falls on North Fork New River, and numerous small impoundments on tributaries.

Invasive Species. Numerous nonnative aquatic animal species are established in the basin. As identified in previous basin accounts, nonnative vegetation can also negatively impact native aquatic animal communities. This includes both aquatic and riparian plant species and nonnative plant pathogens that can alter riparian vegetation and affect aquatic habitats (e.g., Hemlock Wooly Adelgid). Overall, impacts of invasive species on populations of native species are unclear at present, but should be a focus of long-term monitoring and specific investigations.

4.5.13.5 Basin Specific Recommendations

Conservation priorities that apply statewide to all river basins are presented in Section 4.5.3.3. Priority 12-digit HUCs identified in the New River Basin are shown in Figure 4.5.13-2 at the end of this section.

Surveys

While the general distributions of most SGCN species are known, surveys are still needed to complete primary distributional status for SGCN species (see Appendix 3).

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Aquatic Snails – complete primary distribution inventories; determine potential habitats and distribution surveys. Seep Mudalia
• Mussels – populations of native mussels have decreased in the last three decades. More surveys are needed to determine the current distribution of extant populations. Green Floater Purple Wartyback Spike
• Determine distribution of nonnative species in the basin.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to continued impacts to state waters. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. Baseline data and sites for long-term monitoring of fish, crayfish, and mussels are established and should be monitored periodically. These efforts will inform species and habitat management decisions. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Freshwater Fish - Continue periodic monitoring of priority areas and priority and state listed fish species.

Kanawha Darter	Logperch	Sharpnose Darter
New River Shiner	Appalachia Darter	Brook Trout

- Freshwater Mussels - Continue periodic monitoring of priority and state listed mussel species.

Spike	Purple Wartyback	Green Floater

- Crayfish - Continue periodic monitoring of priority crayfish species.

  Cambarus sp. A

- Snails - Establish baselines and sites for long-term monitoring of snails in the basin.

- Monitor status of nonnative species (e.g., numerous fish species).

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Work with partners to resolve taxonomic issues with for crayfish species in the genus Cambarus. *Cambarus* sp. A
• Work with partners to identify causes of mussel declines.
• Work with partners at conservation hatcheries to propagate and reintroduce Green Floaters and other mussel species. Green Floater
• Study the life history and habitat preferences for rare fish (e.g., Sharpnose Darter). Sharpnose Darter

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats. In addition, education about, and regulation and prevention of the introduction and spread of exotic or invasive species are vital. Specific issues in this basin include secondary and cumulative impacts upon water quality, riparian vegetation and stream bank restoration and conservation, mitigation of hydropower development impacts, and species restoration opportunities.

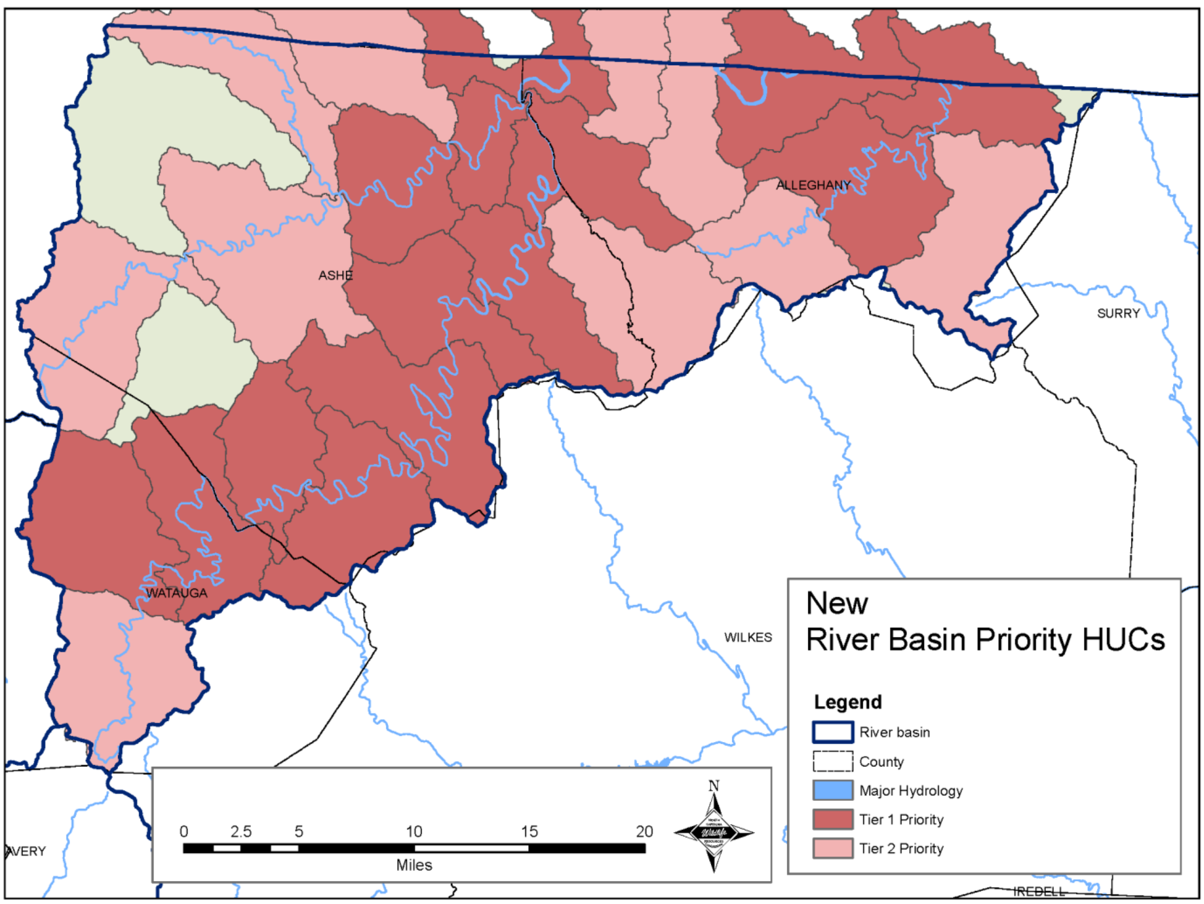
Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Support conservation and restoration of streams and riparian zones in priority areas.
• Support removal of relict dams and enhancement of aquatic organism passage at other barriers.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Partner with Soil and Water Conservation District programs, such as the Agriculture Cost Share Program, as they are also effective partner programs for conservation in priority areas.
• Work with regional land trusts and conservation oriented non-profit groups to enroll priority riparian areas into conservation easements. New River Conservancy Mountain True

Figure 4.5.13-2 Location of priority watersheds in New River Basin.



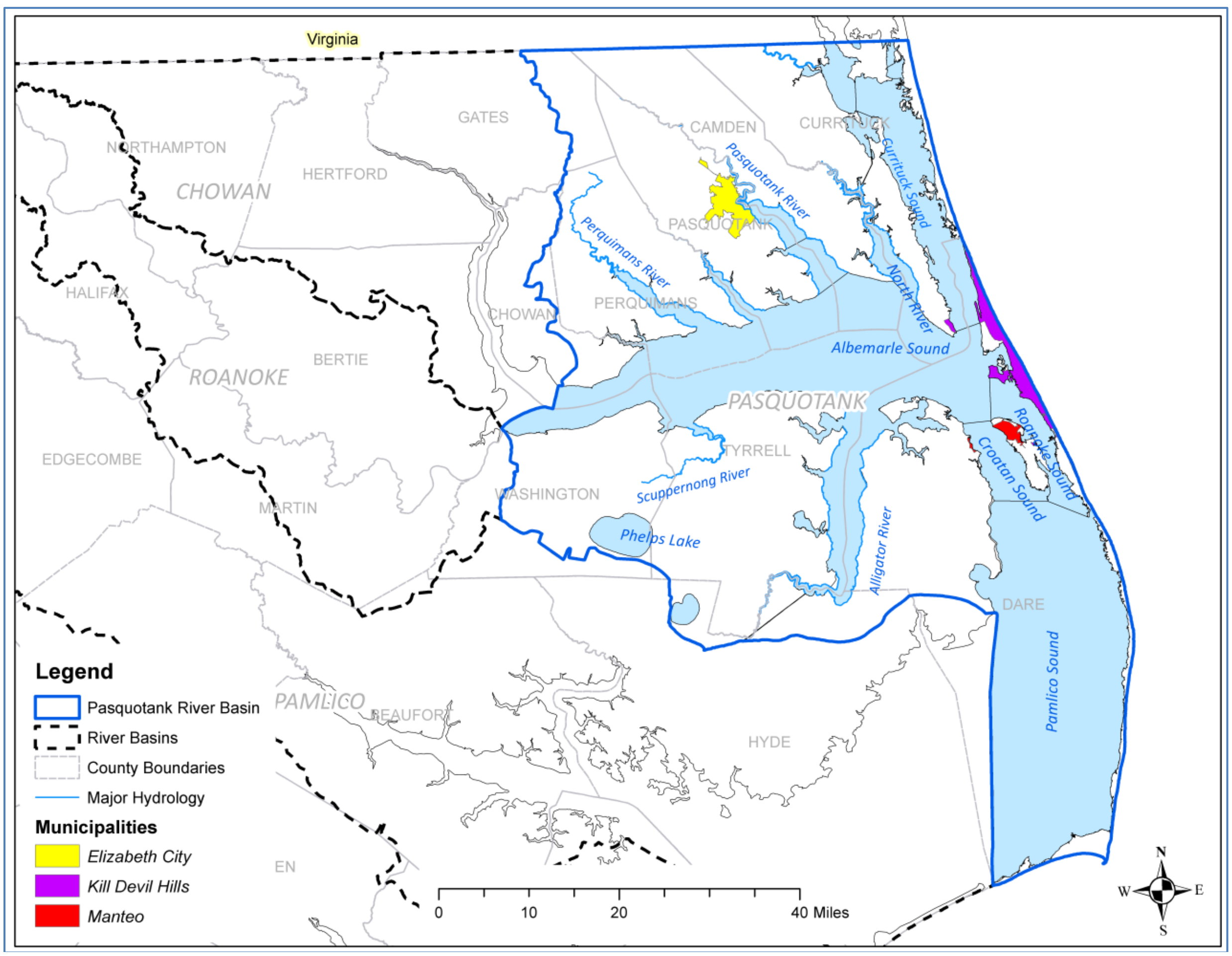
4.5.14 Pasquotank River Basin

4.5.14.1 River Basin Description

The Pasquotank River Basin is an Atlantic Slope drainage with a small portion of its headwaters in Virginia. The remainder of the basin lies in North Carolina's Coastal Plain and drains into the Albemarle Sound. The Pasquotank River flows as freshwater until tidal influence begins downstream of Elizabeth City. The Pasquotank is the fifth largest river basin in the state (3,366 square miles) and has 107 miles of Atlantic coastline. Major tributaries within the river basin include Alligator River, Perquimans River, Little River, Yeopim River, Scuppernong River, and North River. There are no major reservoirs in the basin.

There are 13 municipalities within the 10 counties in the basin. The largest municipalities are Elizabeth City, Manteo, and Kill Devil Hills on the Outer Banks. According to USCB data (2010), the human population is estimated to be 139,127; however, seasonal populations may be higher, as the Outer Banks are a popular vacation destination. Figure 4.5.1411 shows the location of the Pasquotank River Basin.

Figure 4.5.14-1 Location of the Pasquotank River Basin



Based on the 2011 National Land Cover Dataset, land use in the basin was estimated to be 6% forested, 20% agricultural, 33% wetland, 4% urban or developed, and less than 1% grassland (NLCD 2011; Yin et al. 2013). Land in the basin is very flat and geology consists of alternating layers of sand, silt, clay, and limestone. Low flows over the warmest months of the year limits the ability of streams in the basin to maintain high DO levels.

Nearly 22% of the land in the basin is classified as a national wildlife refuge (Alligator River, Currituck, Great Dismal Swamp, Mackay Island, Pea Island, and Pocosin Lakes). Lake Phelps, located in Pettigrew State Park, is the state's second largest natural lake at 16,000 acres. Additionally, the basin contains the 70-mile long Cape Hatteras National Seashore. The basin contains all or portions of 13 NCWRC game lands (including Buckridge, Gull Rock, New Lake, Northwest River Marsh, and Roanoke Island Marshes), representing over 103,838 acres (5% of the basin). These game lands include a black bear sanctuary on North River Game Land and waterfowl impoundments on the North River, Futch, and Lantern Acres game lands.

4.5.14.2 Aquatic Resource Conditions

Waterbodies in the basin exhibit a broad range of conditions, from the brackish waters of the Albemarle Sound to the tidal freshwater marshes of the upper Currituck to the freshwater rivers and streams throughout. Unique in this basin is Phelps Lake, a large shallow natural lake located in Pettigrew State Park.

Segments of the Alligator, Little, North, Pasquotank, Perquimans, Scuppernong, and Yeopim rivers and many of their tributaries, Phelps Lake, Swan Creek Lake, and Sandy Ridge Gut have been designated as High Quality Waters (HQW) or Outstanding Resource Waters (ORW) (NCDWR 2015h; NCDWR 2015c, NCDEQ 2025). The NCDWR assigns best-use classifications to state waters, monitors them to determine if they are supporting their use classification(s), and assigned use-support ratings. These ratings are published in the most recent 303(d) impaired waterbodies list (USEPA 2014a; NCDWR 2015a, NCDEQ 2024).

There are ORW Special Management Strategy Areas in the basin for Lake Phelps Area (15,926 acres) and Alligator River Area (61,608 acres) (NCDWR 2015c). These areas require site-specific provisions to protect resource values (no new discharges or expansion of existing discharges) (see 15A NCAC 02B.0225). There are approximately 43 miles of freshwater streams classified as nutrient-sensitive waters (NSW) in the Pasquotank River Basin (NCDWR 2015a, NCDEQ 2025). The NSW classification applies to Black Walnut Swamp and the portions of Edenton Bay, Pembroke Creek, Pollock Swamp, and Queen Anne Creek in the basin (NCDWR 2015c,d). This classification is intended for those waters that need additional nutrient management due to greater vulnerability to excessive aquatic vegetation growth (NCDWR 2007c).

The NC Division of Marine Fisheries (NCDMF) classifies coastal waters for shellfish harvesting by means of a sanitary survey, which includes a shoreline survey of sources of pollution, a hydrographic and meteorological survey, and a bacteriological survey of growing waters (NCDMF

2015). Sanitary surveys are conducted for all potential shellfish-growing areas in coastal North Carolina and recommendations are made to the NCDMF which areas should be closed for shellfish harvesting. Waters are classified as either 'Approved,' 'Conditionally Approved,' or 'Prohibited' based on the analysis of the data collected from each sampling station. There are 16 designated shellfish harvesting areas around the Albemarle and Currituck sounds that are considered impaired and classified as Prohibited for the harvest of any oysters, clams, or mussels.

4.5.14.3 Aquatic Species

Appendix 3 provides lists of SGCN and other priority species for which there are knowledge gaps or management concerns. Appendix 3-18 identifies aquatic SGCN associated with aquatic communities found in this river basin.

In addition to the crayfish, freshwater fish and mussels, and aquatic snails found in the basin, there are also species that have both aquatic and terrestrial stages to their life history. The following list of SGCN are also associated with the aquatic communities in the Pasquotank River Basin

Common Name	**Scientific Name**	**Federal Status**	**State Status**
REPTILES			
Rainbow Snake	*Farancia erytrogramma*	--	--
Carolina Saltmarsh Snake	*Nerodia sipedon williamengelsi*	--	**SC**
Diamondback Terrapin	*Malaclemys terrapin*	--	**SC**
Glossy Crayfish Snake	*Liodytes rigida*	--	--
Carolina Swamp Snake	*Seminatrix pygaea paludis*	--	**SC**

4.5.14.4 Threats Affecting Aquatic Species

Pollution. The cumulative effects of nonpoint source pollution are the primary threat to water quality across the state and throughout the Pasquotank River Basin. The presence of nonpoint source pollution can be identified through the NCDWR basinwide plan and the NCDMF sanitary surveys, but actions to address these impacts must be taken at the local level. Without proactive land-use planning initiatives and local water quality strategies, population growth and development in the basin increases the risk of waterbody impairment (NCDWQ 2007c).

Another major water quality problem in the basin is fecal coliform bacteria contamination (affecting shellfish harvesting). Fecal coliform bacteria contamination is primarily attributed to nonpoint source pollution associated with runoff from urban areas and agricultural lands. The task of quantifying nonpoint sources of pollution and developing management strategies for these impaired waters is very resource intensive. Federal and state stormwater regulations and initiatives are in place to help reduce and prevent stormwater runoff in developing coastal communities (NCDWQ 2007c).

Water Quality. There are 20 permitted Confined Animal Feeding Operations (CAFOs) in the basin, with 45 associated waste lagoons (NCDEQ 2024(a)). Waste from these sites is a source of high levels of nutrients (e.g., nitrogen and phosphorus) (NCDWR 2015b). Animal-waste lagoons and spray fields that discharge nutrients and bacteria contamination near or into aquatic environments through runoff, percolation into groundwater, and volatilization of ammonia and the release of bacterial contamination can significantly degrade water quality and endanger health (Mallin 2003; Mallin and Cahoon 2003).

It is important to note that all waters in the state are rated as impaired based on a state-wide fish consumption advisory for mercury contamination. Waters are assessed to determine how well they are meeting classification standards and are given a rating to indicate whether they meet these standards. In some cases, waters may not be assessed or rated, or data is not available for the waterbody to be rated (NCDWR 2007c). Detailed information on water quality parameters in the basin is available online from the NCDWR Basin Planning Branch (http://portal.ncdenr.org/web/wq/ps/bpu).

4.5.14.5 Basin Specific Recommendations

Conservation priorities that apply statewide to all river basins are presented in Section 4.5.3.3. Priority 12-digit HUCs identified in the Pasquotank River Basin are shown in Figure 4.5.14-2 at the end of this section.

Surveys

General surveys are needed to complete primary distributional status for SGCN and other priority species (see Appendix 3).

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Fishes – determine distribution and status of SGCN and other priority species. In addition, conduct exploratory surveys for priority species that have a high potential of occurring in the river basin, but are not currently known to occur in the river basin.

Banded Sunfish	Bridle Shiner	Ironcolor Shiner
Blackbanded Sunfish		

- Crayfishes – conduct baseline distribution surveys for all species that occur in the basin.

- Aquatic Snails – conduct baseline distribution survey for all species that occur in the basin.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to continued impacts to state waters. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. These efforts will inform species and habitat management decisions. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Identify long-term monitoring sites and develop monitoring protocols for SGCN and other priority species.		
Banded Sunfish	Ironcolor Shiner	Lake Phelps Killifish
Blackbanded Sunfish		

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Study habitat use and life history characteristics of SGCN and other priority species.		
Banded Sunfish	Ironcolor Shiner	Lake Phelps Killifish
Blackbanded Sunfish		
• Support taxonomic research for SGCN and other priority species.		
Lake Phelps Killifish		
• Support development of captive propagation techniques for SGCN and other priority species.		

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
Banded Sunfish	Blackbanded Sunfish	Ironcolor Shiner
• Support genetics research that informs augmentation policy for SGCN and other priority species.		
Banded Sunfish	Blackbanded Sunfish	Ironcolor Shiner
• Determine impacts of nonnative species on SGCN and other priority species.		
Red Swamp Crawfish		
• Conduct exploratory surveys to determine if Bridle Shiner occur in watershed.		
Bridle Shiner		

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats. In addition, education about, regulation and prevention of the introduction and spread of exotic or invasive species are vital.

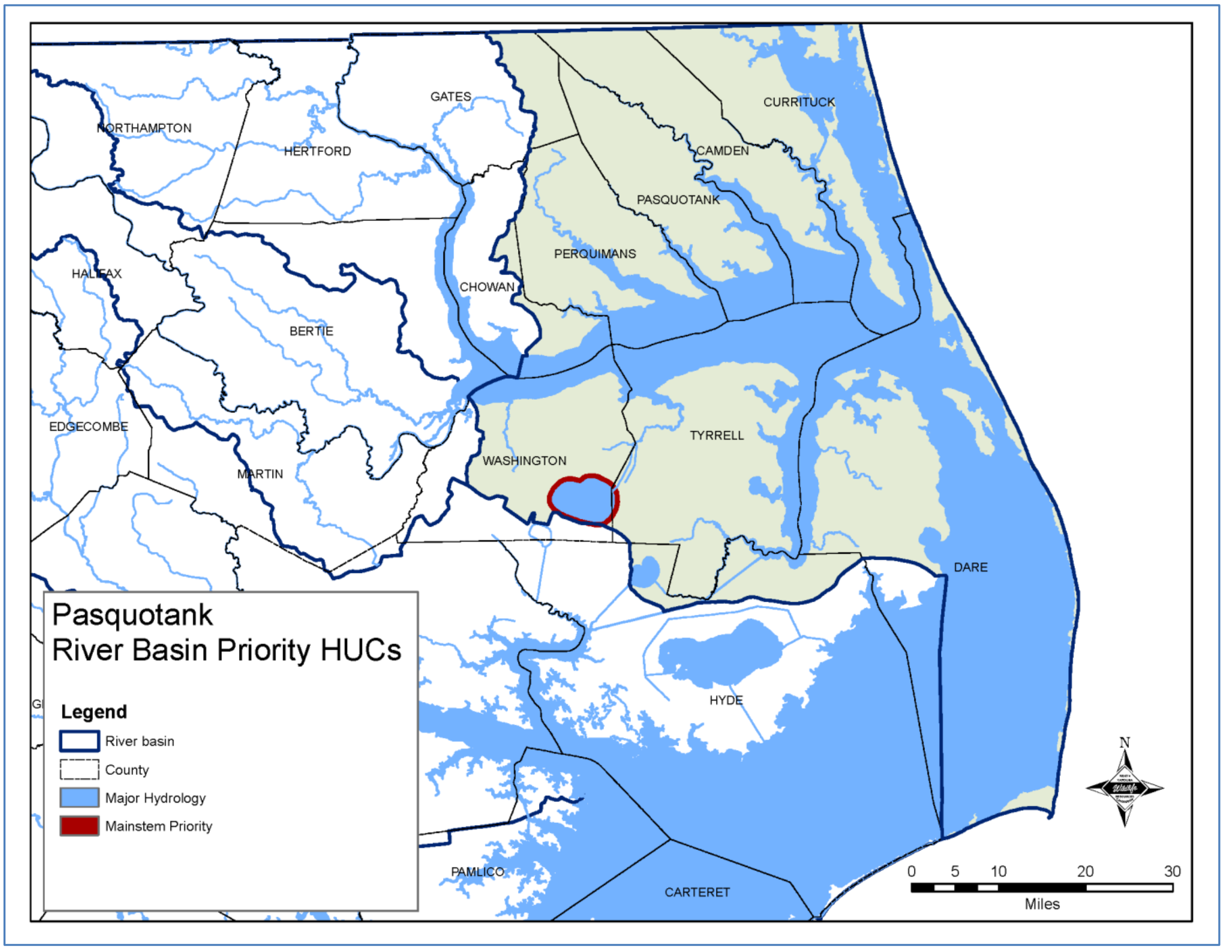
Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Support efforts to restore the native aquatic community (e.g., reintroduction or augmentation).
• Support acquisition of land that is adjacent to current conservation holdings or priority watersheds.
• Support other regulatory agencies to minimize impacts on species and habitats.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Wetland and marsh restoration projects and shoreline stabilization are high priorities for areas prone to erosion from natural exposure or from heavy boat traffic (NCEEP 2009).
• The NCDMS has identified targeted local watersheds as restoration priorities in most river basins using 14-digit HUCs. Information about these priorities in the Pasquotank River Basin is available online http://portal.ncdenr.org/web/eep/rbrps/pasquotank.
• Guide academic research projects to help achieve specific conservation goals and objectives.
• Support the development and application of an aquatic nuisance species management plan with other agencies/groups.
• Address secondary and cumulative impacts upon water quality (buffer ordinances, water supply watershed protection, and headwaters protection).
• Work with and promote existing programs that help farmers reduce sedimentation/erosion (installing fences to keep livestock out of streams, improving tilling practices) as well as reduce pesticide and herbicide use.
• Support stormwater management and wastewater treatment plant improvements and upgrades.

Figure 4.5.14-2 Location of priority watersheds in the Pasquotank River Basin.



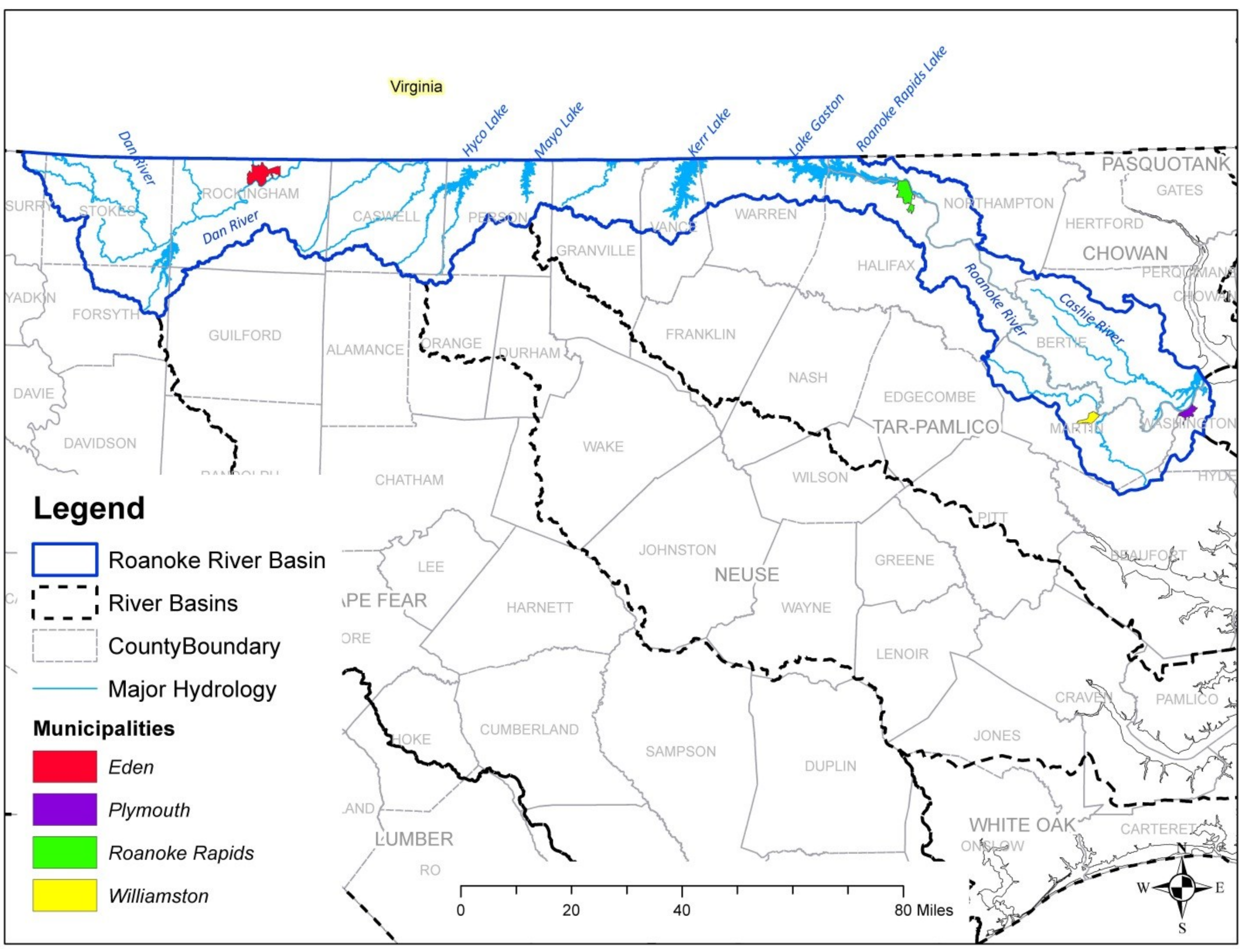
4.5.15 Roanoke River Basin

4.5.15.1 River Basin Description

The Roanoke River Basin is an Atlantic Slope basin with headwaters that begin in the Mountains of Virginia and flow eastward to drain into the Albemarle Sound in North Carolina. Nearly 65% of the basin is located in Virginia. The entire basin is approximately 9,766 square miles and in North Carolina it covers 3,493 square miles, making it the sixth largest river basin in the state. The Roanoke River carries the most water and has the widest floodplain (up to 5 miles wide in parts) of any North Carolina river.

There are 34 municipalities within the 17 counties covered by the basin. The most populated areas are located northeast of the Greensboro/Winston-Salem area and around the larger municipalities in the basin such as Roanoke Rapids, Eden, Williamston, and Plymouth. Figure 4.5.15-1 shows the location of the Roanoke River Basin.

Figure 4.5.15-1 Location of the Roanoke River Basin.



There are 8,439 freshwater stream miles, 35,955 acres of freshwater lakes and impoundments, and approximately 4.2 miles of coastline in the basin (NCDWR 2015d). According to National Hydrography Dataset, there are 1,476 estuarine acres in the basin (USEPA 2014b; Jin et al. 2013). Major tributaries to the Roanoke River include the Dan River, Mayo River, Smith River, Country Line Creek, Hyco Creek/River, Cashie River, and Conoho Creek. Major impoundments include the John H. Kerr Reservoir, Hyco Lake, Lake Gaston, Roanoke Rapids Lake and Belews Lake.

The NC portion has two distinct parts: the western section in the Piedmont ecoregion, which includes the area above Roanoke Rapids Dam, and the eastern section in the Coastal Plain ecoregion, which begins below Roanoke Rapids Dam. The upper Dan River watershed in western Piedmont shows characteristics of both the Mountain and Piedmont ecoregions, with fairly steep topography typical of Mountain headwaters. The Piedmont portion features rolling hills and is underlain with crystalline or sedimentary rocks and many tributary streams that carry large sediment bed loads. The transition zone between the Piedmont and Coastal Plain occurs below Roanoke Rapids Lake, with the lower 60 miles of river within the Coastal Plain. The Coastal Plain portion features a flat topography and is underlain by sand, silt, clay, and limestone.

Land use in the basin is approximately 51% forested, 13% wetland, 7% urban or developed, 6% grassland, and 20% agricultural (MRLC 2011; Jin et al. 2013). There are several federal- and state-owned public lands in the basin, including over 1.14 million acres of game lands (e.g., Caswell, Bertie County, Hyco, Roanoke River, Tillery), 32,751 acres of state and federal park lands (Hanging Rock State Park, Kerr Lake Recreation Area), and 29,960 acres of Roanoke River National Wildlife Refuge.

4.5.15.2 Aquatic Resource Conditions

There are about 8,439 miles of streams and rivers, including small intermittent and ephemeral streams, and numerous acres of freshwater and estuarine wetland communities in the basin. Segments of Country Line Creek, South Hyco Creek, Storys Creek, Double Creek, their tributaries, and other streams in the basin have supplemental classifications as High Quality Waters (HQW) or Outstanding Resource Waters (ORW) because they either have excellent water quality or they are a significant resource to humans and/or wildlife (NCDWQ 2010; NCDWR 2015c,d).

There are ORW Special Management Strategy Areas in the basin for the Cascade Creek and Indian Creek areas (506 acres) (NCDWR 2015c, NCDEQ 2025). These areas require site-specific provisions to protect resource values (no new discharges or expansion of existing discharges) (see 15A NCAC 02B.0225).

Another supplemental classification is NCDWR’s trout water designation (Tr), which protects freshwaters for natural propagation of trout and survival of stocked trout on a year-round basis. There are about 120 miles of streams in the Roanoke River Basin designated Tr. This is not the same as the Commission's designated public Mountain Trout Waters, which is used to designate waters that support trout and are open to public fishing.

4.5.15.3 Aquatic Species

Appendix 3 provides lists of aquatic SGCN and other priority species for which there are knowledge gaps or management concerns. Appendix 3-18 identifies aquatic SGCN associated with the aquatic communities found in this river basin.

In addition to the crayfish, freshwater fish and mussels, and aquatic snails found in the basin, there are also species that have both aquatic and terrestrial stages to their life history. The following list of SGCN are also associated with the aquatic communities in the Roanoke River Basin.

Common Name	Scientific Name	Federal Status	State Status
DRAGONFLIES			
Edmund's Snaketail	Ophiogomphus edmundo	At-Risk	--
Mountain River Cruiser	Macromia margarita	At-Risk	--
Septima's Clubtail	Gomphurus septima	At-Risk	--
Skillet Clubtail	Gomphurus ventricosus	--	--
Splendid Clubtail	Gomphurus lineatifrons	--	--

4.5.15.4 Threats Affecting Aquatic Species

Water Quality. There are 29 permitted Confined Animal Feeding Operations (CAFOs) for swine in the basin, with 44 waste lagoons associated with these facilities (NCDENR 2024(a)). Nonpoint wastewater discharges from CAFOs contain high levels of nutrients (e.g., nitrogen, phosphorus), as well as fecal coliform bacteria and chemical compounds associated with livestock operations (e.g., antibiotics, hormone products) (NCDWR 2015b). Animal-waste lagoons that use spray fields to discharge wastewater near aquatic environments are a source of contamination because runoff, percolation of wastewater into groundwater, and volatilization of ammonia release bacteria that significantly degrade water quality and endanger human and animal health (Mallin 2003; Mallin and Cahoon 2003).

Pollution. Upstream waters located in Virginia are a source of contamination. For example, the waters of Kerr Reservoir in Virginia are considered by the VA Department of Environmental Quality to be impaired for polychlorinated biphenyls (PCBs) and low DO (CBF 2005). Other sources come from point sources that include industrial and municipal wastewater, selenium ash pond discharge, and urban stormwater discharges that contribute toxic compounds and elements such as ammonia, chlorine, mercury, and various organic compounds. Waters in Welch Creek and Batchelor Bay in the eastern part of the basin are rated impaired for dioxin contamination.

Impoundments. According to the National Aquatic Barrier Inventory Tool (SARP 2024) there are 2,793 dams in the basin. While many are used for recreation, flood control or stormwater management, irrigation, or water supply, six are licensed for by the Federal Energy Regulatory Commission (FERC) for hydroelectric energy production: Roanoke Rapids (Northampton and Halifax Counties); Gaston South Saddle (Halifax County); and Town of Mayodan Mayo River (Rockingham County) (SARP 2024). These can physically alter instream habitat, change flow regimes, and often reduce DO levels. Water withdrawals for irrigation and similar uses further change flow patterns and reduce the quality/quantity of the habitat available for aquatic species (NCDWQ 2002).

Large reservoirs in the Roanoke River Basin include Hyco, Mayo, Kerr, and Lake Gaston. The Mayo and Hyco reservoirs provide water for cooling Duke Energy's coal-fired power plants. Hyco Lake has been listed on the state's impaired waters list for exceeding thresholds for mercury. Freshwater streams in the eastern portion of the basin are heavily used by anadromous fishes, and impoundments are barriers to movement between coastal and upstream freshwater spawning habitats.

Development. According to 2010 census data there was a population increase of roughly 1.5% in the North Carolina portion of the basin from 2000 census data (NCDWR 2012). Recent Census data for the period 2010 to 2014, estimates a slight population decrease for the Roanoke Rapids area and the basin's counties (USCB 2015). However, development in adjacent urbanizing areas of central Piedmont, including the Greensboro-Highpoint area and the Triangle region, is likely to spur demands for water supplies that could result in interbasin withdrawals from the Roanoke River Basin (NCOEE 2007). The demand for water by consumers living in the basin is expected to increase by as much as 55% by 2020.

4.5.15.5 Basin Specific Recommendations

Conservation priorities that apply statewide to all river basins are presented.3.3. Priority 12-digit HUCs identified in the Roanoke River Basin are shown in Figure 4.5.15-2 at the end of this section.

Surveys

General surveys are needed to complete primary distributional status for SGCN and other priority species (see Appendix 3).

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Fish—survey for SGCN and state listed species on a routine basis.

American Brook Lamprey	Cutlip Minnow	Roanoke Bass
Bigeye Jumprock	Orangefin Madtom	Roanoke Logperch

Priority Conservation Action, Examples of Focal Species or Focal Habitats

		Rustyside Sucker

- Mussels – continue to track mussel population health in priority areas.

Dan River	Roanoke River	Aarons Creek
May River	Country Line Creek	Little Grassy Creek

- Crayfishes – continue inventories and update status of SGCN and other priority species.

Carolina Ladle Crayfish	North Carolina Spiny Crayfish
Chowanoke Crayfish	

- Aquatic Snails – inventory primary distribution; determine potential habitats and distribution surveys for all species

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to continued impacts to state waters. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. These efforts will inform species and habitat management decisions. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Fish—monitor priority and state listed species on a routine basis.

Banded Sunfish	Ironcolor Shiner	Roanoke Bass
Bigeye Jumprock	Orangefin Madtom	Roanoke Logperch

- Mussels – monitor priority species in priority areas Dan, Mayo, and Roanoke rivers, and Country Line, Aarons, and Little Grassy creeks).

Atlantic Pigtoe	Green Floater	Roanoke Slabshell
Brook Floater	James Spinymussel	Yellow Lampmussel

- Crayfishes – monitor SGCN and other priority species (e.g., and).

Carolina Ladle Crayfish	Chowanoke Crayfish	North Carolina Spiny Crayfish

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed. In addition to the

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Study habitat use and life history characteristics of federal and state-listed aquatic species and SGCN priority species.

- Support taxonomic research for SGCN priority species.

Cambarus sp. C complex	*Elliptio* mussels	*Sagittunio* mussels *Strophitus* mussels

- Continue to support captive propagation for priority species.

- Continue to support genetics research that informs species conservation for priority species.

Atlantic Pigtoe Green Floater	James Spinymussel Triangle Floater	Ironcolor Shiner Orangefin Madtom Roanoke Logperch

- Continue to assess impacts of nonnative species on priority species.

Basket Clam Flathead Catfish	Virile Crayfish Chinese Mystery Snail Japanese Mystery Snail	Hydrilla Lyngbya

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats. In addition, education about, and regulation and prevention of the introduction and spread of exotic or invasive species are vital.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Support efforts to restore the native aquatic community through reintroduction or augmentation.

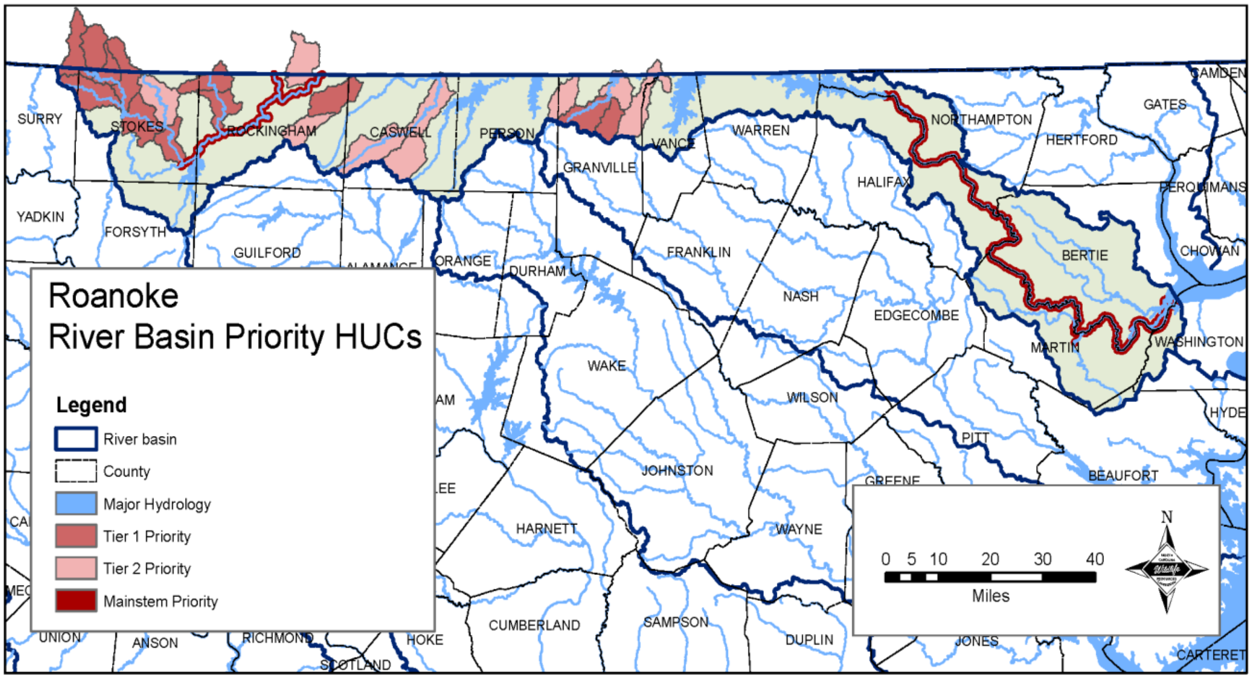
Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Support acquisition of land that is adjacent to current conservation holdings or priority watersheds.
• Support other regulatory agencies to minimize impacts on species and habitats.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Work with and promote existing programs that help farmers reduce sedimentation/erosion (e.g., install fences to keep livestock out of streams, improve tilling practices) as well as reduce pesticide and herbicide use.
• Support stormwater management and wastewater treatment plant improvements and upgrades.
• Maintain partnerships with Piedmont Lands Conservancy, Dan River Basin Association, and Piedmont Conservation Council to conserve and preserve aquatic habitats.

Figure 4.5.15-2 Location of priority watersheds in the Roanoke River Basin



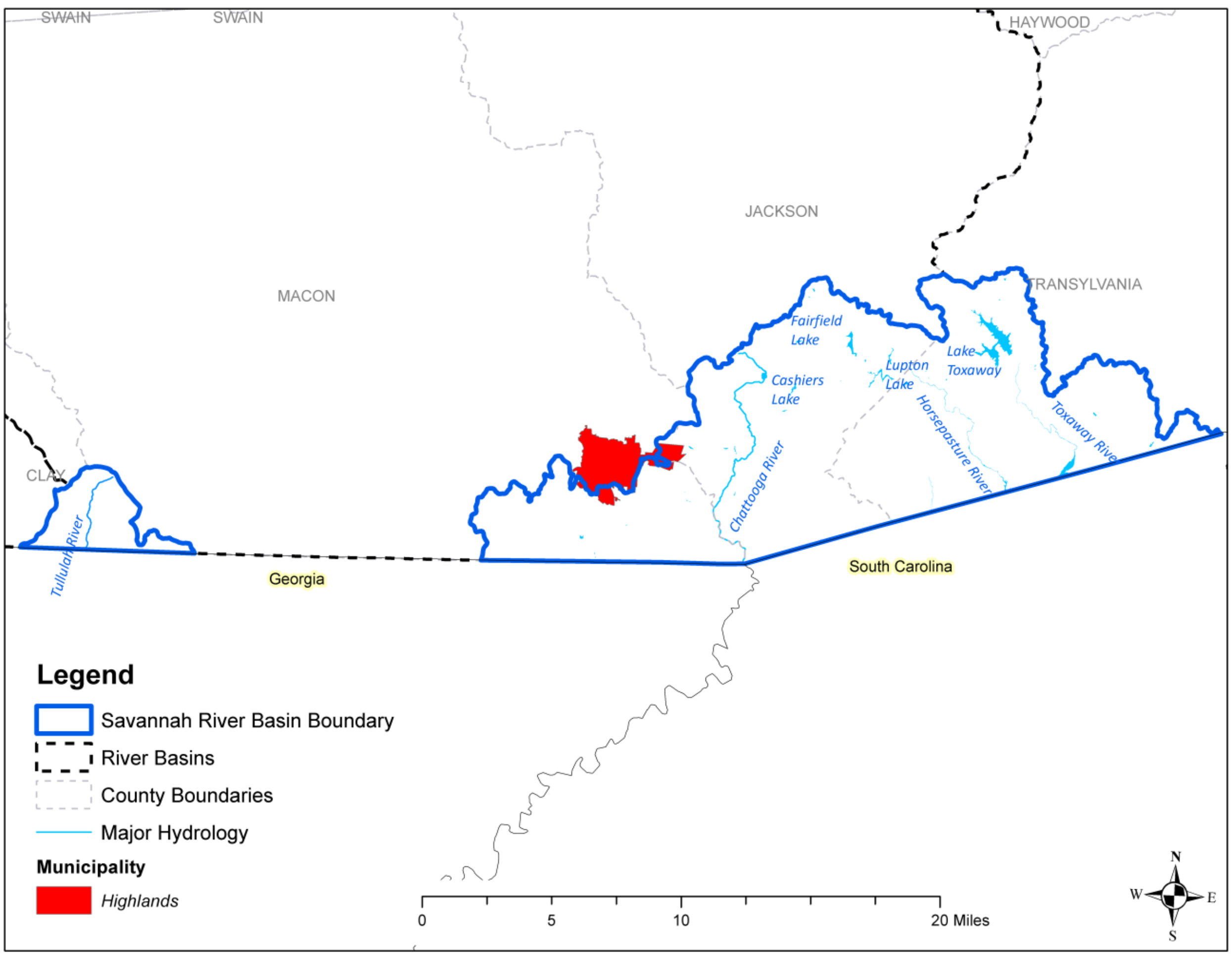
4.5.16 Savannah River Basin

4.5.16.1 River Basin Description

The headwaters of the Savannah River Basin begin along the eastern slopes of the Blue Ridge Mountains and flow south through Georgia and South Carolina to empty into the Atlantic Ocean. Only 2% of the total Savannah River Basin is within North Carolina. The basin encompasses 172 square miles, making it the smallest of the state's river basins. The North Carolina portion has approximately 176 miles of streams and 1,366 reservoir acres.

The basin encompasses all or part of four counties (Clay, Jackson, Macon, and Transylvania) and has one sizable municipality (Highlands). Figure 4.5.16-1 depicts the location of the basin.

Figure 4.5.16-1 Location of the Savannah River Basin.



Streams in the North Carolina portion of this river basin are part of the Tugaloo River and Seneca River subbasins; however, both of these named rivers begin outside the state. Major tributaries of the Tugaloo in North Carolina are the Overflow and Big creeks, and the Chattooga

River. Major tributaries of the Seneca River in North Carolina include the Toxaway, Horsepasture, Thompson, and Whitewater rivers.

Land use cover in the basin is 91% forested, 1% agricultural, 7% urban or developed, and less than 1% grassland and wetland (MRLC 2011; Jin et al. 2013). A significant portion of the basin is publicly owned land, primarily Nantahala National Forest (189,060 acres), Pisgah National Forest (107,111 acres), NCWRC game lands (nearly 3,000 acres), and Gorges State Park (7,640 acres).

4.5.16.2 Aquatic Resource Conditions

Water quality is generally good for areas where data are available; however, there are problems in parts of the basin (described below), and the lack of data for nearly half the basin provides an unclear assessment of overall water quality. Most of the Tugaloo River tributaries in North Carolina and four miles of the Horsepasture River are designated Outstanding Resource Waters (ORW), and portions of Bearwallow Creek and Whitewater River are designated High-Quality Waters (HQW). The requirements for classification as ORW are more stringent than those for HQW and in some circumstances, the unique characteristics of the resources require that a specialized management strategy be developed (NCDWQ 2015d).

Water quality in the Savannah River Basin is excellent in major streams and most small headwater streams. There are 211 miles and 619 acres of NCDWR designated Trout waters (Tr) in the basin. This is not the same as the Commission's designated public Mountain Trout Waters, which is used to designate waters that are open to public trout fishing.

There are several small reservoirs, including Cashiers Reservoir, Fairfield Reservoir, and Toxaway Reservoir, and many smaller ponds associated with golf courses and second home developments in the Cashiers/Highlands area.

4.5.16.3 Aquatic Species

Appendix 3 provides lists of SGCN and other priority species for which there are knowledge gaps or management concerns. Appendix 3-18 identifies aquatic SGCN associated with aquatic communities found in this river basin.

4.5.16.4 Threats Affecting Aquatic Species

Development. While much of the North Carolina portion of the basin is in national forest and state-owned lands, development is increasing on private lands. There are no permitted Confined Animal Feeding Operations (CAFOs) in the basin, but nutrient enrichment may be a problem (NCDWQ 2012g). Nonpoint source problems (primarily erosion and sedimentation) from land clearing, removal of riparian vegetation, and rural roads are potential problems.

Impoundments. According to the National Aquatic Barrier Inventory Tool (SARP 2024) there are 71 dams in the basin. Most impoundments are small privately owned lakes used for recreation, and these small impoundments fragment headwater habitats, contribute to temperature pollution, and can be a source of nonnative introductions. All of the major tributaries in the North Carolina part of the basin are upstream from major impoundments in Georgia and South Carolina that isolate them from the rest of the basin. Short reaches of the Horsepasture and Toxoway rivers are impounded just inside the North Carolina border (Lake Jocassee, Duke Energy, Lake Toxoway).

Invasive Species. Little is known of the extent to which nonnative aquatic species have become established in the North Carolina portion of the basin. Nonnative vegetation can also negatively impact native aquatic animal communities. This includes both aquatic and riparian plant species and nonnative plant pathogens that can alter riparian vegetation and affect aquatic habitats (e.g., Hemlock Wooly Adelgid).

4.5.16.5 Basin Specific Recommendations

Conservation priorities that apply statewide to all river basins are presented in Section 4.5.3.3. Priorities identified in the Savannah River Basin are shown in Figure 4.5.16-2 at the end of this section.

Surveys

While the general distributions of most SGCN species are known, surveys are still needed to complete primary distributional status for certain SGCN species (see Table 4.5.16.2).

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Fish – work with other agency staff to complete distribution surveys for Bartram's Bass. Bartram's Bass
• Aquatic Snails – complete primary distribution inventories; determine potential habitats and distribution surveys.
• Determine distribution of nonnative species.

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to continued impacts to state waters. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. These efforts will inform species and habitat management decisions.

Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible. Continue periodic monitoring of priority areas and species.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Fish – continue routine monitoring for SGCN, listed species, and other priority species.

Bartram's Bass	Rosyface Chub	Turquoise Darter
Brook Trout	Sooty-banded Darter	Yellowfin Shiner

- Crayfish – continue routine monitoring for SGCN, listed species, and other priority species

Chauga Crayfish	French Broad Crayfish

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Work with partners to resolve taxonomic problems with crayfishes.

  Cambarus sp.

- Investigate impacts of fragmentation on priority species..

- Work with other agency staff and partners to assess population trends of Bartram's Bass and current level of genetic introgression with other Micropterus species.

Bartram's Bass	*Micropterus* species

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats. In addition, education about, and regulation and prevention of the introduction and spread of exotic or invasive species are vital.

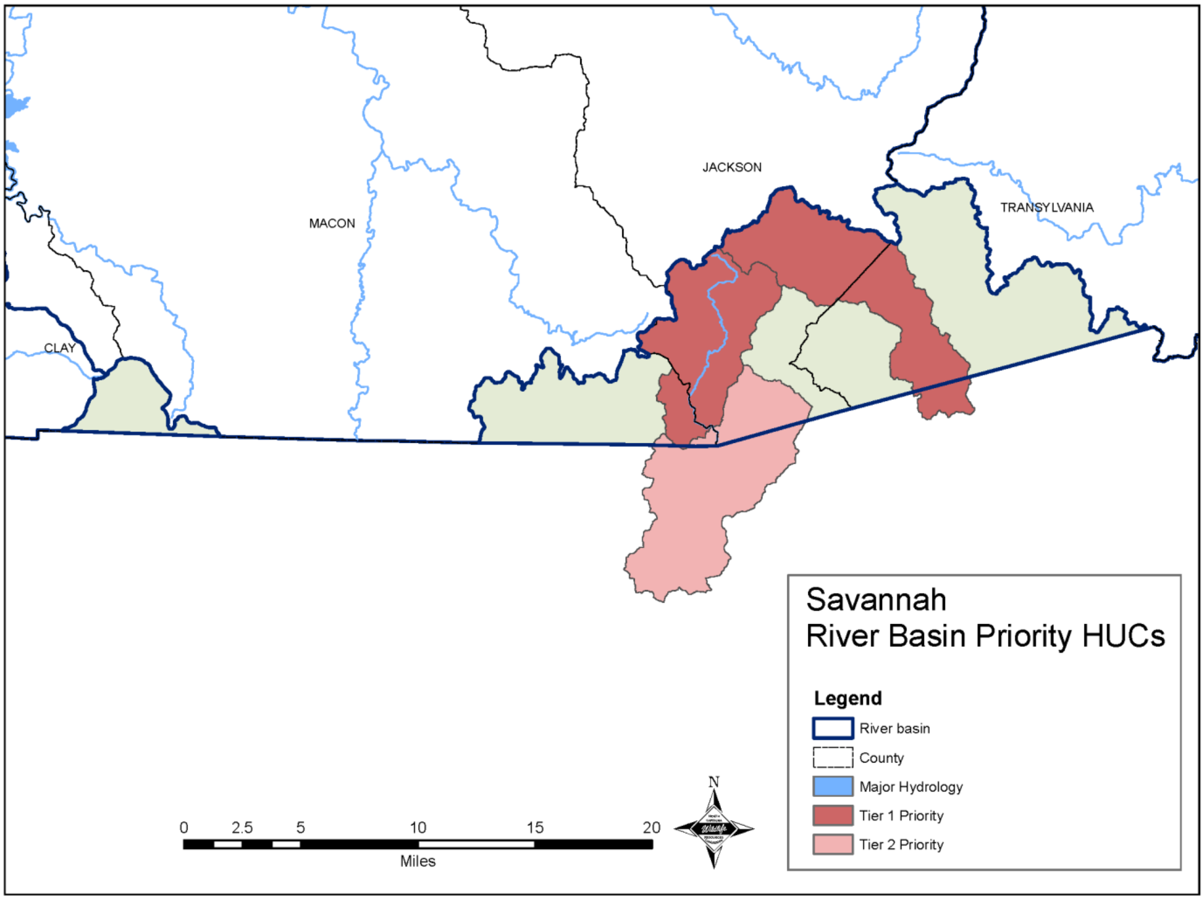
Priority Conservation Action, Examples of Focal Species or Focal Habitats	
• Support conservation and restoration of streams and riparian zones in priority areas.	
• Incorporate management goals for aquatic community conservation and enhancement planning for Gorges State Park and Toxaway Game Lands.	
Gorges State Park	Toxaway Game Lands
• Prioritize education and other measures to prevent the introduction or spread of invasive nonnative species, particularly crayfishes.	
• Support removal of relict dams and enhancement of aquatic organism passage at other barriers.	

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Support the Watershed Restoration Plan (WRP) developed by NCDMS for the Savannah River Basin.
• Cooperate with NC Division of Parks and Recreation (NCDPR), the US Forest Service (USFS), and NCWRC, who manage much of the basin in North Carolina.

Figure 4.5.16-2 Location of priority HUC12 watersheds in the Savannah River Basin.



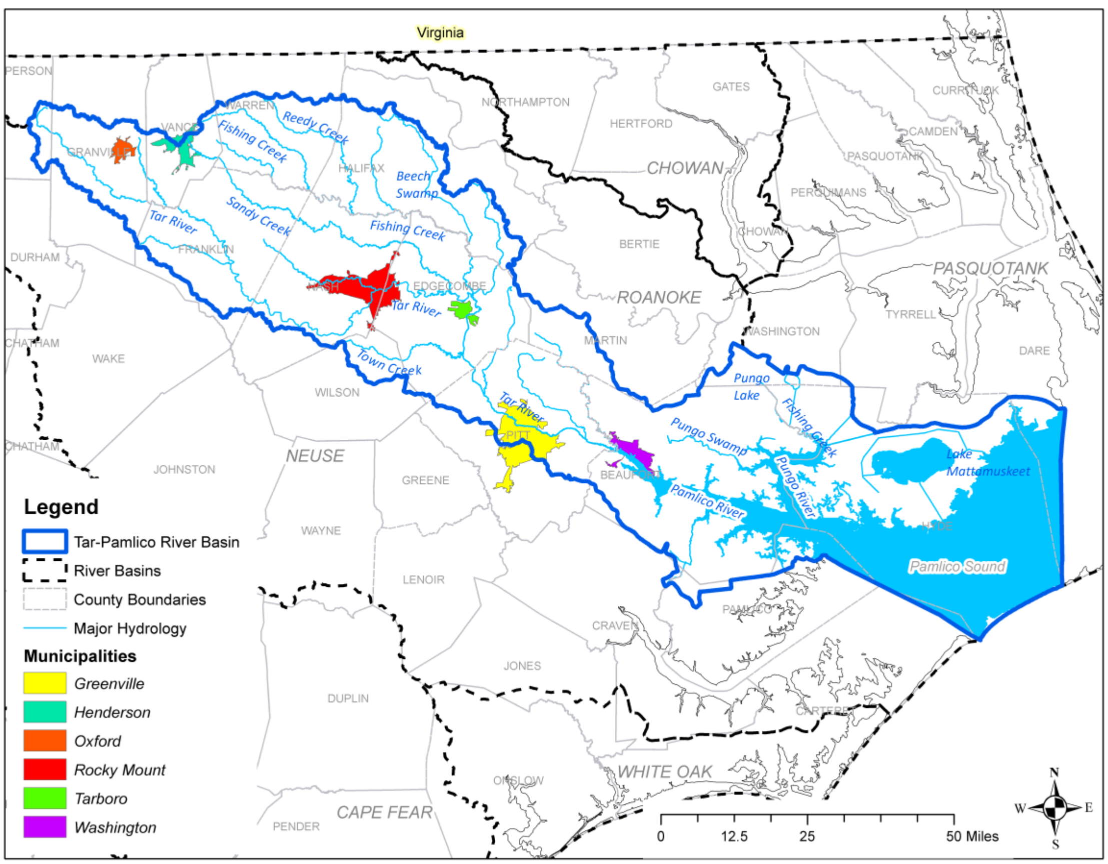
4.5.17 Tar-Pamlico River Basin

4.5.17.1 River Basin Description

The Tar-Pamlico River Basin covers 6,148 square miles, making it the fourth largest river basin in North Carolina. It is one of only four river basins whose boundaries are located entirely within the state. The Tar River and its headwaters originate in Person, Granville, and Vance counties in the north central part of the Piedmont. It flows southeast until it reaches tidal waters near Washington and becomes the Pamlico River and empties into the Pamlico Sound. Major tributaries include Fishing Creek, Swift Creek, Cokey Swamp, Tranters Creek, and the Pungo River (NCDWR 2015d).

The Tar-Pamlico River Basin contains all or parts of 19 counties and 52 municipalities of varying size, including Rocky Mount, Greenville, Henderson, Oxford, Tarboro, and Washington. Figure 4.5.17-1 depicts the location of the basin.

Figure 4.5.17.1 Location of the Tar-Pamlico River Basin.



There are two distinct portions of the Tar-Pamlico River Basin: the upper one-fifth, which is in the Piedmont physiographic region, and the lower four-fifths, which is in the Coastal Plain physiographic region.

- The Piedmont portion, running from the river headwaters to the fall line, lies on the Carolina Slate Belt and Triassic Basin geologic units. This portion of the basin features low gradients with sluggish pools separated by riffles and occasional small rapids. Soils are highly erodible and are underlain by fractured rock formations that have limited water storage capacity. Streams in the Piedmont tend to have low summer flows and limited ability to assimilate oxygen-consuming wastes (NCDWQ 2014d).

- The Coastal Plain portion features slow-moving blackwater streams, low-lying swamps, and productive estuarine waters. The larger waterbodies are meandering, often lined with swamps and bottomland hardwoods, and have naturally low levels of DO and low pH. Soils are deep sands that have a high groundwater storage capacity. Natural lakes include the remnants of bay lakes in the lower Coastal Plain (NCDWQ 2014d).

Land use in the basin is approximately 26% forested, 22% agricultural, 18% wetland, 5% urban or developed, and 3% grassland (MRLC 2011; Jin et al. 2013). Publicly owned lands include nearly 38,000 acres of NCWRC game lands, including Brinkleyville, Embro, Lower Fishing Creek, Shocco Creek, Tar River, and Voice of America, three national wildlife refuges (Lake Mattamuskeet, Pocosin Lakes, and Swanquarter) and two state parks (Goose Creek and Medoc Mountain). North Carolina's largest natural lake, Lake Mattamuskeet, also is located in this basin.

4.5.17.2 Aquatic Resource Conditions

There are about 9,766 miles of streams and rivers, including small intermittent and ephemeral streams, and numerous acres of freshwater and estuarine wetland communities in the basin. Segments of the Pamlico, Pungo, and Long Shoal rivers and their tributaries have supplemental classifications as High Quality Waters (HQW) or Outstanding Resource Waters (ORW) because they either have excellent water quality or they are a significant resource to humans and/or wildlife (NCDWQ 2010; NCDWR 2015c,d). Coastal estuarine waters of Core Sound, Swanquarter Bay Refuge, and Juniper, Back, Rose, Wysocking, Germantown, Deep, Spencer and other bays carry either a HWQ or ORW classification (NCDWR 2015a,c,d).

There are ORW Special Management Strategy Areas in the basin for the Swift Creek area (116,782 acres) and Swanquarter Bay and Juniper Bay areas (28,536 acres) (NCDWR 2015c). These areas require site-specific provisions to protect resource values (no new discharges or expansion of existing discharges) (see 15A NCAC 02B .0225).

The Pamlico Sound estuarine system is somewhat protected from oceanic influences because of the Outer Banks barrier islands. The estuary dynamics, including tidal, climatic, long retention time and nutrient loading conditions, enable eutrophication processes within the Pamlico River.

During low-flow conditions, wind and tidal saltwater intrusion in the Tar River has been documented up to Greenville.

The entire Tar-Pamlico River Basin was designated as nutrient-sensitive water (NSW) in 1989 due to excessive levels of nutrients resulting in massive algal blooms and fish kills. This designation resulted in the development and implementation of a nutrient management strategy to achieve a decrease in total nitrogen by 30% and no increase in total phosphorus loads compared to 1991 conditions.

There are no natural lakes in the Piedmont, but there are a few reservoirs that serve as water supplies and flood control structures. Old millponds and beaver impoundments are scattered across this region. Impoundments and reservoirs owned by local governments or agencies are used primarily for drinking water supply, recreation, or irrigation.

4.5.17.4 Aquatic Species

Appendix 3 provides lists of SGCN and other priority species for which there are knowledge gaps or management concerns. Appendix 3-18 identifies aquatic SGCN associated with aquatic communities found in this river basin.

In addition to the crayfish, freshwater fish and mussels, and aquatic snails found in the basin, there are also species that have both aquatic and terrestrial stages to their life history. The following list of SGCN are also associated with the aquatic communities in the Tar-Pamlico River Basin

Common Name	Scientific Name	Federal Status	State Status
AMPHIBIANS			
Neuse River Waterdog	*Necturus lewisi*	**T**	**T**
DRAGONFLIES			
Coppery Emerald	*Somatochlora georgiana*	--	--
Mountain River Cruiser	*Macromia margarita*	At-Risk	--
Septima's Clubtail	*Gomphurus septima*	At-Risk	--
Skillet Clubtail	*Gomphurus ventricosus*	--	--
Sweetflag Spreadwing	*Lestes forcipatus*	--	--

Common Name	Scientific Name	Federal Status	State Status
REPTILES			
Carolina Saltmarsh Snake	*Nerodia sipedon williamengelsi*	--	**SC**
Carolina Swamp Snake	*Seminatrix pygaea paludis*		**SC**
Diamondback Terrapin	*Malaclemys terrapin*	--	**SC**
Glossy Crayfish Snake	*Liodytes rigida*	--	--
Rainbow Snake	*Farancia erytrogramma*	--	--

4.5.17.5 Threats Affecting Aquatic Species

Invasive Species. Invasive species (e.g., Red Swamp Crayfish, Green Sunfish, Redear Sunfish, Channel and Flathead Catfish, Asian Clam) have become established in the basin and continue to negatively impact native species populations (Fuller et al. 1999; Cooper 2005).

Pollution. Nutrient enrichment of the waterbodies within this basin continues to be the main water quality issue and the focus of regulatory- and strategy-related activities. Overall water quality in the Fishing Creek watershed is considered excellent; however, nutrient data analysis conducted by NCDWR indicates an increase in nitrogen concentrations since 1991. This watershed is a NCDWR priority for aquatic threatened and endangered species protection. Water quality standards have not been met in the Pamlico River Estuary even though the NSW strategy has been implemented by wastewater treatment plant dischargers, municipal stormwater programs, and agricultural programs. The trend analyses point toward a rise in organic nitrogen. This warrants identifying sources and reducing inputs of organic nitrogen throughout the basin. Potential sources that need more research include groundwater and atmospheric deposition (NCDWR 2014).

The Tar-Pamlico Basin Association (TPBA) currently has 16 members representing 20 discharge facilities that account for 98% of the known effluent flow to the basin. The remaining 2% of effluent flow is from 18 small facilities that have permit limits based on their size and capability. All National Pollutant Discharge Elimination System (NPDES) permitted facilities use 7Q10 standards (the lowest stream flow for seven consecutive days that would be expected to occur once in ten years) as critical flow in determining permit limits for non-carcinogen toxicants (USEPA 2013b).Low-flow conditions impact the ability of a stream to assimilate both point and nonpoint source pollutants. Droughts, as well as the demand on water resources, are likely to increase; therefore, the reevaluation of stream flow will become more critical to water quality in the future (NCDWR 2015d).

Water Quality. There are 118 permitted Confined Animal Feeding Operations (CAFOs) for cattle, poultry, and swine production in the Tar-Pamlico River Basin with 241 waste lagoons associated with the facilities (NCDEQ 2024(a)). Waste from these sites contains high levels of nutrients (e.g., nitrogen and phosphorus) in addition to fecal coliform bacteria and any chemical compounds, such as antibiotics or hormone products used in commercial feeding operations (NCDWR 2015b). Animal-waste lagoons and spray fields that discharge near or into aquatic environments are a source of contamination from runoff, percolation into groundwater, and volatilization of ammonia and the release of bacterial contamination. These sources can significantly degrade water quality and endanger human and animal health (Mallin 2003; Mallin and Cahoon 2003).

The progress achieved by the agriculture sector in implementing the Tar-Pamlico Agriculture Nutrient Control Strategy Rule is well documented in the Annual Agricultural Progress Reports submitted to the NCDENR Environmental Management Commission (EMC) every fall since 2003. As of 2002, the agriculture sector exceeded its collective 30% nutrient reduction goal, and in 2013, reported a 43% reduction in estimated nitrogen loss to the basin through the implementation of a combination of BMPs, crop shifts, fertilization rate reductions, and loss of overall cropland acres (NCDWR 2015d).

Nutrient stormwater controls are in place for only 54% of the basin. The Tar-Pamlico stormwater rule establishes nutrient export goals for new residential and commercial development projects within the planning and zoning jurisdictions of six of the largest and fastest-growing local municipalities and five counties within the basin. The municipalities are: Greenville, Henderson, Oxford, Rocky Mount, Tarboro, and Washington. The counties are: Beaufort, Edgecombe, Franklin, Nash, and Pitt. Each of these local governments has successfully implemented and managed its stormwater program since 2006 and continues to achieve nutrient export targets through a combination of on-site BMPs and off-site nutrient offsets (NCDWR 2014).

Impoundments. According to the National Aquatic Barrier Inventory Tool (SARP 2024) there are 2,627 dams in the basin. Most are small privately owned earthen dams impounding waters for recreation and agriculture uses. There are no FERC licensed facilities. Impoundments in the basin have affected aquatic species by physically altering habitat, reducing flows and DO, and causing erosion. Modification of flow regimes by upstream impoundments affects various life history characteristics of downstream migratory fishes and other aquatic fauna by limiting dispersal and recolonization. Additionally, water withdrawals for irrigation reduce the amount of habitat available for aquatic species (NCDWQ 2009).

Development. The Upper Tar subbasin has and will likely continue to observe the largest population growth of any of the subbasins, due in large part to its proximity to Raleigh. As the population continues to increase in areas of the basin, the potential exists for the basin to become more vulnerable to water quantity demands and other water management issues.

4.5.17.6 Basin Specific Recommendations

Conservation priorities that apply statewide to all river basins are presented in Section 4.5.3.3. Priorities identified in the Tar-Pamlico River Basin are shown in Figure 4.5.17-2 at the end of this section.

Surveys

General surveys are needed to complete primary distributional status for SGCN and other priority species (see Appendix 3).

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Fishes – determine distribution and status of priority species.		
American Brook Lamprey Banded Sunfish Black Banded Sunfish	Ironcolor Shiner Least Brook Lamprey	Mimic Shiner V-lip Redhorse
• Continue to conduct exploratory surveys for priority species that have a high potential of occurring in the river basin but are not currently known to occur.		
Bridle Shiner	Ironcolor Shiner	
• Mussels – determine distribution and status of priority species.		
Alewife Floater Creeper	Dwarf Wedgemussel Eastern Pondmussel Green Floater	Triangle Floater Yellow Lampmussel
• Crayfishes – determine distribution and status of priority species.		
Carolina Ladle Crayfish	Pamlico Crayfish	North Carolina Spiny Crayfish
• Snails – conduct baseline distribution surveys on all species that occur in the basin.		
Ridged Lioplax		

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to continued impacts to state waters. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. These efforts will inform species and habitat management decisions. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Identify long-term monitoring sites and develop monitoring protocols for priority species

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species, as well as investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Study habitat use and life history characteristics of priority species.

American Brook Lamprey	Carolina Ladle Crayfish	Triangle Floater
Least Brook Lamprey	Green Floater	V-lip Redhorse

- Support taxonomic research for priority species.

Cambarus sp. C complex	Chameleon Lampmussel	Mimic Shiner
Elliptio sp.		

- Support development of captive propagation techniques for priority species.

Bridle Shiner	Green Floater	Triangle Floater

- Support genetics research that informs augmentation policy for priority species.

Chameleon Lampmussel	Green Floater	Ironcolor Shiner
Creeper	Triangle Floater	

- Determine impacts of nonnative species on priority species.

Red Swamp Crawfish	Flathead Catfish

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats. In addition, education about, and regulation and prevention of the introduction and spread of exotic or invasive species are vital.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Support efforts to restore the native aquatic community through reintroduction or augmentation.
• Support acquisition of land that is adjacent to current conservation holdings or priority watersheds.
• Support other regulatory agencies to minimize impacts on species and habitats.
• Support dam removal where appropriate.

Conservation Programs and Partnerships

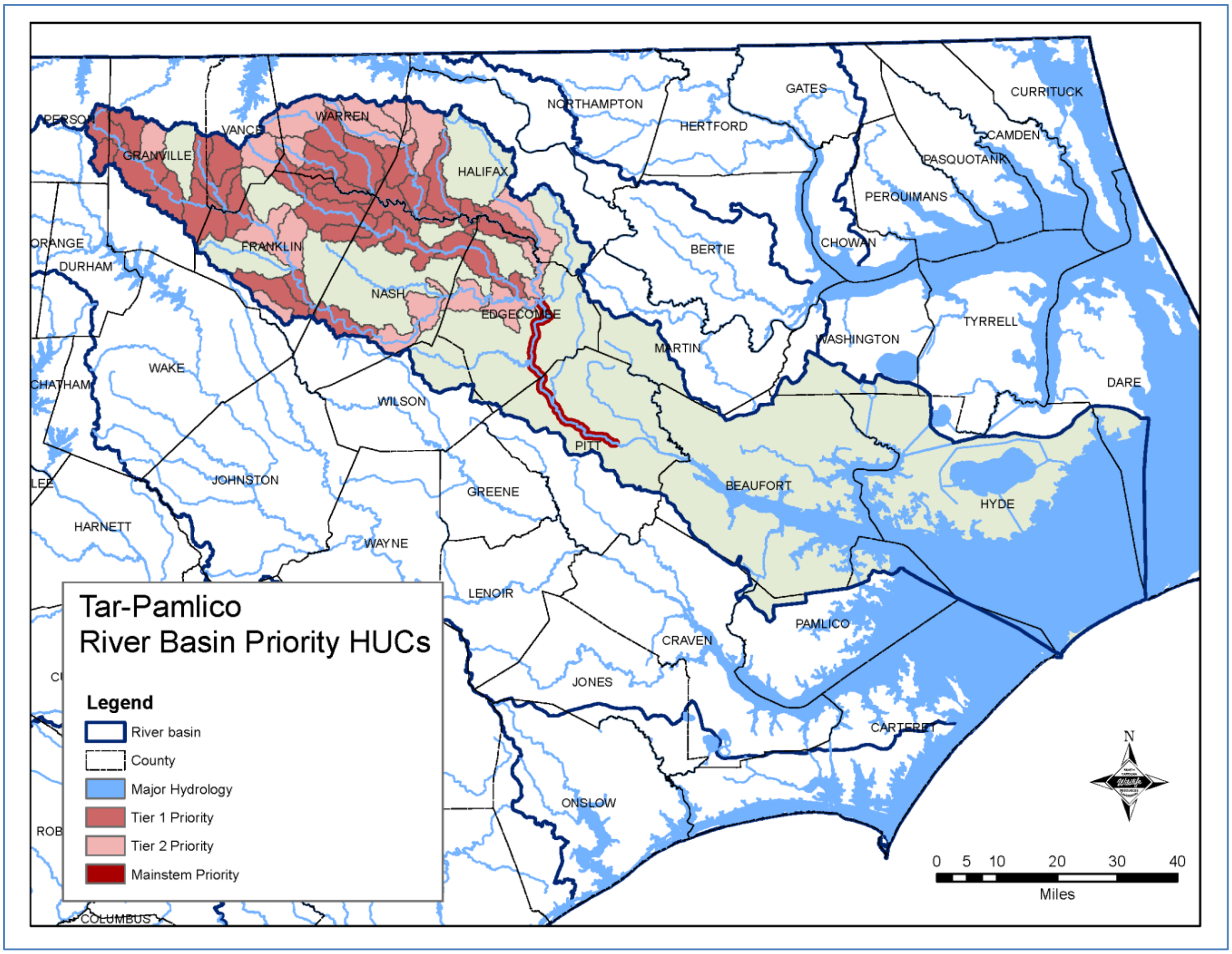
Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Guide academic research projects to help achieve specific conservation goals and objectives.
• Continue to support the application of an aquatic nuisance species management plan with other agencies/groups.
• Address secondary and cumulative impacts upon water quality (buffer ordinances, water supply watershed protection, and headwaters protection).
• Work with and promote existing programs that help farmers reduce sedimentation/erosion (installing fences to keep livestock out of streams, improving tilling practices) as well as reduce pesticide and herbicide use.
• Support stormwater management and wastewater treatment plant improvements and upgrades.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Continue working with Tar River Land Conservancy and Sound Rivers to conserve aquatic habitats.

Figure 4.5.17-2 Location of priority watersheds in the Tar-Pamlico River Basin.



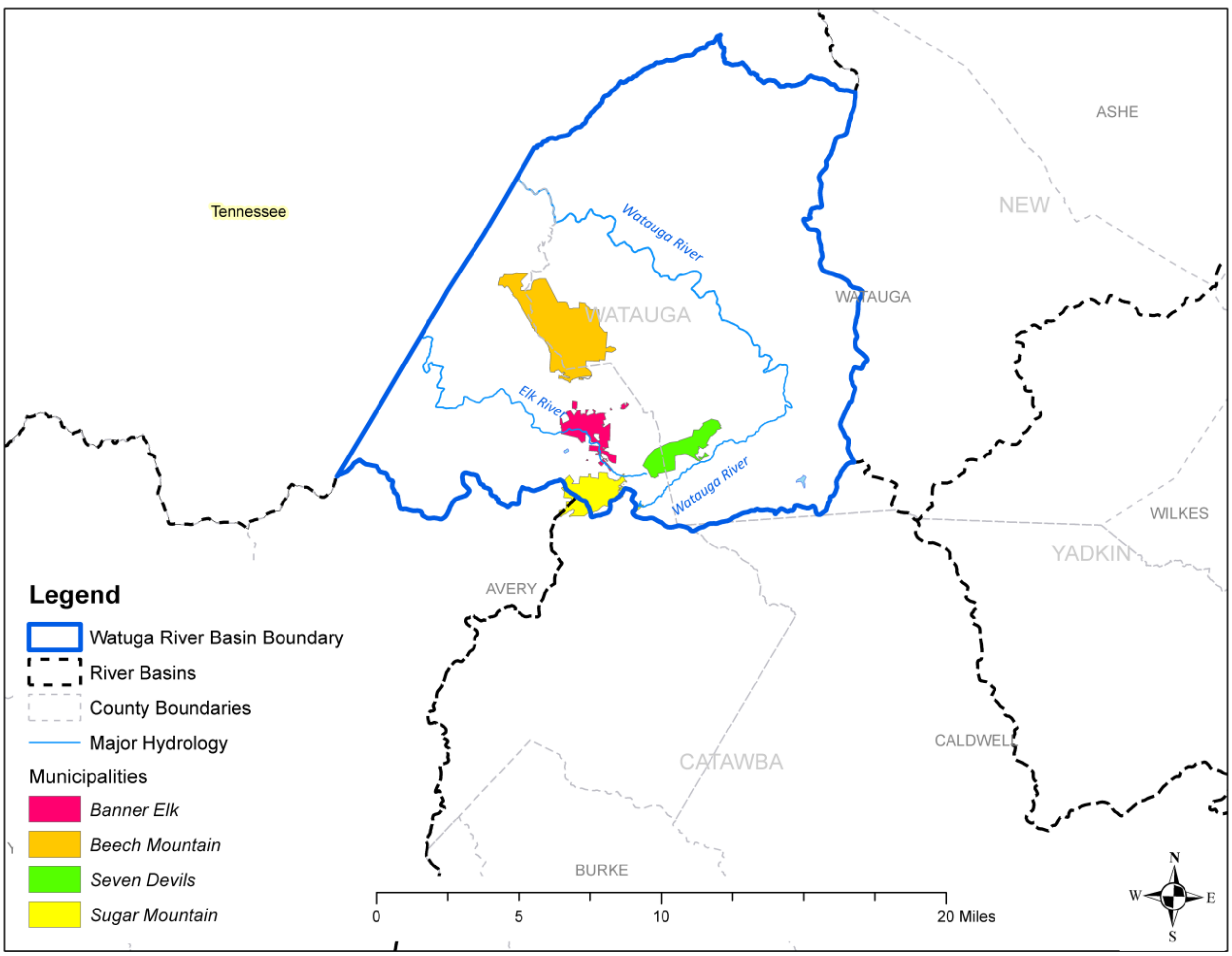
4.5.18 Watauga River Basin

4.5.18.1 River Basin Description

The Watauga River watershed drains northwest into Tennessee where it flows into Watauga Reservoir. The Watauga River is a tributary of the Holston River, which is a major tributary of the Tennessee River. The basin is one of the smallest in North Carolina, encompassing only 205 square miles (131,056 acres) and approximately 270 stream miles, and is entirely within the Mountain ecoregion. The North Carolina portion of the Watauga River Basin includes the headwaters and tributaries of the Elk and Watauga rivers. The Watauga River originates on the north slopes of Grandfather Mountain on land protected by The Nature Conservancy.

The basin encompasses parts of two counties (Avery and Watauga) and has six municipalities, including Banner Elk, Beech Mountain, Seven Devils, and Sugar Mountain. Figure 4.5.18-1 depicts the location of the basin.

Figure 4.5.18-1 Location of the Watauga River Basin.



Based on 2011 National Land Cover Dataset information (MRLC 2011; Jin et al. 2013), land use cover in the basin is 79% forested, 10% agricultural, 10% developed or urban, 1% grassland, and less than 1% wetland (MRLC 2011; Jin et al. 2013). Most land ownership is private, with less than 10% public lands (which includes portions of the Pisgah National Forest, Blue Ridge Parkway, Elk Knob Game Land, and Grandfather Mountain State Park).

4.5.18.2 Aquatic Resource Conditions

Water quality is generally good for areas where data are available; however, there are problems in parts of the basin (described below) and the lack of data for nearly half the basin provides an unclear assessment of overall water quality. There are more than 300 miles of freshwater streams in the basin that have been classified by NCDWR for best uses (NCDWR 2015dd, NCDEQ 2025). Some streams have more than one classification.

There are 14 streams designated as High-Quality Waters (HQW) in the basin, including the Watauga River. Seventeen streams have been designated Outstanding Resource Waters (ORW) (NCDWR 2025).There are four streams designated as Critical Areas (CA) because of their proximity to drinking water supply waters (NCDEQ 2025).

There are 53 streams designated by NCDWR-as trout waters (Tr) in the basin (NCDEQ 2025). North Carolina Division of Water Resources' trout water designation is a supplemental classification that protects freshwaters for natural propagation of trout and survival of stocked trout on a year-round basis. This is not the same as the Commission's designated public Mountain Trout Waters, which is used to designate waters that support trout and are open to public fishing.

4.5.18.3 Aquatic Species

Appendix 3 provides lists of SGCN and other priority species for which there are knowledge gaps or management concerns. Appendix 3-18 identifies aquatic SGCN associated with aquatic communities found in this river basin.

In addition to the crayfish, freshwater fish and mussels, and aquatic snails found in the basin, there are also species that may have both aquatic and terrestrial stages to their life history. The following list of SGCN are also associated with the aquatic communities in the basin

Common Name	Scientific Name	Federal Status	State Status
AMPHIBIANS			
Eastern Hellbender	*Cryptobranchus alleganiensis alleganiensis*	**PE**	**SC**
Eastern Long-tailed Salamander	*Eurycea longicauda longicauda*	**T**	**T**

4.5.18.4 Threats Affecting Aquatic Species

Pollution. While water quality conditions are generally very good at present, past pollution events may have had a profound effect on the extant aquatic fauna in the Watauga River Basin. A tannery near Valle Crucis caused severe pollution in the early 20th century and may have led to the extirpation of many native species. Apparently, no extensive surveys for aquatic species were made prior to this period of degradation and the extent of species loss is unknown.

Erosion and Sedimentation. Presently, excessive erosion and sedimentation from nonpoint sources are the primary problems affecting species and habitats. Most development and agricultural activities are located in the valleys due to abundance of steep slopes within the watershed. Narrow riparian corridors or total lack of riparian vegetation along portions of the Watauga River and many tributaries have led to excessive stream bank erosion and loss of habitat due to sediment deposition and over-widening of channels. Impacts from row-crop agriculture and poorly managed livestock pasture (causing sedimentation from runoff and stream bank erosion) are also significant.

Development. The area appears to be experiencing an acceleration of development, and threats to water and habitat quality are increasing. Development (primarily home construction) is rapidly increasing on steeper slopes. As related development increases (e.g., golf courses, commercial), stormwater runoff contributes more sedimentation and other nonpoint problems. Christmas tree farming is also increasing in the basin. Relatively large amounts of herbicides and pesticides are used in this form of silviculture, but the relative impacts of runoff from tree farms is unclear. Impacts from nonnative species (e.g., Margined Madtom) are also unclear, but could negatively affect native fish communities.

Impoundments. According to the Southeast Aquatic Resources Partnership (SARP) dam inventory (SARP 2024), there are 51 impoundments in the basin, most of which are small ponds used for recreation, agriculture, or water management. There are no major impoundments within the North Carolina portion of the basin. There are several small impoundments on tributaries, including Beech Mountain Reservoir on Buckeye Creek (drinking water reservoir), Price Lake on Boone Fork Creek (recreation), and Seven Devils Resort Lake on an unnamed tributary to the Watauga River (recreation).

Impoundments can affect aquatic species by physically altering habitat, reducing flows and DO, and causing erosion. Modification of flow regimes by upstream impoundments affects various life history characteristics of downstream migratory fishes and other aquatic fauna by limiting dispersal and recolonization. Additionally, water withdrawals for irrigation reduce the amount of habitat available for aquatic species (NCDWQ 2009).

4.5.18.5 Basin Specific Recommendations

Conservation priorities that apply statewide to all river basins are presented in Section 4.5.3.3. Priorities identified in the Watauga River Basin are shown in Figure 4.5.18-2 at the end of this section.

Distributional Surveys

While the general distribution of most species is known, surveys are still needed to complete primary distributional status for some SGCN (see Appendix 3).

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Aquatic Snails – complete primary distribution inventories; determine potential habitats and distribution surveys.
• Determine distribution of non-native species.
• Continue to delineate the distribution of the Grandfather Mountain Crayfish. Grandfather Mountain Crayfish

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to continued impacts to state waters. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. Baseline data and monitoring strategies have been developed for most priority species and habitats in the basin. These efforts will inform species and habitat management decisions. Monitoring plans should be coordinated with other existing monitoring programs where feasible.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Mussels - Continue periodic monitoring of priority areas and species. Green Floater
• Fish - Continue routine monitoring of SGCN and other priority fish species. Brook Trout
• Crayfish - Continue routine monitoring of priority crayfish species. Grandfather Mountain Crayfish

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Investigate aquatic community response to restoration projects in priority areas.
• Investigate potential for species reintroduction in the basin, particularly native mussels in the Watauga River.
• Obtain more information on impacts and mitigation of water withdrawals in headwater systems.
• Continue to work with partners to resolve taxonomic issues for crayfish within the genus Cambarus. *Cambarus* spp.
• Work with partners to identify causes for mussel population declines.

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats. In addition, education about, and regulation and prevention of the introduction and spread of exotic or invasive species are vital. Specific issues in this basin include secondary and cumulative impacts upon water quality, riparian vegetation and stream bank restoration and conservation, mitigation of hydropower development impacts, and species restoration opportunities.

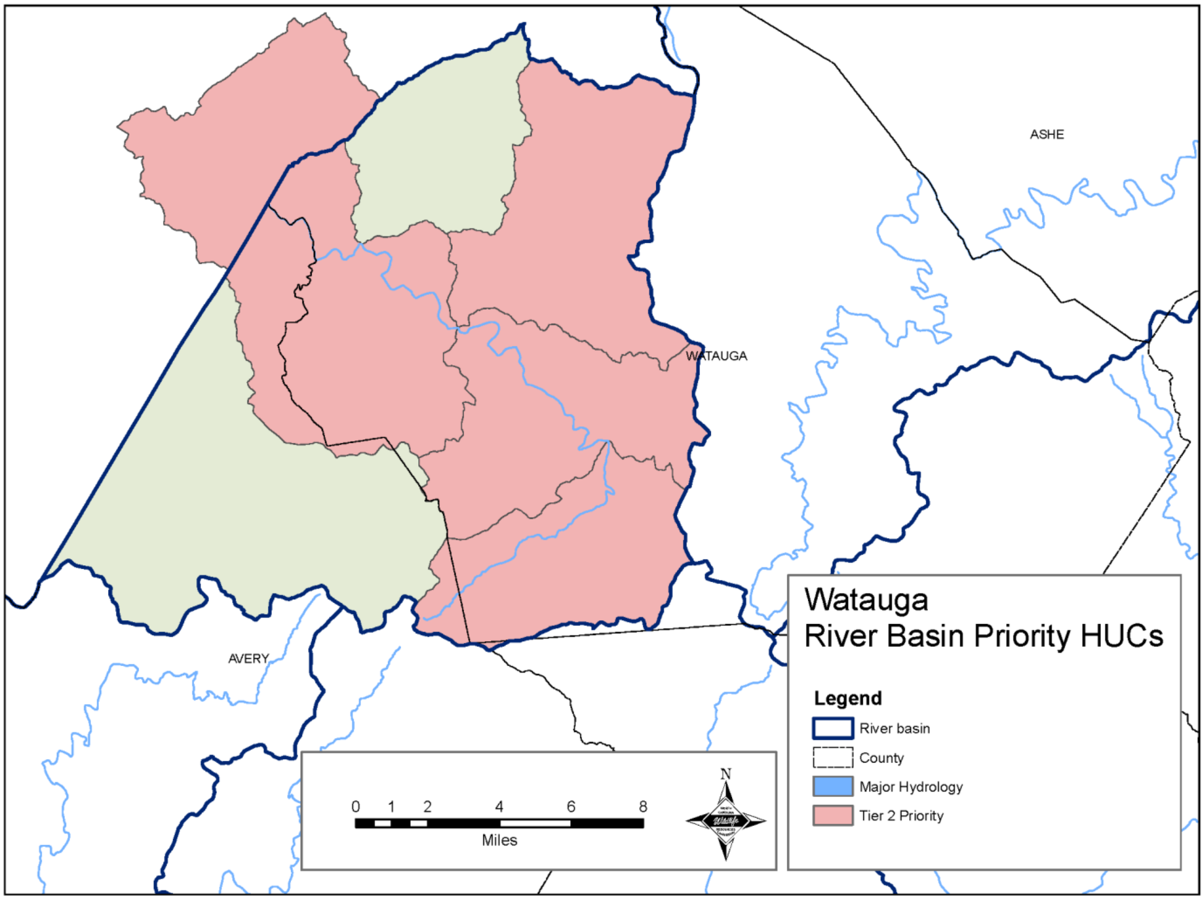
Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Prioritize education and other measures to prevent the introduction or spread of invasive nonnative species, particularly crayfishes.
• Support stream and riparian area conservation and restoration throughout the basin, particularly in priority areas.
• Support removal of relict dams and enhancement of aquatic organism passage at other barriers.

Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Support the Watershed Restoration Plan (WRP) and River Basin Restoration Priorities (RBRP) developed by NCDMS for the Watauga River Basin.
• Work together with Soil and Water Conservation District programs, such as the Agriculture Cost Share Program, to conserve priority areas.
• Work with regional land trusts and conservation oriented non-profit groups such as Mountan True to enroll priority riparian areas into conservation easements.

Figure 4.5.18-2 Location of priority watersheds in the Watauga River Basin.



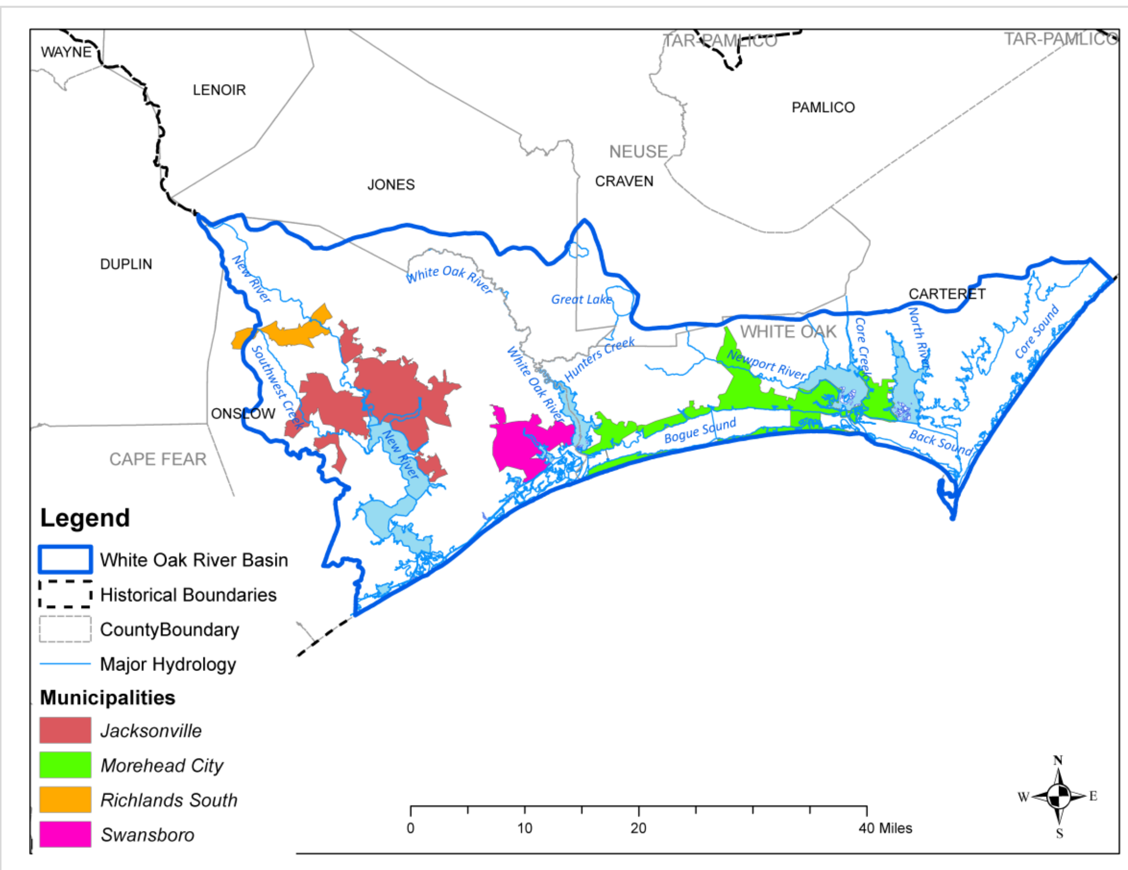
4.5.19 White Oak River Basin

4.5.19.1 River Basin Description

The White Oak River Basin lies entirely within the Coastal Plain and is composed of four small river systems (New River, White Oak River, Newport River, and North River), which all drain south directly into the Atlantic Ocean and associated sounds. The White Oak River is approximately 40 miles long and is a blackwater river. This basin encompasses 1,382 square miles, making it the smallest basin contained entirely within the state. There are 1,571 stream miles, 3,777 acres of freshwater lakes and impoundments, and 132 miles of Atlantic coastline in the basin (NCDWR 2015d, h). Due to the location and size of this basin, there is a relatively small amount of freshwater habitat available, but what is available has the characteristics typical of Coastal Plain streams: meandering waters associated with swamps, hardwood bottomlands, and wetland communities (NCDWQ 2007e).

The White Oak River Basin is located mostly in Onslow County and the southern portions of Jones, Craven, and Carteret counties. All or parts of 16 municipalities are located in the basin, including Jacksonville, Newport, Morehead City, and Beaufort. Figure 4.5.19-1 depicts the geographic location of the basin.

Figure 4.5.19-1 Location of the White Oak River Basin.



Land use in the basin is 25% forested, 32% wetland, 12% urban or developed, 3% grassland, and 11% agricultural (MRLC 2011). Public lands make up a large portion of this basin and include all or portions of the Croatan National Forest, Hoffman State Forest, Rocky Run, Stones Creek, Carteret County and White Oak River Game Lands, and Camp Lejeune. The estimated 2010 human population was 336,209, which represents an increase of more than 40% since 1990 and significantly exceeds predicted increases (USCB 2012; NCDWR 2015h).

4.5.19.2 Aquatic Resource Conditions

There are a number of impaired streams in this drainage, totaling 169.3 miles (NCDWR 2014a). There are 68 water bodies (stream reaches, intracoastal waterways, sounds, bays) that have an Outstanding Resource Waters (ORW) classification and 187 water bodies that have a High-Quality Waters (HQW) classification, because they either have excellent water quality or they are a significant resource to humans and/or wildlife (NCDWQ 2015d).

Site-specific management strategies have been developed to protect water quality conditions and the outstanding resource values of some ORW. Generally, these strategies restrict new discharges or expansions of existing discharges and can require expanded stormwater controls (NCAC 2019). The following specific ORWs in the White Oak River Basin have special management strategies.

- Roosevelt Natural Areas, all fresh and saline waters in NCDWR Stream Index Nos. 20-36-9.5-(1) and 20-36-9.5-(2)],
- Core Sound section of the Southeast Pamlico, Core, and Back Sound Area, all waters of Core Sound and its tributaries,
- Western Bogue Sound section of the Western Bogue Sound and Bear Island Area, including Taylor Bay and the Intracoastal Waterway,
- Back Sound section of the Southeast Pamlico, Core, and Back Sound Area, including Shackleford Banks, Middle Marshes, Harker’s Island.
- Bear Island section of the Western Bogue Sound and Bear Island Area, including Goose Creek, Queen Creek, Huggins Island, and Dudley Island,

4.5.19.3 Aquatic Species

Appendix 3 provides lists of SGCN and other priority species for which there are knowledge gaps or management concerns. Appendix 3-18 identifies aquatic SGCN associated with aquatic communities found in this river basin.

In addition to the crayfish, freshwater fish and mussels, and aquatic snails found in the basin, there are also species that may have both aquatic and terrestrial stages to their life history. The following list of SGCN are also associated with the aquatic communities in the basin

Common Name	Scientific Name	Federal Status	State Status
REPTILES			
Carolina Swamp Snake	*Seminatrix pygaea paludis*		
Carolina Saltmarsh Snake	*Nerodia sipedon williamengelsi*	--	**SC**
Diamondback Terrapin	*Malaclemys terrapin*	--	**SC**
Glossy Crayfish Snake	*Liodytes rigida*	--	--
Rainbow Snake	*Farancia erytrogramma*	--	--

4.5.19.4 Threats Affecting Aquatic Species

Pollution. Impacts affecting species and their habitats within the White Oak River Basin include nonpoint sources of pollution resulting from inadequate management practices related to agriculture, forestry, construction, and stormwater discharges. Sedimentation due to erosion is one of the most significant causes of habitat loss in this and all other North Carolina river basins.

The NCDWR publishes a list of streams, rivers, reservoirs and other water bodies in North Carolina considered to be "impaired," or that do not meet water quality standards for the classification for intended uses. The draft 303(d) list for 2024 contains 18,941 acres of impaired waters in the White Oak River Basin. Many of the impaired waters are listed because of shellfish growing area impacts from fecal coliform exceedances and sanitary surveys.

The National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating point sources, such as industrial, municipal, and other facilities that discharge pollutants into surface waters. Point source water pollution can include toxic compounds and elements such as ammonia, chlorine, and mercury. Individual permits are written to address the specific design and applicable water quality standards to an individual facility, while general permits authorize a category of discharges within a geographical area (USEPA 2015). In the White Oak River Basin there are 37 individual NPDES permits and 14 general permits (NCDWQ 2015i,j). Four of the individual permits are for major discharges from industrial processes and commercial facilities or municipal wastewater treatment plans that discharge one million gallons per day or more.

Water Quality. There are 42 permitted Confined Animal Feeding Operations (CAFOs) in the White Oak River Basin, with 60 associated waste lagoons (NCDEQ 2024(a)). Most are located in the northwestern portion of the basin along the New and White Oak rivers. Waste from these sites contains high levels of nutrients (e.g., nitrogen and phosphorus) in addition to fecal coliform bacteria and any chemical compounds, such as antibiotics or hormone products used in commercial feeding operations (NCDWR 2015b). Animal-waste lagoons and spray fields that discharge near or into aquatic environments through runoff, percolation into groundwater, and volatilization of ammonia and the release of bacterial contamination can significantly degrade water quality and endanger human and animal health (Mallin 2003; Mallin and Cahoon 2003).

Impoundments. According to the National Aquatic Barrier Inventory Tool (SARP 2024) there are 43 man-made impoundments in the basin. Those present can physically alter instream habitat, change flow regimes, and often reduce DO levels. Water withdrawals for irrigation and similar uses further change flow patterns and reduce the quality and quantity of habitat available for aquatic species (NCDWQ 2002).

Invasive Species. Invasive species (e.g., Flathead Catfish and Red Swamp Crayfish) are established in the White Oak River Basin and continue to negatively impact native species populations (Fuller et al. 1999; Cooper 2005) via predation and competition.

4.5.19.5 Basin Specific Recommendations

Conservation priorities that apply statewide to all river basins are presented in Section 4.5.3.3. Priorities identified in the Tar-Pamlico River Basin are shown in Figure 4.5.19-2 at the end of this section.

Surveys

Priorities for distribution and status surveys should focus on aquatic SGCN believed to be declining or dependent on at-risk or sensitive communities (see Appendix 3).

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Fish – Conduct surveys for SGCN and other priority species in the basin.

Banded Sunfish	Ironcolor Shiner

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to continued impacts to state waters. Studies include identification of population trends, as well as assessment of conservation or development activities. These efforts will inform species and habitat management decisions.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Monitor the presence and distribution of exotic species in the basin, as well as the status of priority populations

Banded Sunfish	Ironcolor Shiner

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, impacts of climate change and invasive species, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. Studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Determine vulnerability of species across all taxa groups to contaminants such as endocrine-disrupting chemicals (EDCs), microplastics, and other compounds that are present, as well as the prevalence of these compounds in this unique watershed.

- Support research on the effects of climate change on aquatic communities in the basin, particularly changes in temperature regimes, sea level rise, and extreme weather patterns.

- Support research investigating drivers behind the apparent decline in the Ironcolor Shiner.

  Ironcolor Shiner

- Support research resolving taxonomic uncertainty in priority taxa, such as crayfishes.

- Identify ways to eradicate or reduce the impacts of nonnative species throughout the basin as well as proactively preventing future introductions.

  Blue Catfish Flathead Catfish Red Swamp Crayfish

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats. In addition, education about, and regulation and prevention of the introduction and spread of exotic or invasive species are vital.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Promote programs to upgrade/increase compliance at wastewater treatment facilities and animal feeding operations (CAFOs).

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Provide support for land protection, particularly in riparian areas (acquisition, easements).
• Continue to identify areas critical to aquatic ecosystem health for conservation or restoration.
• Coordinate and provide management guidance on managed properties, such as military bases and national forests, to maximize effective conservation and restoration activities on these public lands.
• Promote prevention and awareness of the spread of exotic species and damage to native resources, communities and economic impacts.

Conservation Programs and Partnerships

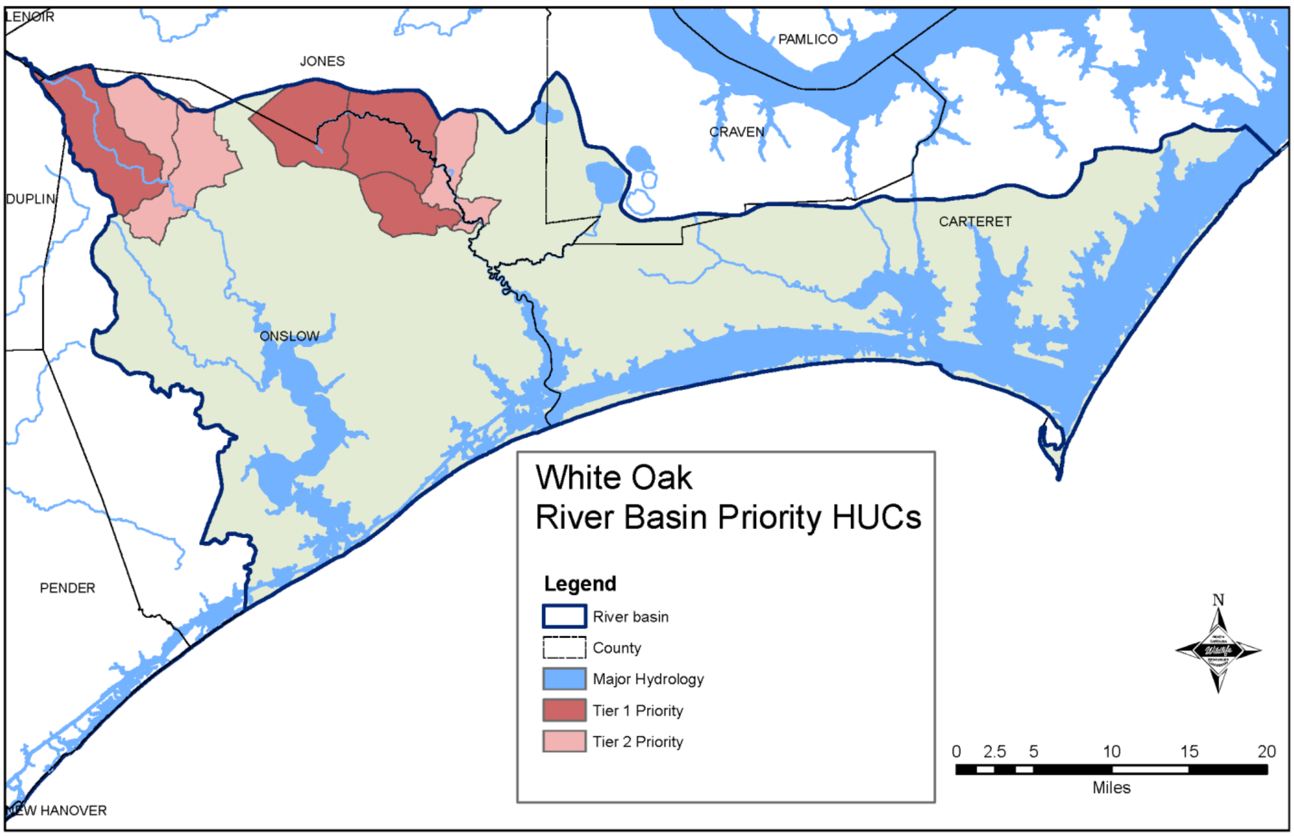
Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Guide academic research projects to help achieve specific conservation goals and objectives.
• Support the development and application of an aquatic nuisance species management plan with other agencies and groups.
• Address secondary and cumulative impacts upon water quality (buffer ordinances, water supply watershed protection, headwaters protection) (NCWRC 2002).
• Work with and promote existing programs that help farmers reduce sedimentation/erosion (e.g., install fences to keep livestock out of streams) as well as reduce pesticide and herbicide use.
• Support programs providing education and guidance about protecting aquatic habitats and water quality to landowners, developers, and municipal planners.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Continue work with conservation partners to advance species and habitat recovery goals

Figure 4.5.19-2 Location of priority watersheds in the White Oak River Basin.



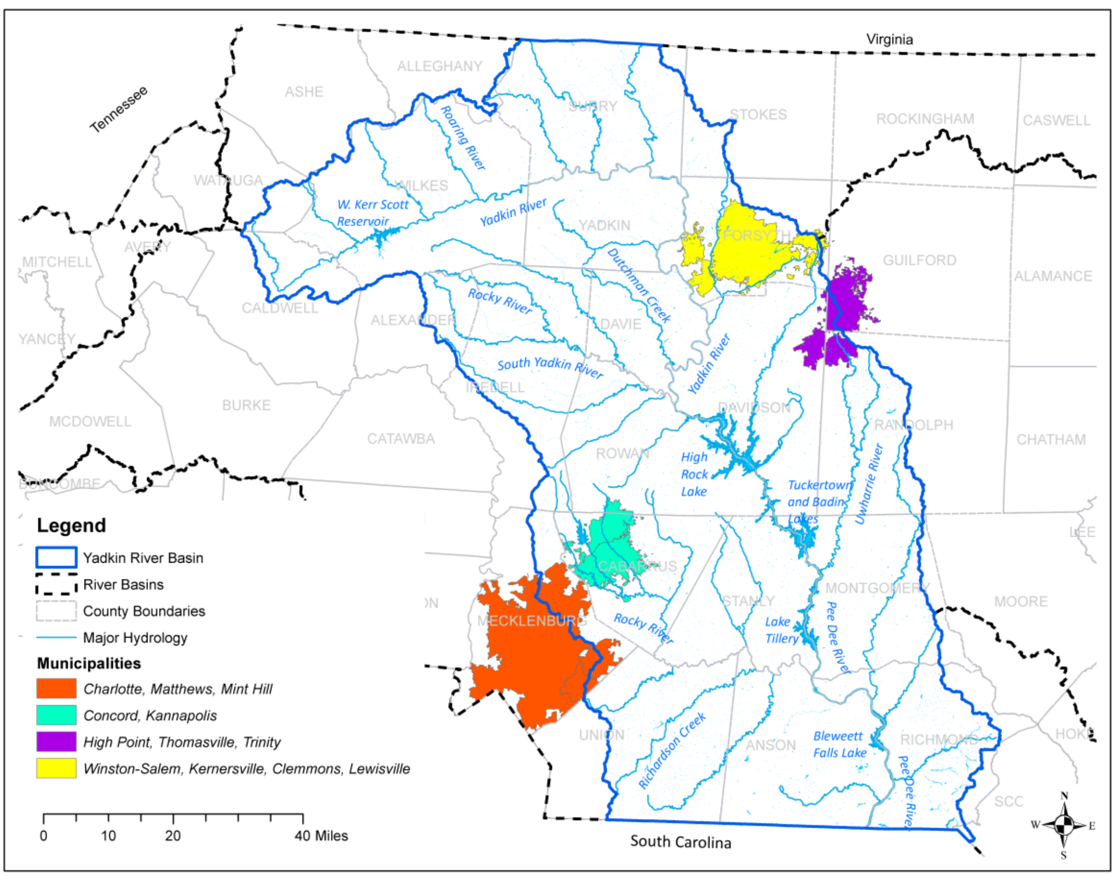
4.5.20 YadkinPee Dee River Basin

4.5.20.1 River Basin Description

The majority of the North Carolina section of the Yadkin–Pee Dee River Basin is located in the Piedmont ecoregion. The headwaters, which are partially in the Mountain ecoregion, are located in northwestern North Carolina and a small portion of southern Virginia. The Yadkin River flows east before turning southeast, and at the confluence with the Uwharrie River, the name changes to the Pee Dee River. The Pee Dee River continues into South Carolina south of Rockingham and ultimately empties into Winyah Bay along the Atlantic coast (NCDWQ 2008b). The North Carolina portion of the Yadkin–Pee Dee River drains an area of about 7,213 square miles, making it the second largest river basin in the state (NCDWQ 2008b).

The Yadkin–Pee-Dee River Basin crosses 21 counties, and 93 municipalities are completely or partially located within the basin. There are several large population centers formed by adjacent municipalities, such as Charlotte, Matthews, Mint Hill and others that comprise the Charlotte-Mecklenburg area; the High Point, Thomasville, and Trinity area; and the Winston-Salem, Kernersville, Clemmons, and Lewisville area. Figure 4.5.20-1 depicts the geographic location of the basin.

Figure 4.5.20-1 Location of the Yadkin–Pee Dee River Basin.



There are approximately 5,862 stream miles and 22,988 lake acres in the basin (NCDWQ 2003). Major tributaries in the Yadkin—Pee Dee basin are South Yadkin, Uwharrie River, and Rocky River. There are eight impoundments on the main stem of the Yadkin and Pee Dee rivers (W. Kerr Scott Reservoir, Idols Dam, High Rock Lake, Tuckertown Reservoir, Badin Lake, Falls Reservoir, Lake Tillery, and Blewett Falls Lake), plus many smaller reservoirs on tributaries. Many tributaries flow through densely populated areas of central North Carolina such as Charlotte, Winston-Salem, and their suburban areas. The Uwharrie Lakes region is comprised of impounded waters from six major hydroelectric projects which include the four upstream dams operated by Alcoa Power Generating, Inc. (APGI) and two lower dams operated by Duke Energy (Burns et al. 2012).

Land use in the basin is 55% forested, 24% agricultural, 13% urban or developed, 6% grassland, and 1% wetland (MRLC 2011; Yin et al. 2013). Urban and developed areas have steadily increased in size as the populations of Charlotte and other cities in the basin have grown. Public lands make up less than 5% of the Yadkin–Pee Dee River Basin.

The estimated 2024 population for the 13 counties with the largest urban centers in the basin was over 3.1 million people; population is projected to increase up to 20% by 2040 (OSBM 2025). The largest population increases are projected for Union, Mecklenburg, Cabarrus, and Iredell Counties.

4.5.20.2 Aquatic Resource Conditions

There are over 7,800 miles of freshwater streams in the basin that have been classified by NCDWR for best uses (NCDWR 2015d). In addition to the best-use classifications, NCDWR also monitors state waters to determine if they are supporting their use classification(s), and assigns use-support ratings based on that information. These ratings are published in the most recent 303(d) impaired waterbodies list (NCDWQ 2015a, 2015b).

Some waterbodies in the basin have supplemental classifications as High-Quality Waters (HQW) or Outstanding Resource Waters (ORW), because they either have excellent water quality or they are a significant resource to humans or wildlife (NCDWQ 2015d). There are 111 stream reaches that have a HQW classification, including portions of Elkin Creek (River), Dutch Buffalo Creek, Denson's Creek and the Fisher, Little, Reddies, and South Yadkin rivers as well as other headwaters and tributaries (NCDEQ 2025).

There are seven HQW Special Management Strategy Areas (SMSAs) totaling over 49,000 acres in the basin including Denson's Creek (17,490 acres), Little River (12,594 acres), Rocky Creek (6,638 acres), Bridger Creek (4,754 acres), and four other locations (NCDWR 2015c). There are four ORW SMSAs covering more than 92,975 acres in the basin, including Mitchell River Area (32,149 acres) and Elk Creek Area (32,284 acres) (NCDWR 2015c). These areas require site-specific provisions to protect resource values (e.g., no new discharges or expansion of existing discharges) (see 15A NCAC 02B.0225).

Another supplemental classification is NCDWR's trout water designation (Tr), which protects freshwaters for natural propagation of trout and survival of stocked trout on a year-round basis. There are about 46 miles of streams in the Yadkin - Pee Dee River Basin designated as Tr waters. This is not the same as the Commission's public Mountain Trout Waters, which is used to designate waters that support trout and are open to public fishing.

4.5.20.3 Aquatic Species

Appendix 3 provides lists of SGCN and other priority species for which there are knowledge gaps or management concerns. Appendix 3-18 identifies aquatic SGCN associated with aquatic communities found in this river basin.

In addition to the crayfish, freshwater fish and mussels, and aquatic snails found in the basin, there are also species that have both aquatic and terrestrial stages to their life history. The following list of SGCN are also associated with the aquatic communities in the Yadkin Pee Dee River basin.

Common Name	Scientific Name	Federal Status	State Status
DRAGONFLIES			
Cherokee Clubtail	*Stenogomphurus consanguis*	--	--
Midland Clubtail	*Gomphurus fraternus*	--	--
Mountain River Cruiser	*Macromia margarita*	**At-Risk**	--
Ocellated Darner	*Boyeria grafiana*	--	--
Septima's Clubtail	*Gomphurus septima*	**At-Risk**	--
Sweetflag Spreadwing	*Lestes forcipatus*	--	--
Zebra Clubtail	*Stylurus scudderi*	--	--

4.5.20.4 Threats Affecting Aquatic Species

Invasive Species. Invasive species (e.g., Flathead Catfish, Blue Catfish, Red Swamp Crawfish, mystery snails) are established in the Yadkin - Pee Dee River Basin and continue to negatively impact native species populations (Fuller et al. 1999; Cooper 2005; NCWRC 2005) via predation and competition.

Impoundments. The Yadkin - Pee Dee River Basin has numerous problems affecting both species and their habitats. According to the National Aquatic Barrier Inventory Tool (SARP 2024) there are over 5,400 dams in the basin. Many are small privately owned structures used for recreation, agriculture, and water control. However, there is a significant loss of riverine habitat in this basin due to eight mainstem dams and the numerous impoundments on tributaries (e.g, W. Kerr Scott Reservoir and Lake Tillery hydroelectric plants, municipal water supply lakes, and mill dams). Impoundments can physically alter instream habitat, change flow regimes, and often reduce DO levels. Water withdrawals for irrigation and similar uses further change flow patterns and reduce the quality and quantity of habitat available for aquatic species (NCDWQ 2008b).

Water Quality. There are 152 permitted Confined Animal Feeding Operations (CAFOs) for cattle, swine, and poultry production with 234 permitted waste lagoons in the Yadkin–Pee Dee River Basin (NCDEQ 2024(a)). Waste from these sites contains high levels of nutrients (e.g., nitrogen and phosphorus) in addition to fecal coliform bacteria and any chemical compounds, such as antibiotics or hormone products used in commercial feeding operations (NCDWR 2015b). Animal-waste lagoons and spray fields that discharge near or into aquatic environments are a source of contamination from runoff, percolation into groundwater, and volatilization of ammonia and the release of bacterial contamination. These sources can significantly degrade water quality and endanger human and animal health (Mallin 2003; Mallin and Cahoon 2003).

Streams are being impacted by excessive sedimentation and changes in hydrology and geomorphology, all due to urban development, agriculture, and instream mining (Williams et al. 1993; Etnier 1997; Neves et al. 1997; Warren et al. 2000). Water quality is also degraded by excessive nutrient input and other chemicals from wastewater discharges and surface water runoff from agriculture. There are 358 permitted discharges in the 21 counties of the Yadkin - Pee Dee River Basin, 46 of which are major discharges with ≥ 1 million gallons per day (NCDWQ 2015a).

4.5.20.5 Basin Specific Recommendations

Conservation priorities that apply statewide to all river basins are presented in Section 4.5.3.3. Priorities identified in the Tar-Pamlico River Basin are shown in Figure 4.5.17-2 at the end of this section.

Surveys

General distribution of most priority species is known; however, surveys are needed to complete distributional status for some SGCN and other priority species (see Appendix 3) as well as for invasive species.

Priority Conservation Action, Examples of Focal Species or Focal Habitats

- Fish—survey for priority and state listed species on a routine basis.

Carolina Redhorse	Pinewoods Darter	Sandhills Chub
Robust Redhorse	Snail Bullhead	Thicklip Chub

Priority Conservation Action, Examples of Focal Species or Focal Habitats
Ironcolor Shiner · Siouan Thinlip Chub · V-Lip Redhorse
• Mussels – continue to track mussel population health in priority areas such as Roaring and Mitchell Rivers, the Yadkin River upstream of Winston Salem, Dutchman's Creek, Goose, Duck and Crooked Creeks, the Uwharrie and Little Rivers and tributaries, and the Pee Dee River tailraces and mainstem upstream of the SC state line. Atlantic Pigtoe · Eastern Creekshell · Notched Rainbow Carolina Creekshell · Eastern Lampmussel · Savannah Lilliput Creeper · Green Floater · Triangle Floater
• Crayfishes – continue inventories and update status of priority species. Carolina Ladle Crayfish · Falls Crayfish · Greensboro Burrowing Crayfish Foothills Crayfish · Stony Fork Crayfish,
• Aquatic Snails – inventory primary distribution; determine potential habitats and distribution surveys for both native and nonnative species in the basin. Ridged Lioplax

Monitoring

Long-term monitoring is critical to assessing species and ecosystem health over time and gauging the resilience of organisms to continued impacts to state waters. Studies should include identification of population trends, as well as assessment of impacts from conservation or development activities. These efforts will inform species and habitat management decisions. Long-term monitoring sites need to be identified and monitoring protocols developed for all priority species. Monitoring plans should be coordinated with other existing monitoring programs where feasible. Monitor the presence and distribution of exotic species in the basin.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Fish—monitor priority and state listed species on a routine basis. Blackbanded Sunfish · Carolina Redhorse · Robust Redhorse Brook Trout · Ironcolor Shiner · Sandhills Chub Carolina Darter · Pinewoods Darter · Thicklip Chub
• Mussels – monitor priority species in priority areas (Roaring and Mitchell Rivers, the Yadkin River upstream of Winston Salem, Dutchman's Creek, Goose, Duck and Crooked Creeks, the Uwharrie and Little Rivers, and the Pee Dee River tailraces and mainstem upstream of the SC state line). Atlantic Pigtoe · Eastern Lampmussel · Triangle Floater Brook Floater · Green Floater · Uwharrie Elktoe

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
Carolina Creekshell Creeper	Notched Rainbow Roanoke Slabshell	Yellow Lampmussel
• Crayfishes – monitor priority species.		
Carolina Foothills Crayfish	Carolina Ladle Crayfish	

Research

Research topics that facilitate appropriate conservation actions include habitat use and preferences, reproductive behavior, fecundity, population dynamics and genetics, feeding, competition, impacts of climate change and invasive species, and food web dynamics. Increased understanding of life histories and status helps determine the vulnerability of priority species to further imperilment, in addition to identifying possibilities for improved management and conservation. All studies should provide recommendations for mitigation and restoration. Formal descriptions for known or putative undescribed species and investigations aimed at resolving taxonomic status are needed.

Priority Conservation Action, Examples of Focal Species or Focal Habitats		
• Support species descriptions for undescribed taxa.		
Carolina Redhorse	Moravian Crayfish Roaring River Crayfish	*Sagittunio* spp.mussels
• Determine vulnerability of species across all taxa groups to contaminants such as endocrine-disrupting chemicals (EDCs) and other compounds present in many of the waterways of the Yadkin Pee Dee Basin.		
• Identify limiting factors of declining species.		
• Identify ways to eradicate or reduce the impacts of nonnative species in throughout the basin as well as proactively preventing future introductions.		
Blue Catfish Flathead Catfish	Japanese Mystery Snail Chinese Mystery Snail	Hydrilla

Management Practices

Management practices that reduce impacts and work synergistically with other conservation actions are needed to enhance the resilience of natural resources. Particular needs include preserving biodiversity, protecting native populations and their habitats, and improving degraded habitats. In addition, education about, and regulation and prevention of the introduction and spread of exotic or invasive species are vital. Specific issues in this basin include secondary and cumulative impacts upon water quality, riparian vegetation and stream bank restoration and conservation, mitigation of hydropower development impacts, and species restoration opportunities.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Promote programs to upgrade or increase compliance at wastewater treatment facilities and CAFOs.
• Provide support for land protection, particularly in riparian areas through acquisition or easements.
• Support well-planned stream restoration work in collaboration with other organizations.
• Support measures to remove relict or non-functioning stream barriers where appropriate.
• Reintroduce or augment rare mollusk and fish species populations in areas where water quality and stream habitats have recovered sufficiently to support them.
• Continue to identify areas critical to aquatic ecosystem health that can be conserved or restored.
• Promote prevention and awareness of the spread of exotic species and damage to native resources, communities and economic impacts.

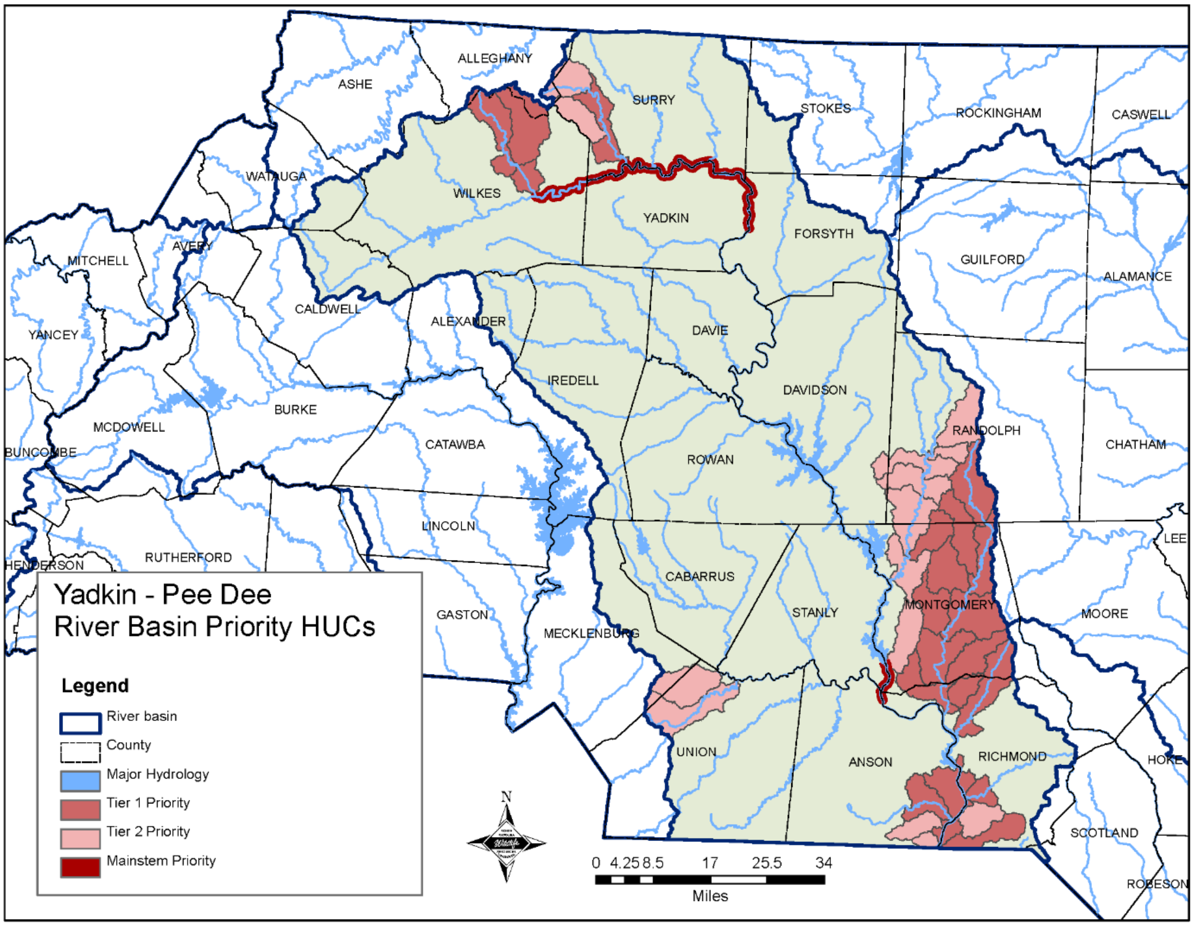
Conservation Programs and Partnerships

Conservation programs, incentives, and partnerships should be utilized to the fullest extent in order to preserve high-quality resources and protect important natural communities. Protective measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable. Land conservation or preservation can serve numerous purposes in the face of anticipated climate change, but above all, it promotes ecosystem resilience.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Guide academic research projects to help achieve specific conservation goals and objectives.

Priority Conservation Action, Examples of Focal Species or Focal Habitats
• Support application of an aquatic nuisance species management plan with other agencies/ groups.
• Address secondary and cumulative impacts upon water quality (buffer ordinances, water supply watershed protection, headwaters protection) (NCDWQ 2000a, NCWRC 2002).
• Work with and promote existing programs that help farmers reduce sedimentation and erosion (installing fences to keep livestock out of streams) as well as reduce pesticide and herbicide use.
• Maintain partnerships with Piedmont Lands Conservancy, Three River Land Trust, and Piedmont Conservation Council to conserve and preserve aquatic habitats.
• Continue work with conservation partners to advance species and habitat recovery goals.

Figure 4.5.20-2 Location of priority watersheds in the Yadkin - Pee Dee River Basin.



Chapter 5
Threats

5

CHAPTER 5. THREATS

> ***Required Element 3:*** *Descriptions of problems which may adversely affect species identified in Required Element 1 or their habitats, and priority research and survey efforts needed to identify factors which may assist in restoration and improved conservation of these species and habitats.*

5.1 Introduction

Natural communities are subject to numerous natural processes that can trigger, reinforce, or constrain the components of an ecosystem. Today, many of the stressors that cause impacts to wildlife and their habitats can be tied to anthropogenic activities. Burning fossil fuels, overharvesting, ecosystem degradation, habitat fragmentation, and wide-spread development are human legacies that impact biodiversity and ecosystem services, not only in North Carolina, but around the world (Balmford et al. 2011).

The impacts influencing ecosystem change that are most frequently mentioned when discussing threats to wildlife and their natural habitats include many that have long existed: land-use conversion, pollution, and invasive species. More recent threats are often associated with emerging issues, especially disease and pathogens, and climate change: sea level rise (SLR) and extreme changes in regional precipitation and temperature patterns (MEA 2005). The advent of new threats will drive the need for additional research and monitoring in order to make informed decisions about appropriate management and policy actions.

5.2 Threats, Stressors, and Emerging Concerns

Threats and environmental changes will affect the fitness, survival, and reproductive success of wildlife and, ultimately, the survival of populations and ecosystems. Many of the impacts will come from habitat destruction, disruption of food chains, changes in disease and pathogen loads, invasive species, increased pollution, and the direct and indirect effects of climate change (Milligan et al. 2009).

Following a best practice guide recommendation (AFWA 2012), a list of the 11 threats most likely to impact fish and wildlife are considered in this chapter. The list is based on the definitions and hierarchical classification scheme published by Salafsky et al. (2008) and adopted by the IUCN Conservation Measures Partnership (IUCN 2012), with two modifications.

First, the threat category covering geologic events (volcanic, earthquake, and avalanches) was eliminated based on an expectation these events will have little to no impact on wildlife in North Carolina over the 10-year planning horizon represented by this Plan.

Second, disease and pathogens are addressed as a separate threat category because of the serious threat they pose to fish and wildlife and ecosystems instead of considering these topics as a subset of Section 5.10 Invasive and Other Problematic Genes.

The threat categories listed in Table 5.2-1.are discussed in Chapter 5 subsections. The categories represent a source of stress to fish and wildlife species, habitat diversity, and ecosystems

Table 5.2-1 Chapter section and threat category description.

Threat Category	Section/Category Description
1	**5.3 Residential & Commercial Development** Threats are from human settlements or other nonagricultural land uses with a substantial footprint. These include housing and urban areas; commercial and industrial areas; and tourism and recreation areas.
2	**5.4 Agriculture & Aquaculture** Threats are from farming and ranching as a result of agricultural expansion and intensification, including silviculture, mariculture, and aquaculture. These include annual and perennial non-timber crops; wood and pulp plantations; and livestock farming and ranching.
3	**5.5 Energy Production & Mining** Threats are from production of non-biological resources, and exploring for, developing, and producing petroleum and other liquid hydrocarbons. These include oil and gas drilling; mining and quarrying; and renewable energy.
4	**5.6 Transportation & Service Corridors** Threats are from long, narrow transport corridors and the vehicles that use them, including associated wildlife mortality. These include roads and railroads; utility and service lines; shipping lines; and flight paths.
5	**5.7 Biological Resource Use** Threats are from consumptive use of “wild” biological resources, including deliberate and unintentional harvesting effects, as well as persecution or control of specific species. These include hunting and collecting terrestrial animals; gathering terrestrial plants; logging and wood harvesting; and fishing and harvesting aquatic resources.
6	**5.8 Human Intrusions & Disturbance** Threats are from human activities that alter, destroy, and disturb habitats and species associated with non-consumptive uses of biological resources. These include all recreational activities; military exercises; work; and other activities (research, vandalism, law enforcement, illegal activities).
7	**5.9 Natural System Modifications** Threats are from actions that convert or degrade habitat in service of “managing” natural or semi-natural systems, often to improve human welfare. These include fire and fire suppression; man-made dams and water management/use; and other ecosystem modifications (land reclamation; shoreline hardening; beach reconstruction, snag removal from streams, etc.).
8	**5.10 Invasive & Other Problematic Species & Genes** Threats are from nonnative and native plants, animals, pathogens/microbes, or genetic materials that have or are predicted to have harmful effects on biodiversity following their introduction, spread, and/or increase in abundance. These include invasive nonnative/alien species; problematic native species (e.g., beavers); introduced genetic material (e.g., genetically modified insects; hatchery or aquaculture raised species).

Table 5.2-1 Chapter section and threat category description.

Threat Category	Section/Category Description
9	**5.11 Pollution** Threats are from introduction of exotic and/or excess materials or energy from point and nonpoint sources. These include household sewage and urban wastewater; industrial and military effluents; agricultural and forestry effluents; garbage and solid waste; airborne pollutants; and excess energy (e.g., ambient noise, sonar, cold or hot water from power plants, beach lights, etc.).
10	**5.12 Climate Change & Severe Weather** Threats are from long-term climatic changes that may be linked to global warming and other severe climatic or weather events outside the natural range of variation that could wipe out a vulnerable species or habitat. These include habitat shifting and alteration; droughts; temperature extremes; storms and flooding.
11	**5.13 Disease & Pathogens** Threats are from bacteria, viruses, protozoa, fungi, and parasites. These include exotic or introduced pathogens; prion (nonviral, nonbacterial) disease; and zoonotic diseases. Wildlife species may act as hosts or reservoirs.

Although some threats may create minor impacts when acting alone, the cumulative impact or the synergistic effects from multiple threats may lead to dramatic ecological changes (Fischlin et al. 2007) so we have included information in each threat category about expected impacts to Species of Greatest Conservation Need (SGCN) and priority species.

Information about emerging issues and concerns is also discussed in this chapter. Finding solutions to specific conservation problems will have as much to do with addressing these overarching issues as it will with addressing more immediate problems. Many threats to wildlife are also general activities that can be important to the economic wellbeing of our state. It is important to work collaboratively so that ecosystem stewardship and economic goals are not mutually exclusive.

As previously noted, the threat categories addressed in this chapter are based on the definitions and hierarchical classification scheme published by Salafsky et al. (2008) with modifications. These threats were incorporated into the species evaluation and ranking process as Conservation Concern Metric 9 and Knowledge Gap Metric 14 and were used by Taxa Teams as part of their evaluations to determine SGCN. The Taxa Teams applied Metric 9 to gauge the scope and severity of the threat impacts using a Bayesian analysis. Metric 14 was applied to assess and rank the importance of each threat as a research topic to address knowledge gaps. Metrics 9 and 14 are incorporated in this chapter without additional analysis beyond Taxa Team consideration. The SGCN evaluation methodology is described in a white paper provided in Appendix 3 as Reference 3-1. Lists of SGCN and other priority species are located in Appendix 3. All references cited in this document are located in a separate section at the end of the Plan.

5.3 Residential and Commercial Development

> For this discussion, development includes housing and urban areas, commercial and industrial areas, and tourism and recreation areas that have a substantial footprint (Salafsky et al. 2008).

The US Geological Survey (USGS) suggests that the threat to ecosystems from development patterns and current practices in the Southeast rivals threats from climate change (Terando et al. 2014). Habitat degradation and fragmentation arising from sprawling development patterns are some of the most significant causes of species imperilment in the United States (Brown and Laband 2006; Doyle et al. 2001; Ewing et al. 2005). Encroachment of major development adjacent to existing conserved lands and within high-quality wildlife corridors is of particular concern due to the need to maintain the integrity of protected habitats and the ability of wildlife and plants to disperse across the landscape.

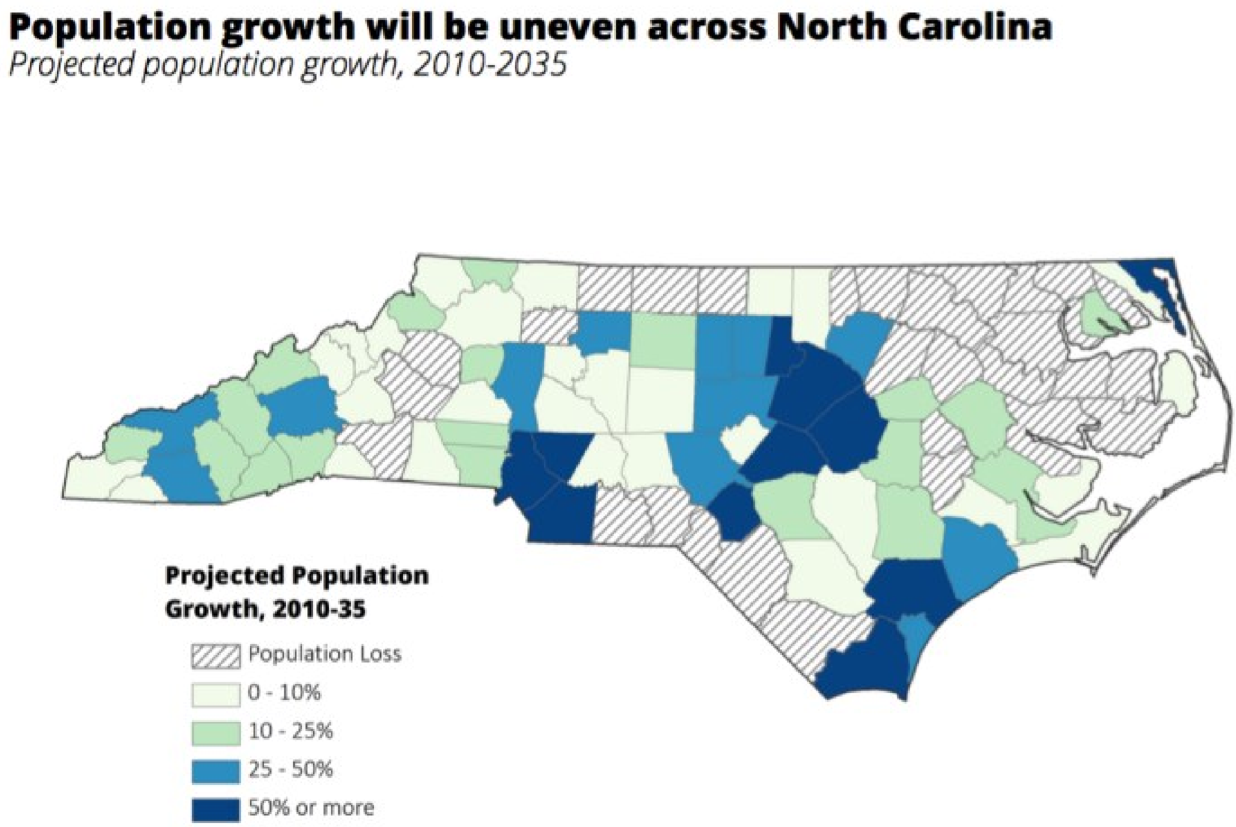
In addition to the land use and habitat fragmentation that are common to any type of development, manufacturing and industrial facilities can also be a source of air, water, and noise pollution that can disrupt natural wildlife activities. Urbanized land can have a disproportionate effect on freshwater stream health, with estimates indicating urbanized basins can impair as much as three times the length of stream impacts when compared to stream impacts from agricultural land uses (Smoot et al. 2004).

North Carolina has been consistently among the 12 largest and fastest growing states in the country, according to recent census reports, and is now the 9th most populous state. The Office of State Budget and Management reports NC is projected to become the 7th most populated state by the early 2030s (OSBM, 2024). The Triangle region in particular has been the 10th fastest growing region since 2020 (Eanes, 2024). Over one acre of land is developed for each new resident in the state and the rate of land development has been growing faster than the rate of population growth (ENCRPC 2007). These growth rates are projected to continue, with a 10% projected population growth rate from 2020 to 2030, when the total population is expected to be almost 11.7 million (NCOSBM 2014).

Instead of encouraging major development in or near town centers, land-use policies in our state are leading to fragmented and spread-out patterns of development in which our rural landscapes are being converted to sprawling suburban land uses with large parking lots and extensive lawn-dominated landscaping. Lack of redevelopment within town and city centers, separation of land uses instead of mixed-use development, and leapfrog development on the outskirts of towns and cities make North Carolina home to the most urban sprawl of any state (Otto et al. 2002).

Haphazard development causes negative impacts to fish and wildlife that are among the top threats, especially to those species that are identified as conservation priorities (NCWRC 2012). The encroachment of development into unfragmented habitat also causes species displacement due to competition from habitat generalist wildlife species that can thrive in urban and suburban landscapes. Nonnative invasive plant species—which reduce native insect populations—and increased predation from generalist wildlife and outdoor cats can cause local extirpation of wildlife of conservation concern. Human–wildlife conflict is another issue of particular concern that is exacerbated by spread-out development patterns. The more conflict people perceive as being caused by wildlife, the less support the public may have for wildlife conservation.

Figure 5.3-1 Population growth projection 2010 to 2035
(Source: communitydevelopment.ces.ncsu.edu)



Areas of the state that are highest in biodiversity, species rarity, and endemism are experiencing the greatest rates of urban and rural sprawl. Among these areas of the state are the southeast Coastal Plain, the Sandhills, and the southeast Mountains. In addition, most priority wildlife habitats depend on the ecosystem process of fire. Some are completely fire dependent, such as the Longleaf Pine ecosystem and many small wetland community types. The ability to conduct prescribed burning is all but lost in exurban and urban areas.

The Wilmington metropolitan area and NC beach communities drive development growth on the southeast Coastal Plain. Populations in the region increased by 40% from 2000 to 2010 (USCB 2014). The Wilmington region ranks among the top 10 most diverse areas in reptiles and birds on the continent (Ricketts et al. 1999).

Fayetteville sits in the heart of the Sandhills ecoregion, which comprises the third most endangered ecosystem in the United States (Noss and Peters 1995) and communities in the region grow by 15%–30% every 10 years. From 2010 to 2025, Sandhills communities are projected to grow by 14%–32%.

Four NC cities in the Piedmont are among the top 100 fastest growing cities in the nation, with Charlotte and Raleigh listed among the top ten (City Mayors Statistics 2012). In the Charlotte region, five times more land is developed, and in Raleigh, three times more land is developed, per person, now than in the 1970s (UNCC 2009, 2012). The primary concern regarding expanding urban areas is the cumulative effect of sedimentation on rare and endangered aquatic species and the further fragmentation of habitat for fairly common terrestrial species that require large unfragmented habitats.

Land development in the southern Appalachians has outpaced population growth by a factor of 10:1 since the 1970s (RENCI 2010). The southern Appalachians of North Carolina is predicted to experience growth rates of 12%–25% through 2030 (NC Office of State Budget and Management 2014) and is among the most biologically diverse regions of North America, with over 400 endemic species (Ricketts et al. 1999).

Compounding this problem is the “land-use planning gap”—or the lack of effective habitat conservation strategies in land-use planning efforts. Many communities in North Carolina are not consistently using conservation data and have not had access to information on how to incorporate habitat conservation into plans, incentives, ordinances, and development design. Numerous reports have called for increased coordination between wildlife agencies and land-use planners (Azerrad and Nilon 2006; Beatley 2000; Jenkins et al. 2007; Environmental Law Institute 2007). At least ten other state wildlife agencies actively address the threat from development patterns to priority wildlife.

5.3.1 Anticipated Impacts

Fragmentation due to development and road projects makes movement between existing populations and nearby habitat more difficult. It also increases the risk of mortality from road crossings and predation by domestic pets and feral animals from nearby neighborhoods. Road impacts to amphibians and reptiles are of particular concern in the Sandhills and the southeast Coastal Plain. Conservation-based development ordinances or projects often do not address habitat fragmentation.

Lands between existing managed conservation areas are at risk, in developing counties, from major development that will impede wildlife travel and habitat corridors. Reduced ability to conduct prescribed burning and hunting can occur due to the encroachment of major development adjacent to managed conservation lands.

Bald eagles and colonial nesting waterbirds have been known to abandon their nests when development takes place during the nesting season within 330 feet or more of their nests (Rogers and Smith 1995; Carney and Sydeman 1999; USFWS 2007).

Converting pervious land surfaces to impervious surfaces such as roads, rooftops, and parking lots alters stream hydrology by increasing surface runoff during rain events and reducing infiltration. An increase in imperviousness causes streamflows to increase more rapidly following rain events and subside more quickly. With less rainfall soaking into the ground, there is less groundwater to contribute to baseflows. Altered stream hydrology can impact aquatic communities. Contamination originating from developed areas can flow into surface waters used by aquatic species and breeding and larval amphibians when stormwater runoff and other nonpoint sources carry toxic materials such as gas and oil and chemical pest control treatments from lawns and fields. Road projects and mining in areas with acidic rock types can degrade streams.

Development often encroaches on floodplains, reducing lateral connectivity and exacerbating flood damage to streams and riparian areas. Reduced or eliminated riparian buffers along streams results in increased water temperatures and less stable stream banks, leading to increased sedimentation. Increased numbers of road crossings, particularly culverts, further fragments streams and other aquatic systems, leading to reduced organism movements and gene flow.

In the Coastal Plain ecoregion development and use of beaches increases impacts to nesting seabirds and other waterbirds, Diamondback Terrapins, and sea turtles. Lack of living shorelines along open waterbodies will increase erosion and further reduce forage, nesting areas, and cover for wildlife. Development of barrier islands, coastal forest, and wetland communities further reduces natural habitat that is already highly fragmented, which may completely isolate and threaten species with specialized life histories and limited movement ability. Examples include the Buxton Woods White-footed Deermouse, Eastern Woodrat, Eastern Coral Snake, and many amphibian species. Development of uplands adjacent to brackish wetlands impacts species such as the Diamondback Terrapin and waterbirds. Tidal swamp forests and species are also particularly threatened by development.

In the Sandhills and Coastal Plain ecoregions, impacts in landscapes surrounding upland pools, depressions and seeps, and wet and mesic pine savannas are of particular concern for winter-breeding amphibian species and seasonal wetland reptiles, such as the Chicken Turtle, Pine Barrens Treefrog, and Mabee’s Salamander. Bachmann’s Sparrow, Bobwhite Quail, Loggerhead

Shrike, and Red-cockaded Woodpecker are also of major concern. Development in and adjacent to forested wetlands, mesic forests, and floodplains particularly impacts colonial nesting waterbirds, priority herpetofauna, and bats, among other priority wildlife.

In the Piedmont ecoregion species that are common in other parts of the state may decline due to development of priority habitats such as forests of 75 to 500 acres or more. Floodplain and riparian forest impacts, and impacts to seasonal wetlands are of particular concern for species such as the Four-toed Salamander, Mole Salamander, and Eastern Spadefoot Toad. Early successional habitat-associated species are impacted by leapfrog development encroaching on farmland, particularly species such as Grasshopper Sparrow, Loggerhead Shrike, and Bobwhite Quail.

In the Mountains ecoregion development that impacts unfragmented forest, rock outcrops, and seasonal wetland communities will impact species such as the Cerulean Warbler, Green Salamander, Timber Rattlesnake, and other priority amphibians and reptiles. Impacts from major and minor development to spruce–fir and northern hardwood forest are of particular concern for the Carolina Northern Flying Squirrel, small mammal species, and bats that use these habitat types. Development of early successional habitats and bogs will impact species such as the Bog Turtle, Golden-winged Warbler, and Bobolink.

5.3.2 SGCN Priority Species

The Taxa Team evaluation considered the level of threat that residential and commercial development represents to SGCN priority species. Lists of the SGCN and other priority species this threat is expected to have a very high or high impact on can be found in Appendix 3.

5.4 Agriculture and Aquaculture

> This category considers threats from farming and ranching as a result of agricultural expansion and intensification and includes silviculture, mariculture, and aquaculture. (Salafsky et al. 2008).

Our state has a rich agricultural heritage. North Carolina has over 8.4 million acres of farmland and ranks 7th nationally for farm profits (USDA 2014). Our state leads the nation in tobacco and sweet potato production and ranks 2nd for Christmas trees, hogs, and turkeys (USDA 2014). In North Carolina, the state Department of Agriculture and Consumer Services (NCDACS) has responsibility for agriculture and aquaculture operations.

Livestock farming and ranching are agriculture components and involve raising terrestrial animals (e.g., cattle, swine, poultry) on farms or feed lots. Examples include dairy, chicken, horse, and cattle farms; cattle and swine feed lots; sheep and goat herds; and exotic animal herds (e.g., llamas, alpacas, ostriches). Annual and perennial non-timber crops, orchards, vineyards, and mixed agroforestry planted and harvested from traditional and industrial farms or plantations and used for food, fodder, fiber, fuel, or other uses as agricultural concerns are silviculture concerns.

Aquaculture is a fast growing source of food production throughout the world (FAO 1997; Fu et al. 2012). Freshwater and marine aquaculture (mariculture) includes aquatic animals raised in one location on farmed or nonlocal resources and hatchery fish allowed to roam in the wild. Shrimp or finfish aquaculture, fish ponds on farms, hatchery fish, seeded shellfish beds, and artificial algal beds are examples of aquaculture operations (Salafsky et al. 2008).

Freshwater aquaculture can generally be defined as the propagation and rearing of aquatic species in controlled or selected environments such as constructed ponds or lakes and hatcheries. Aquaculture facilities in the Mountain ecoregion tend to focus on cool- and coldwater production of fish using flow-through tank production. Freshwater aquaculture facilities in the Piedmont ecoregion generally use recirculating tank production, while those in the Coastal Plain ecoregion typically use warmwater ponds for production (Turano et al. 2013).

Mariculture involves propagation and rearing of marine aquatic species in controlled or selected environments such as ocean ranching, constructed ponds or lakes, hatcheries, seeded beds (shellfish), or facilities constructed in natural waters (Salafsky et al. 2008). Mariculture in North Carolina involves raising finfish species (e.g., Black Sea Bass) as well as clams, oysters, and soft crabs (Turano et al. 2013). The NC Marine Fisheries Commission is responsible for the management, protection, preservation, and enhancement of marine and estuarine resources, including mariculture operations.

5.4.1 Agriculture - Anticipated Impacts

As with all threat categories, there can be positive or negative impacts to wildlife depending on its scale and location. Potential impacts (both positive and negative) to fish and wildlife resources from agriculture are numerous. Impacts that can be harmful to wildlife include loss of habitat from conversion of forested or early successional land to cleared agricultural land, erosion of agricultural fields that leads to increased turbidity and sedimentation in surface waters, and contamination from application of pesticides and herbicides. Agricultural crops can provide an important food resource for many wildlife species; however, depredation impacts from wildlife can be significant on agricultural commodity crops. On the positive side, harvested crops within the Coastal Plain provide suitable fall and winter food supplies for waterfowl, Black Bear, White-tailed Deer, and other small wildlife species.

Clearing forested or early successional land and converting it to agriculture can displace birds and small mammals that rely on this community type and reduce the number and diversity of species inhabiting the area. The loss of forested habitats that serve as corridors for species moving among adjacent habitats can be especially harmful to wildlife as it reduces available cover for predator avoidance.

Agricultural practices also affect wetlands, streams, and groundwater in several ways. Wetlands and other similar habitats can be converted directly to agricultural land or their functions can be lost by changes to the soils or hydrology from practices such as ditching and draining. Furthermore, surface and groundwater hydrology can be affected by irrigation.

Without appropriate sedimentation and erosion control measures, rain events can lead to erosion of cleared fields resulting in increased turbidity and sedimentation of nearby surface waters. Increased turbidity and sedimentation affects foraging and reproduction in streams and lakes and can lead to changes in community composition and species extirpation. In the Coastal Plain, pumping of water during high-water events can result in sedimentation, contaminants, and large volumes of freshwater being dumped into our estuaries, which can negatively affect marine species.

Agricultural land uses that include aerial spraying of pesticides and herbicides can affect local amphibian populations when wind carries chemicals into nearby surface waters and wetlands. Little has been published about this source of contamination but research conducted in California found a significant relationship between amphibian declines in locations with known populations and pesticide drift from upwind sources of agrochemical applications (Davidson 2000).

Studies have shown that greater cattle access to wetlands contributes to a higher prevalence of *Frog Virus 3* (FV3) (Gray et al. 2007a). Pathogenic relationships between cattle and amphibians can occur when suitable hosts are present in drinking water supplies. For example, American Bullfrogs are suitable hosts of the human pathogen *Escherichia coli* (E. coli), which can provide an exposure pathway between food safety and human consumption when cattle operations contaminate waters with amphibian populations (Gray et al. 2007b; Hickling 2011). This is another reason why agricultural producers need to restrict livestock access to aquatic environments.

5.4.2 Aquaculture - Anticipated Impacts

Aquaculture operations are a potential source of accidental release of nonnative species that can become invasive in surface waters (see Section 5.10 for more information on invasive species). The aquaculture, aquarium, biological supply, and live-bait industries are potentially the most important vectors responsible for the introduction of nonnative crayfishes throughout North America (Lodge et al. 2000; Kilian et al. 2009). In Maryland, Red Swamp Crayfish has become established in streams adjacent to all aquaculture ponds where it was introduced for commercial culture or for aquaculture-related research (Killian et al. 2009). Studies in North Carolina indicate this aggressive crayfish is likely to out-compete and displace native species for shelter and other limited resources, thereby resulting in changes to the composition of aquatic communities (Cooper and Armstrong 2007; Killian et al. 2009).

Genetic contamination of wild stocks can occur by release or escape of hatchery organisms that breed with wild organisms. The traits that are beneficial in an aquaculture setting may be detrimental to wild animals. Also, a strain of fish or other aquatic organism from a particular river basin may be genetically compromised by a cultured organism whose lineage is from a different river basin. This is particularly an issue with some anadromous species, such as Striped Bass.

Aquaculture operations can be a source of various pathogens and parasites that can affect wild populations (see Section 5.13 for more information on diseases and pathogens). Bacterial infection is reported as the main cause of disease-induced mortality of fish raised in aquaculture, likely because the high densities associated with fish farming increases exploitation of pathogenic bacteria (Johansen et al. 2011; Cervino et al. 2012). About 150 different bacterial pathogens associated with farmed and wild-caught fish have been identified (Austin and Austin 2012; Richards 2014), but disease transfer between farmed and wild stocks is poorly understood (Weir and Grant 2005; Cervino et al. 2012). In many cases pathogens in aquaculture can remain undetected until some stress makes the animal more susceptible to infection (Austin and Austin 2012; Richards 2014). The incidence, prevalence, and origin of diseases are difficult to measure in wild populations and the complex relationships between host, pathogen, and the environment can be influenced by many factors (McVicar 1997; Bakke and Harris 1998; Weir and Grant 2005; Hedrick 1998; Cervino et al. 2012). Water discharges and stock escapes from aquaculture are therefore important sources of exposure for diseases and pathogens to native populations (Richards 2014).

5.4.3 Silviculture - Anticipated Impacts

Generally, silviculture is the science of managing forests or forest crops to meet diverse needs and values. For purposes of this section, the topic is focused on the management of tree plantations for wood fiber, timber, Christmas trees, or production of nonnative species for other uses (Salafsky et al. 2008). Natural forests are not included in this definition (see Sections 5.5, 5.7, and 5.9 for discussions on management and alterations to natural forests). Silvicultural operations remove various amounts of planted forest materials for processing into wood and pulp products. The mission of NC Forest Service is to protect, manage, and develop the forest resources of the state.

Converting naturally diverse forests to monocultural tree farms reduces habitat diversity, which, in turn, is a major cause of wildlife species loss (Wilcove et al. 1998; Thompson et al. 2013; Roberts and Gilliam 1995; Martin-Queller et al. 2013). At a minimum, the loss of canopy and understory vegetation diminishes availability of cover and forage for wildlife, or, in the case of clearcuts, removes these wildlife resources entirely. Sites allowed to revegetate naturally through successional growth seeded from nearby natural communities could result in poor genetic diversity from the weedy or invasive species that tend to be early colonizers on disturbed sites.

Particular forest structures and ranges of food sources may be more important than particular tree species for certain wildlife (e.g., mammals) (von Haartman 1971; Cannell 1999) or there may be life history dependence on particular species (e.g., Red-cockaded Woodpecker). The conversion of a mixed species forest to an even-aged monoculture, such as those associated with pine plantations, changes the diversity of habitats, but management options are available to improve diversity of plantation landscapes (Cannell 1999). Stand-level wildlife habitat elements such as snags, mast trees, down and coarse woody debris, den trees, and nest trees provide important perching, nesting, foraging, and displaying habitats for a wide variety of wildlife (Jones et al. 2009; Hodson et al. 2010).

In addition to the loss of vegetation, some timber operations create impacts that directly affect landscapes through changes to soil properties caused by mechanized clearing, cutting, and site preparation activities. These impacts include soil compaction, especially to organic soils, increased erosion from disturbance, nutrient loss, removal of seed resources, lost or diminished genetic diversity, changes to microtopography, and changes to hydrogeomorphic processes (FAO 1997; Carter and Grace 2012).

5.4.4 SGCN Priority Species

The Taxa Team evaluation considered the level of threat agriculture, aquaculture, and silviculture represent to SGCN priority species. Lists of the SGCN and other priority species this threat is expected to have a very high or high impact on can be found in Appendix 3.

5.5 Energy Production and Mining

> This category addresses threats from production of nonbiological resources related to exploring for, developing, and producing energy and mining resources. Resources include oil and gas drilling on land and in ocean waters; coal and gold mines; and rock, sand, and phosphate quarries. Renewable resources also fall under this category, such as hydropower and emerging technologies associated with solar farms, windmills, tidal wave energy capture, and geothermal power production (Salafsky et al. 2008).

Renewable energy is defined by NC General Statute (G.S.) 62-133.8(a)(7) and (8) and North Carolina has a Renewable Energy and Energy Efficiency Portfolio Standard(REPS) that was passed into law in 2007 (Session Law 2007-397, Senate Bill 3). This standard requires all investor-owned utilities to reach 12.5% renewable energy production by 2021. There is the potential for future reduction of this target. Rural electric cooperatives and municipal electric suppliers have a 10% REPS requirement (NC Renewable Energy and Energy Efficiency Portfolio Standard [REPS] 2007).

Renewable energy facilities include those that generate electric power using renewable energy resources, combined heat and power systems, and solar thermal energy facilities. Solar electric, solar thermal, wind, hydropower, geothermal, and ocean current or wave energy resources are considered renewable energy resources.

Another example of a renewable energy resource covered under the REPS includes biomass or biofuels, which use agricultural waste, animal waste, wood waste, spent pulping liquors, combustible residues, combustible liquids, combustible gases, energy crops, or landfill methane for energy production. Information about other renewable energy resources covered by the REPS is available online from the NC Utilities Commission website: http://www.ncuc.commerce.state.nc.us/reps/reps.htm.

5.5.1 Biomass and Biofuels – Anticipated Impacts

Biomass resources includes organic matter from a variety of wood materials and energy crops that can be gasified, used in combined heat and power technologies or in biochemical conversions, used to create biofuels, or used for direct combustion (Milbrant 2005; Fargione et al. 2009). There are two main types of biofuels in use today that are made from biomass resources: ethanol and biodiesel (Biofuels, n.d.).

Wood waste products include logging debris that remains from timber clearing operations, thinning of commercial forest stands, and residues left over from lumber mill production. Common energy crops are corn, soybeans, wheat, various grasses (switch grass and *Miscanthus spp.* in particular), willow, and hybrid poplar species. These resources, as well as many other similar plant and wood resources, can be used to produce biofuels such as biodiesel and ethanol for vehicles and as a replacement for coal used by utilities and industrial plants.

Biomass production often involves intensive management that uses fertilizers, pesticides, and monocultures of high-yield nonnative cultivars (Fargione et al. 2009). Grassland birds are a primary taxa group of concern because the loss of early successional and grassland habitats converted or managed for biomass production will likely impact species dependent on herbaceous communities (Fargione et al. 2009). Overall, songbird and small mammal species richness, diversity, and abundance is expected to be lower where herbaceous biomass crops are produced (Semere and Slater 2007; Sage et al. 2010; Riffell et al. 2011; Robertson et al. 2011a, 2011b; Northrup and Wittmyer 2013). The greatest concern is when biomass crops replace native forests or lands in conservation holdings (Riffell et al. 2011; Northrup and Wittmyer 2013).

Biomass crops may pose a risk of becoming invasive if exotic crop species are used, if exotic or native species are modified through breeding or genetic engineering, or if native species are used outside their home range (Raghu et al. 2006; Barney and DiTomaso 2008; Fargione et al. 2009). Breeding and genetic modification of species may make species more likely to become invasive because desirable agronomic traits such as a fast growth rate and high establishment success are also associated with successful invasive species (DiTomaso et al. 2007; Fargione et al. 2009; Buddenhagen et al. 2009; Northrup and Wittmyer 2013).

Managing for specific species is often the easiest task, especially when the ecological needs of the species are well understood (Fargione et al. 2009). Frequent harvest of vegetation will very likely favor grassland birds requiring short, sparse vegetation (e.g., Grasshopper Sparrow and Savannah Sparrow) and negatively affect those requiring tall, dense vegetation (e.g., Sedge Wren and Henslow's Sparrow) (Fargione et al. 2009). Research is needed to determine the appropriate scale and placement of habitat patches; however, the best harvest scenario is likely to be one that produces a mosaic of harvested and unharvested patches (Fargione et al. 2009). Small habitat patches may become population sinks if birds using these areas suffer higher predation rates (Fargione et al. 2009). From a wildlife perspective, having multiple harvest times throughout the year can provide a mosaic of habitat conditions that support a wider range of species (Fargione et al. 2009).

Wood product companies have expanded production in North Carolina in recent years and, along with wood chipping facilities and a deep water berth at the Morehead City Port, the export of wood chip products from the state is likely to increase because of high demand from international markets for wood pellet exports from the US (Fox 2012; Wood Resources International 2014). The harvest and chipping of forest vegetation infested by exotic insects (i.e., Emerald Ash Borer, Redbay Ambrosia Beetle) carries the risk of transporting pests that survive the chipping process (Spence et al. 2013) both locally (during transport and storage) and elsewhere (to domestic and international markets).

Impacts can be mitigated by using biomass sources that do not require additional land, and thus do not increase the footprint of agriculture, such as agricultural residues, cover crops, and, potentially, algae (Fargione et al. 2009). The second approach is to produce biomass with land-use practices that are compatible with wildlife, including the use of perennial biomass crops and native plants, adjusting the timing and frequency of harvest, and leaving suitable stubble height (Fargione et al. 2009). Harvest schedules should consider priority species, whether those species are migratory or resident, and the timing of the life-cycle events that have the greatest impact on populations (nesting, brood rearing, winter migrating, etc.) (Fargione et al. 2009).

5.5.2 Coal Energy – Anticipated Impacts

Coal mined from other states is used for energy production in North Carolina. Coal is burned to heat water into steam that turns turbine generators, which produce electricity. Coal-fired power plants need large amounts of water; therefore, power plants in North Carolina are typically located on large rivers or on impoundments. Burning coal produces carbon dioxide and other air pollutants such as sulfur dioxide and methylmercury. Air pollution concerns have led to improved technologies to capture air pollutants. Coal fly ash remains after coal combustion and must be properly disposed of if it is not used to manufacture other materials.

Surface impoundment of coal fly ash residues is widely practiced, despite inherent environmental hazards from leachate that can pollute groundwater and spill into surface waters in the disposal facilities fail. These facilities are also harmfully attractive to amphibians and birds for foraging or reproduction (Lemly and Skorupa 2012). Coal fly ash contains numerous elements that vary in concentration based on the source of the coal, the method of combustion, and the air pollution-control equipment installed (Patra et al. 2012; Souza et al. 2013). Coal ash is composed of oxides of silicon, aluminum, iron, and calcium and, in lower concentrations, can also include arsenic, barium, cadmium, chromium, copper, lead, selenium, and strontium (Rowe et al. 2002; Patra et al. 2012; Souza et al. 2013). In many cases, the priority for remediating spill sites is the removal of ash by dredging to prevent transport and dispersion during storm events and to prevent upstream flooding (Mathews et al. 2014).

Fish and wildlife damage from exposure to coal ash slurry ranges from physiological, developmental, and behavioral toxicity to major population and community-level changes (Lemly and Skorupa 2012). The earliest reported coal ash pond failure in North Carolina occurred in 1976 and resulted in selenium poisoning that extirpated 19 species of fish in Belews Lake (Lemly and Skorupa 2012). Following a 2008 release of coal ash in Tennessee, an assessment of effects on aquatic species found low potential exposure risk to selenium in Tree Swallows and bats; to aluminum in Mink, Killdeer, Mallard, and Raccoon; and to arsenic in Killdeer (Meyer et al. 2014).

Other studies conducted by Bryan et al. (2003, 2012) evaluated the risk to birds attracted to coal ash settling basins for nesting and the exposure of nestlings to contaminated food. Results indicate arsenic, cadmium, and selenium concentrations were elevated in feather, liver, and carcass, but only liver selenium concentrations approached levels of concern (Bryan et al. 2003, 2012). Exposure is suspected to occur from bioaccumulation concentrations in the food chain, primarily through insects consumed by insectivores and omnivores. Because selenium builds up through the food chain rather than through aqueous exposure, tissue selenium concentrations may increase gradually over a period of several years (Mathews et al. 2014).

Tissues from Raccoons exposed to coal ash showed higher levels of arsenic in hair, iron in muscle, nickel in hair, selenium in hair and muscle, strontium in hair, and vanadium in hair and liver when compared to unexposed animals (Souza et al. 2013). However, long-term monitoring is needed to understand the factors that control when coal fly ash contaminants are more likely to biomagnify (Mathews et al. 2014).

Coal-fired power plants pump large volumes of water to produce electricity. Aquatic organisms can be entrained or impinged unless measures are sufficient to keep organisms from being impacted. After water is used for electricity production, it is returned to surface waters but the temperature can be considerably higher than the temperature of the receiving waterbody. Heated discharge can create refugia for nonnative species and alter aquatic community composition.

5.5.3 Oil and Gas Extraction – Anticipated Impacts

North Carolina has limited oil and gas reserves within shale deposits in the Triassic Basin of the Piedmont ecoregion, primarily in the Durham, Sanford, and Wadesboro subbasins of the Deep River Basin and in the Dan River Basin within portions of Stokes and Rockingham counties. Offshore oil and gas exploration continues to be debated, but no offshore extraction is currently allowed because it is generally controlled by federal regulations and processes.

Two technological advances now make these oil and gas resources more accessible: horizontal drilling and hydraulic fracturing. Horizontal drilling allows access to a larger subterranean area with a single surface drilling location. This technique provides access to large subterranean areas that may be inaccessible otherwise, thereby increasing potential profits. Hydraulic fracturing, also known as fracking, is a well-stimulation technique in which pressurized water, chemicals, and sand are pumped into a well to fracture rock. This allows oil and gas to flow more freely and increases production.

In recent years, the State of North Carolina has assessed existing rules and regulations to determine what changes are necessary to allow horizontal drilling and hydraulic fracturing in our state. Rules and regulations from other states where oil and gas extraction involving horizontal drilling and hydraulic fracturing has been occurring were also assessed.

Potential impacts to wildlife from oil and gas extraction are numerous; they include water quality and water quantity impacts, terrestrial wildlife habitat fragmentation and conversion, increased sand mining, and increased road and utility corridors. Impacts can occur as a result of preparing land for oil and gas extraction, establishing travel and utility corridors, use of natural resources (primarily water and sand) for hydraulic fracturing, and handling and disposing of waste and byproducts. Additional impacts are possible from spills and unintentional discharges.

Hydraulic fracturing typically requires 4–5 million gallons of water per well, spread out over several days. The oil and gas industry typically reuses the water-based fracking fluids to fracture additional wells until the fluid is no longer effective. Even so, there is a potential to impact streamflows, especially if water is withdrawn from small streams during low flow periods. Water withdrawn from impoundments or large rivers will have less impact to streamflows, particularly if the water is withdrawn during high flow periods and the instantaneous withdrawal rate is low.

Surface water quality could be impacted by accidental spills of fracking fluid and surface runoff from well pad sites. Fracking fluids typically contain a large mix of chemicals. Increased use and transport of fracking fluids increases the probability of an accidental spill or discharge that will impact surface waters. Once fracking fluids are no longer usable, they must be treated and disposed of properly. Water treatment plants are often not equipped to treat the chemicals found in fracking fluids. Underground disposal of fracking fluids can be problematic, and inadequate treatment of fracking fluids can impact receiving surface waters. Surface runoff from well pads can contain a mix of chemicals associated with oil and gas operations, including leaked fluids associated with the operation of heavy equipment. During large rain events, polluted runoff from a well site can impact surface waters if stormwater management practices are insufficient.

While horizontal drilling allows operators to reach underground resources with fewer surface wells, impacts to wildlife habitat are likely as operators choose locations for well pad sites. Well pads are likely to be located away from houses and public properties; therefore, alterations to agricultural fields and forested areas are most likely. In addition to land conversion at the well pad, new roads may need to be constructed to access the well pad and an infrastructure of pipelines may also be constructed to transport oil and gas products from the site. These new roads and utility corridors have the potential to fragment terrestrial habitat and impact streams and wetlands at crossings.

Constituents of fracking fluids vary depending on subterranean conditions and the company conducting the hydraulic fracturing, but sand is often a component of fracking fluids. Increased demand for sand for fracking could potentially lead to increased sand mining. Increased sand mining has the potential to impact wildlife habitat (see Section 5.5.5).

Studies have shown that wildlife located in areas of unconventional oil and gas extraction tend to avoid these areas due to noise pollution from increased traffic on rural roads, drilling mud pits, building storage sites, processing plant operations, and compressing stations (Drohan et al.

2012). Drilling mud pits have been reported to entrap migratory birds and other wildlife and wastewater impoundments have been known to entrap deer and foxes (Ramirez 2009). Some species may be more sensitive to this noise pollution than others. Altered habitat selection due to wildlife avoiding these areas may have effects on reproduction and survival. Future research should consider the effects chemicals used in fracking can have on wildlife.

Many animals that have come into contact with chemicals used in fracking show signs of "shale gas syndrome" which is noted to affect the neurological, dermatological, gastrointestinal, respiratory, and vascular systems. Because studies are finding these results in livestock, we can infer that these chemicals could have the same effect on NC wildlife. As with other routes of exposure to chemicals (i.e., industry, agriculture, forestry) this poses a risk to wildlife populations as well as to humans who consume fish and wildlife because many chemicals bioaccumulate in tissue. Contaminants found in a Kentucky stream showed low pH and concentrated toxic chemicals of aluminum and iron that resulted in stressed aquatic life and gill lesions in fish (Papoulias and Velasco 2013). Fish also bioaccumulate these toxins, which can pose a risk to human consumption. In livestock, it has been documented that cattle exposed to sulfur dioxide during gestation from fracking air pollution had an increased risk of calf mortality and higher occurrence of respiratory lesions (Waldner 2008; Waldner and Clark 2009). Further research is needed to investigate the effects chemicals used in fracking will have on wildlife.

5.5.4 Hydropower – Anticipated Impacts

Hydropower is created by harnessing the energy of falling water. In North Carolina, large rivers and high gradient streams have been dammed in the past to create impoundments for hydroelectric power production. Some reservoirs in our state were created solely for the purpose of creating hydropower. For other reservoirs, hydropower is one of several purposes of the impoundment, along with flood control or water supply creation. More recently, existing dams have been retrofitted to allow operators to generate hydropower. In recent years, some inoperable hydroelectric plants have been removed to restore streams and rivers to a free-flowing state.

Hydroelectric plants have similar impacts as other impoundments: streams and rivers impounded by dams are changed from lotic systems to lentic systems. Downstream water quality can also suffer from low dissolved oxygen (DO) levels and altered temperatures (lower water temperatures if water is released from near the bottom of the reservoir). In addition, hydropower generation can significantly change flow regimes downstream of hydropower dams.

Large hydropower facilities are typically peaking operations: they generate electricity during peak demand periods. As a result, large volumes of water are released to generate electricity during peak energy demand periods and water releases diminish during low energy demand periods so that the available water supply can be replenished for future use. This results in a flow regime that can be vastly different from the natural flow regime in terms of magnitude, frequency, duration, timing, and rate of change (Poff et al. 1997). These flow regime alterations can cause changes to the aquatic community, including local extirpation of species.

Dams also fragment habitats and disrupt the movements and migrations of fish and other aquatic organisms. Diadromous fish are those that spend part of their life in the ocean and part of their life in freshwater. They include Striped Bass, American Shad, American Eel, and Shortnose Sturgeon. These species are particularly vulnerable to blockages imposed by dams. Upstream and downstream passage facilities and strategies are often required to reconnect populations of these species to their necessary habitats.

The combined effects of barriers and altered flows can affect other important riverine processes, such as bedload and sediment transport, nutrient cycling, and woody debris transport.

5.5.5 Mining and Quarries – Anticipated Impacts

North Carolina has mines and quarries throughout most of the state that supply sand, gravel, granite, minerals, and other materials used for various development projects. Sand and gravel can be mined from open pits or sometimes directly from rivers. Recently, some exhausted granite quarries have been considered as water supply sources to augment existing water supplies. Existing mines and quarries are expected to expand and new mines and quarries created to continue to supply demand into the future.

North Carolina allows mines to operate in streams to dredge out sand and gold. Dredging in-stream incises the channel, which increases flow velocity and causes sedimentation downstream. In-stream mining also increases turbidity and stream temperatures through the loss of riparian vegetation that provides shade. These changes negatively impact aquatic species, often resulting in reduced reproductive success and survival. They can severely impact habitat and sedentary taxa like mussels at the mine site itself. Near-stream mining is also allowed in North Carolina and has similar, although often less severe impacts. Both types of mining operations can also degrade the surrounding riparian habitat and downstream wetland habitats. . Fracking activities in other parts of the state will increase the demand for sand and water (NCAFS 2002).

The primary direct impacts to wildlife resources from mining and quarries (not instream mining) relate to land conversion. Additional impacts can result if stormwater runoff is discharged offsite to surface waters. New and expanded mines and quarries may impact high-quality terrestrial uplands, wetlands, or streams. Water quality can be impacted if water from a mining site is discharged before it is appropriately treated to remove pollutants.

Instream mining removes sand and gravel directly from a stream bed, resulting in channel instability, altered habitat, increased sedimentation, and increased turbidity (Brown et al. 1998; Meador and Layher 1998). Instream mining can create pools where riffles once occurred and create headcuts that can continue upstream. These impacts to aquatic habitat can cause changes to aquatic community composition, including local extirpation of species such as freshwater mussels and other rare aquatic species (Hartfield 1993; Watters 2000).

5.5.6 Nuclear Energy – Anticipated Impacts

Nuclear power plants in North Carolina provide electricity for utility customers within our state. They require large volumes of water to ensure that nuclear reactors remain cool; therefore, they are sited near large water bodies or impoundments are created to supply cooling water. Most impacts associated with nuclear power plants revolve around the fact that they require large amounts of water to cool the nuclear reactors and the water is considerably warmer than ambient temperature after it has been used for cooling. In North Carolina, nuclear power plants choose between two primary options for discharging heated water: discharge heated water directly into a water body or build a cooling tower that will evaporate and cool water.

Duke Energy’s Brunswick Nuclear Plant near Southport transports heated water along a canal until the water is eventually discharged offshore. Duke Energy’s Harris Nuclear Plant cools water with a cooling tower where most water is evaporated. The small amount of collected water that is not evaporated is returned back to Harris Reservoir.

Returning heated water directly to a water body changes the water quality of the receiving water body, particularly in the area of the discharge, and creates unnaturally warmer water conditions. Other water quality parameters such as DO, salinity, turbidity, pH, and water chemistry parameters may also differ from ambient conditions. Such modifications can affect the species inhabiting the area of the discharge. Use of cooling towers can eliminate the discharge of heated water and deleterious effects on receiving waters. However, water evaporates from cooling towers at a much faster rate than normal and that water is no longer available to contribute to downstream flows.

By withdrawing large volumes of water for cooling, aquatic organisms can be impinged or entrained, resulting in injury or death. Impinged organisms can be caught against screens used to prevent transport of larger debris. Continual water pressure against organisms can lead to eventual death or injury. Additionally, some organisms are small enough to pass through screens and will be entrained in the water transported to the nuclear reactors for cooling where they can be subjected to harsh conditions, nearly always leading to death. Water intake structures use various techniques to reduce the number of organisms that are impinged or entrained. These include slow intake velocities, fine mesh screens, and periodically backwashing screens.

In the future, there is potential for additional nuclear power plants or expansion of existing plants. In addition to the potential impacts described previously and terrestrial land conversion impacts, future nuclear plants will potentially impact river flows due to their dependence on water for cooling. Such river flow impacts could result from creating an impoundment and affecting a section of free-flowing water, pumping water from a river to maintain sufficient water in an impoundment, or expanding an existing reservoir and affecting the timing and volume of downstream flows due to increased demand for cooling water.

5.5.7 Solar Energy – Anticipated Impacts

Electricity produced from solar power has increased greatly in North Carolina in recent years. Solar electricity is produced in two primary ways: concentrated solar power (CSP) and photovoltaic (PV). CSP, not currently used in North Carolina, uses mirrors or lenses to concentrate solar energy that drives steam turbines or similar devices that in turn generate electricity. PV captures light energy using solar panels and generates electricity directly. Solar cells for PV are small but are combined into connected modules and arrays. PV systems can be installed on rooftops or on land that receives adequate sunlight.

In North Carolina, solar farms comprised of many solar arrays on open land are becoming more and more common. Solar farms produce clean, renewable energy but some sites may have impacts to terrestrial and aquatic wildlife resources. Most solar farms in North Carolina generate 5 MW of electricity or less but take up approximately 25 acres of land. However, there are also larger solar farms capable of producing up to 100 MW. Many solar farms are sited on cleared agricultural land that has been traditionally used for farming. Increasingly however, solar farms are proposed in forested areas that will require clearcutting to prepare the land for the solar farm.

Currently peer-reviewed studies are insufficient to adequately assess all the potential impacts of PV solar farms on wildlife (Lovich and Ennin 2011). The primary impact is conversion of wildlife habitat to cleared areas with solar arrays; the degree of impact depends on the quality of the habitat. Impacts will be fewer for solar farms constructed on cleared fields. Solar farms are typically enclosed with chain link fences so movement corridors for wildlife may be altered. In addition to direct impacts from the solar farm, new transmission lines may be needed to connect to the grid. New utility corridors can bisect large forest blocks or cross wetlands and streams.

5.5.8 Wind Energy – Anticipated Impacts

Wind energy uses turbines carrying rotary blades designed to capture kinetic wind energy and convert it into electricity that can be used locally, stored for later use, or provided to an energy grid. Large arrays of wind turbines are often referred to as wind power farms and they require an extensive power collection, storage, and distribution system for delivering electricity. Typical wind power farms also need some type of supervisory control and data acquisition system for two-way communications with each wind turbine as well as maintenance facilities for service equipment, spare parts, lubricants, and other supplies. These maintenance facilities can be located on- or off-site and may be combined into one building. At least one access road is needed to access the wind turbines, delivery systems, and maintenance facilities.

North Carolina has good-to-outstanding wind resource potential along the coast and mountain ridges (WINDExchange 2015). Currently, one wind energy farm is planned to be built in Perquimans and Pasquotank counties by Iberdrola Renewables and will be operational by 2016. The facility will cover 34-square miles and be able to produce 208 megawatts energy with the initial 104 turbines that are each 492 feet tall (Murawski 2015). There have been no wind farms in the state priori to this project so there is no documentation about the effects a wind farm will have on wildlife in NC. There is the potential for turbines to have a greater impact on nocturnal migrating birds and bats, especially in the eastern part of the state where there is a major migratory flyway. Monitoring and research will be needed at the site and in surrounding landscapes to evaluate the impacts, if any, this facility will have on wildlife and nearby habitats.

It is widely acknowledged that birds and bats suffer the most impacts from the operation of large wind turbines due to collision with the turbines' blades. In 2009, the USFWS estimated at least 440,000 birds were killed each year by the approximately 22,000 wind turbines operating in the United States at that time (ABC 2011). A 2005 Government Accountability Office (GAO) report that assessed wind energy impacts on wildlife states that over 1,000 raptors, including Golden Eagles, are killed each year at wind power farms operated in California. The report acknowledges that many wind power facilities have not been studied and much is still unknown about overall species population levels; therefore, scientists cannot draw definitive conclusions about the threat that wind power poses to wildlife in general (GAO 2005). Siting of wind farms in areas actively used by birds (e.g., flyways) was a major contributor to mortalities to birds as well as bats (Kuvlesky et al. 2007; Northrup and Wittmyer 2013). Since publication of the GAO report, wind turbine design has been modified to better address bird strike problems.

In addition to collisions with turbine structures, other impacts occur from construction and operation of the facilities, which vary by region and site, and may have greater effects on other species. These include habitat fragmentation, displacement, sedimentation and erosion from land disturbance, water quality degradation, shadowing, noise, and vibration. However, it is generally recognized that there are insufficient scientific data available about the post-construction effects of wind power facilities on all forms of wildlife (ABC 2015).

The USFWS (2012) issued voluntary guidelines for wind turbines to avoid or minimize impacts to wildlife and their habitats. The recommendations call for a tiered approach that evaluates proposed wind turbine sites, characterizes potential risks, uses field studies to identify onsite wildlife and habitats and predict impacts, and conducts post-construction studies that include mortality assessments and mitigation studies. In North Carolina, utilities are not required to comply with these voluntary guidelines nor are there any requirements from the NC Utilities Commission for the evaluation or mitigation of impacts to wildlife.

5.5.9 SGCN Priority Species

The Taxa Team evaluation considered the level of threat energy production and mining activities represents to SGCN priority species. Lists of the SGCN and other priority species this threat is expected to have a very high or high impact on can be found in Appendix 3.

5.6 Transportation and Service Corridors

> Threats associated with this category relate to roads, railroads, utility and service lines, shipping lanes, and flight paths, and to the vehicles that use them, including associated wildlife mortality (Salafsky et al. 2008).

Roads are significant features of most landscapes, covering about 1% of the United States and ecologically influencing an estimated 15-20% of the US land area (Jochimsen et al. 2004). Land-based transportation systems include highways and secondary road networks, logging and fire access roads, causeways and bridges, and railroads and rail yards. Utility and service corridors and rights-of-way include electrical and telephone lines, oil and gas pipelines, and stormwater and sewer system lines. Coastal shipping lanes, intercoastal waterways (IWW), and canals for boat and ship transportation and utility lines are aquatic-oriented transportation and service corridors. Airport runways and flight paths between airports are another type of transportation corridor (Salafsky et al. 2008).

5.6.1 Anticipated Impacts

Potential impacts from transportation and service corridors on terrestrial wildlife species and their habitats are numerous. The characteristics of a road or service corridor will affect the degree to which it creates a barrier to species (Clark et al. 2010; Clevenger et al. 2003; Wiens 1997). Corridors consist of impervious surfaces or vegetation that is mowed or otherwise maintained periodically. New corridors have the potential to convert diverse wildlife habitat (e.g., mixed hardwood forest) to habitats that support few or no species. Maintained corridors can also serve as pathways for the spread of invasive plant species.

Habitat fragmentation is the most common impact to terrestrial environments but there are other important impacts that can negatively impact wildlife (Clark et al. 2010; Forman and Alexander 1998). The presence of roads increases the mortality of wildlife from vehicular collision, which can lead to changes in demographic and structural changes of populations (Clark et al. 2010; Mazerolle 2004; Row et al. 2007). For small animals with limited dispersal capacity (e.g., some amphibians), roads and service corridors can create a barrier to gene flow, resulting ultimately in loss of diversity and decreased population fitness (Clark et al. 2010; Frankham et al. 2002). The results of a study on the effects of roads on Timber Rattlesnakes demonstrated there was a significant effect on genetic structure and gene flow among populations (Clark et al. 2010).

Highways impact wildlife through avoidance, fragmentation, direct and indirect loss of habitat, and mortality (Ruediger 1996, 1998). Conover et al. (1995), extrapolating from a variety of sources across the United States, estimated 726,000 deer–vehicle collisions annually. Studies have also identified short-term negative impacts on Black Bears (Brody and Pelton 1989; Beringer et al. 1990), Grizzly Bears (Mattson et al. 1987), Gray Wolves (Paquet and Callaghan 1996), and other carnivores (Gibeau and Heuer 1996). North Carolina Wildlife Resources Commission (NCWRC) data indicate that a minimum of

50 to 100 Black Bears are killed in central and northeastern North Carolina by automobiles yearly. Road mortality of amphibians and reptiles is likely to correlate highly with fluctuations in water level, breeding and nesting season, dispersal of juveniles, and availability of food resources (i.e., insects attracted to street lights) (Jochimsen et al. 2004).

There is a clear need for management actions that reduce the incidence of vehicle–wildlife collisions for large mammals. For example, to help select locations for three wildlife underpasses along a new 23-km-long segment of US Highway 64 on the Albemarle/Pamlico peninsula in Washington County, track surveys were conducted to collect species crossing data (Scheick and Jones1998). Survey results identified 1,335 tracks of seven wildlife species (Black Bear, White-tailed Deer, Bobcat, Coyote, Gray Fox, Raccoon, and Opossum). Building underpasses during road construction has several benefits including reduction of both human and animal injury and death (Scheick and Jones1998).

Transportation corridors can also fragment aquatic habitat at stream crossings due to culverts that do not allow aquatic organism passage. Culverts must be properly sized and positioned to allow aquatic organism to move freely upstream and downstream of crossings (Kilgore et al. 2010). Failure of culverts to allow organisms to move upstream of crossings can restrict gene flow and isolate populations (Wofford et al. 2005). Poorly designed culverts can prevent upstream migration and recolonization upstream of culverts, eventually leading to extirpation above crossings (Jackson 2004). River Herring migration may also be impeded by low light levels within culverts (Moser and Terra 1999). Various groups are now working to identify culverts that are barriers to aquatic organism passage and replace them with improved crossing structures.

Utility crossings, such as aerial utility lines or underground pipes, also affect streams and wetlands at crossings because woody riparian vegetation is converted to maintained herbaceous vegetation. These utility corridor crossings create breaks in riparian vegetation that can reduce shading and lead to streambank erosion. These interruptions to riparian corridors can also impact species using forested riparian areas as travel corridors.

The National Wildlife Strike Database reported 99,411 wildlife strikes to airplanes have occurred since 1990, resulting in more than 200 human lives lost (Allan 2002; Dolbeer et al. 2010). The vast majority (97.4%) of all wildlife strikes involve birds (ACRP 2011). Bird management at airports is best considered an adaptive process of deterrence where species composition and behavior can be expected to change during the day, between seasons, and across years, even when techniques in this synthesis are actively employed. Many bird species habituate to deterrent techniques and will return to the area, particularly if the area is attractive to them. Airport managers often use repelling techniques, habitat modification, exclusion, population management, and notification to pilots as strategies to manage hazardous wildlife at or near the airport (Cleary and Dickey 2010; ACRP 2011).

5.6.2 SGCN Priority Species

The Taxa Team evaluation considered the level of threat transportation and service corridors represents to SGCN priority species. Lists of the SGCN and other priority species this threat is expected to have a very high or high impact on can be found in Appendix 3.

5.7 Biological Resource Use

> This threat category considers the consumptive use of wildlife biological resources that may be deliberate (e.g., hunting, harvesting) or unintentional (e.g., fisheries bycatch, accidental mortality) (Salafsky et al. 2008).

Hunting, trapping, and collecting animals, including shellfish harvesting, turtle egg collection, pest or predator control, and persecution are considered a biological resource use. Harvesting aquatic wild animals and plants for commercial, recreation, subsistence, research, or cultural purposes, and for population control are also consumptive uses (Salafsky et al. 2008). Other biological resource uses include clear-cutting of natural hardwood forests, fuel wood collection, charcoal production, and other activities related to harvesting natural stands of trees and woody vegetation for timber, fiber, or fuel uses (Salafsky et al. 2008).

Regardless of the reason, method, intentionality, or end use, this category essentially deals with the removal of plants or animals from a particular ecosystem or habitat. The removal may be selective (i.e., only certain plants or animals) or indiscriminate (e.g., clear-cutting).

5.7.1 Anticipated Impacts

Removal of plants or trees can alter habitat and disrupt food webs and energy and nutrient cycles. When the removal is limited, the impacts may be negligible or confined to a single species. Large-scale removals can result in a change of habitat type, such as from a forest to early successional habitat. Animals and other plants that rely on the removed plant species or original habitat type may be negatively impacted, while other plants and animals may take advantage of the open niche or changed conditions. For example, removal of only oak trees from a forest can be expected to affect species that rely on hard mast, such as White-tailed Deer and Wild Turkey. However, most selective vegetation harvest in North Carolina is not done at a scale to cause shifts in community composition. Shifts in habitat type from large-scale non-selective harvest will be beneficial to some species, but may offer opportunities for invasive species to become established or spread. Conversion to early successional habitat will profit certain birds and butterflies, but may also allow Kudzu to take over.

Removal of fish and wildlife may not only affect the population size and structure of the species harvested, but also can impact other species, both plants and animals, in the community by altering the food web and other species interactions. Again, certain species may benefit while others are harmed.

Removal of wild animals from terrestrial systems is generally limited to hunting, trapping, and collecting. Selective harvest of most game and furbearing species is typically not an issue. However, negative impacts can occur to nongame species, such as terrestrial, aquatic, and sea turtles, from intentional harvest of eggs or adults. Snakes are often killed for no reason other than that people are afraid of them. Bats, mice, and some birds are considered by some to be pests, and removed from human structures. The killing or removal of voles and moles is widespread. Some of these activities may be illegal because the species is protected or the harvest does not follow seasons and bag limits.

In aquatic systems, particularly freshwater ones, the overharvest of most species is not an issue, but localized poaching of species such as trout does occur. Overharvest is fairly common in marine fisheries due to the multiple gear types used, the combination of commercial and recreational fishing effort, and the multiple jurisdictions managing the fish or shellfish. Bycatch is common in marine fisheries because some harvest gear is nonselective. The bycatch may include undersized target fish, nontarget fish, and other organisms (e.g., sea turtles). The impacts of bycatch and overharvest can include reduced population size and altered population size or age structure.

Catch and release of game fish or nontarget fish can cause injury or death of individual animals, but this typically does not rise to the point of affecting the population. Holding a caught fish in a live well and releasing it a long distance from the capture location, for instance at a weigh-in site, can cause local imbalances in fish densities and increase competition for food and habitat.

5.7.2 SGCN Priority Species

The Taxa Team evaluation considered the level of threat biological resource use represents to SGCN priority species. Lists of the SGCN and other priority species this threat is expected to have a very high or high impact on can be found in Appendix 3.

5.8 Human Intrusions and Disturbance

> Threats are from recreational activities, military exercises, civil unrest, and work and other outdoor activities (e.g., law enforcement, illegal activities, vandalism, species research) (Salafsky et al. 2008).

Human activities that may be considered non-consumptive of biological resources (those that do not take or harvest) can alter, destroy, and disturb natural habitats and species. Examples include people spending time in natural areas for recreational activities such as beach driving, driving ATVs, off-road vehicles, jet-skis, and snowmobiles, or riding mountain bikes; flying ultralight planes at low-elevations; dog-walking, bird-watching, hiking, and camping; and caving, spelunking, and rock-climbing (Salafsky et al. 2008).

Disturbance may also be related to military exercises or work activities that occur in natural environments. Training exercises can involve driving tanks and military equipment across the landscape; firing missiles onto bombing ranges; or other munitions or maneuver exercises in coastal areas. Species research often involves survey or monitoring activities that can disturb wildlife (Salafsky et al. 2008).

5.8.1 Anticipated Impacts

In one sense, human intrusion and disturbance is ubiquitous. Nearly all human interactions affect wildlife—either positively or negatively. Potential impacts from human disturbance are diverse and depend on numerous variables such as the wildlife species involved and the duration, frequency, magnitude, timing, and type of intrusion and disturbance. Human intrusion and disturbance can be particularly impactful during breeding and nesting periods (Steven et al. 2011). Impacts can be minimized by using common sense and effective management practices that limit intrusion and disturbance by restricting access on a spatial (e.g., buffer distances) or temporal (e.g., seasonal closures) basis.

North Carolina is home to many military bases with extensive acreages available for wildlife. These habitats may be relatively natural or disturbed and portions of them are used for military training, including foot and vehicular traffic, artillery and small arms fire, explosives, airplane flights, ship movements, and acoustic disturbance. As stated above, the impacts of these activities depend on many factors. Some species may avoid using otherwise suitable habitat. Disturbance can reduce breeding success, foraging and feeding efficiency, and limit population size.

While disturbance can drive some species away, the resulting open niche will often be used by another species that is tolerant of humans. A number of birds, most of which are nonnative, are able to tolerate or even take advantage of human disturbance, including Starling, Canada Geese, Rock Dove (pigeon), and House Sparrow.

An example of human intrusion and disturbance impacts on wildlife is the effect of pedestrian and vehicular traffic on nesting shorebirds and sea turtles along North Carolina's Outer Banks. Several species of shorebirds, such as Piping Plover, American Oystercatcher, Black Skimmer, and Least Tern, nest on beaches at the Outer Banks each year. Sea turtles lay eggs in nests on NC beaches each year.

Pedestrian traffic can reduce reproductive success for nesting shorebirds such as Least Terns (Kanapaux and Kiker 2013), American Oystercatchers (McGowan and Simons 2006; Sabine et al. 2008,) and Piping Plovers (Doherty and Heath 2011). Nesting shorebirds can be impacted by the frequency, duration, and proximity of pedestrians. Vehicular traffic can also reduce reproductive success or reduce hatchling survival of nesting shorebirds (McGowan and Simons 2006; Tarr et al. 2010). The impact of pedestrian traffic and vehicular traffic can be mitigated by establishing buffers around nesting shorebirds and controlling the locations and timing of beach driving.

Among the features that make beach habitats suitable for sea turtle nesting are accessibility from the water, being situated high enough above the active surf zone that sand is not constantly inundated by high tides or the water table below (Mortimer 1982; Miller et al. 2003), and lack of artificial structures and visible lighting (Witherington 1992; Bouchard et al. 1998). Excessive nighttime lighting from buildings or vehicles can render nesting beaches unsuitable or unused because lighting disorients the sea turtles, thereby reducing the number of female sea turtles nesting on NC beaches (Witherington 1992). Sea turtle hatchlings generally emerge from their nests at night, and rely on visual cues for successfully finding and entering ocean waters (seafinding behavior) (Ehrenfeld 1968; Mrosovsky and Shettleworth 1969). When exposed to sources of artificial light, seafinding behavior of hatchlings will become disrupted, and often hatchlings will travel away from the sea (Peters and Verhoeven 1994; Philibosian 1976; Salmon et al. 1995a, b), which increases the time they are exposed to land-based predators, reduces the amount of residual internalized yolk available to hatchlings for their initial swim offshore, and could result in desiccation/death if the hatchlings remain on land after sunrise.

Driving motorized vehicles on the beach has the potential to negatively impact sea turtles by running over nesting females, hatchlings, and stranded turtles that have washed ashore. Driving directly above incubating eggs in a sea turtle nest can cause sand compaction, which result in decreased hatching success and can kill pre-emergent hatchlings. In addition, the ruts left by motorized vehicles in the sand may prevent or impede hatchlings from reaching the ocean following their emergence from the nest (Hosier et al. 1981; Lamont et al. 2002; van de Merwe et al. 2012).

Reducing artificial lighting and nighttime beach driving can increase the number of female sea turtles nesting on our beaches. Marking sea turtle nests and creating protective buffers around nests can prevent nest disturbance. Limiting vehicular traffic during sea turtle emergence can prevent direct mortality and prevent tire ruts that can impede hatchlings as they travel to the ocean.

5.8.2 SGCN Priority Species

The Taxa Team evaluation considered the level of threat human intrusions and disturbance represents to SGCN priority species. Lists of the SGCN and other priority species this threat is expected to have a very high or high impact on can be found in Appendix 3.

5.9 Natural System Modifications

> Threats are from actions that convert or degrade habitat in service of "managing" natural or semi-natural systems, often to improve human welfare. This category includes suppression or increase in fire frequency and/or intensity outside natural range or variation; changing water flow patterns either deliberately or as a result of other activities; and other activities intended to 'manage' natural systems to benefit human welfare (Salafsky et al. 2008).

5.9.1 Anticipated Impacts

When development and land-use patterns do not take the needs of wildlife into consideration, the result is a landscape with fragmented and degraded habitats that are unable to support populations of sensitive species (NCWRC 2012). Habitat degradation and fragmentation is a landscape-scale process in which patches of suitable habitat become smaller and more widely separated by a more or less unsuitable matrix (Stockwell et al. 2003). Fragmentation affects all natural areas, especially forests, and it poses increasing problems for major freshwater systems (MEA 2005). Loss of biodiversity can result when natural communities are degraded or fragmented and can lead to populations that are more susceptible to inbreeding, genetic erosion, and problematic population trends (Clark et al. 2010). Furthermore, prescribed burning as a management tool is more difficult in fragmented areas due to difficulty with smoke management and liability issues.

Destruction and degradation of habitat are widely cited as the greatest threats to aquatic species in the United States (Angermeier 1995; Warren et al. 1997; Williams et al. 1993). Physical alterations such as channelization and dredging, aquifer depletion, impoundment and dam construction, and flow modification have contributed directly to the decline of aquatic species in the South (Walsh et al. 1995; Etnier 1997). Increases in impervious surfaces, and subsequently stormwater flows, have caused changes in sediment transport and stream energy, which has led to limitations in the amount of suitable aquatic habitat and streambed material, especially near urban areas. The Nature Conservancy (TNC 2000; Smith et al. 2002) and NatureServe (TNC and NatureServe 2001) identify altered surface hydrology (i.e., flood control and hydroelectric dams, interbasin transfers of water, drainage ditches, breached levees, artificial levees, dredged inlets and river channels) and a receding water table as among the most significant sources of biological and ecological stress, especially in the Coastal Plain.

Habitat fragmentation limits movement and gene flow of area-sensitive species and can isolate species with small home ranges, which makes populations more vulnerable to disturbance, disease, disruption to gene flow between populations, and depredation. Increased amounts of road surfaces and transportation-related projects have impacted populations and natural communities in ecologically sensitive areas. Roads can separate breeding locations and provide substantial barriers to seasonal animal migration pathways. Increased human development associated with transportation development also brings an increased risk of the introduction of exotic species. Fragmentation disrupts dispersal of many species, especially those that migrate between wet lowlands and dry uplands and can negatively affect population dynamics and reproductive success.

Fragmentation influences evolution by changing, among other things, the costs and benefits of dispersal (Stockwell et al. 2003). A decrease in population dispersal and population size can lead to a reduction in the effective population size followed by increased genetic drift, reduced genetic variation and increased inbreeding, and a decrease in the time to extinction (Marsack and Swanson 2009; Anderson et al. 2004). Inbreeding contributes to genetic mutations that decrease disease resistance and the ability of a population to adapt (Lacy 1993).

While most birds can rapidly find and colonize early successional habitat patches, some bird species (grassland birds in particular) are area sensitive and will not use small patches of habitat surrounded by forest or developed areas. Bobwhite Quail may require large (more than 5,000 acres) areas of contiguous habitat for long-term population viability (Guthery et al. 2000). Fragmentation of forests into smaller contiguous blocks is a concern for forest interior birds (like Wood Thrush, Cooper's Hawk, and Worm-eating Warbler), which may occur in lower densities or suffer lower productivity or survival in small habitat patches.

Animals with large home ranges or dispersal needs may become isolated or absent in small tracts. Fragmentation by roads and development can be particularly problematic for reptiles (particularly Timber Rattlesnake and Box Turtle), amphibians, and small mammals that suffer high mortality on roads when traveling between forest patches.

Upland changes will influence landscapes containing wetlands through changes in downstream outputs and hydrological and biogeochemical processes. Drainage and agricultural activities can degrade nearby wetlands and cause loss of vegetation diversity and ecosystem services (De Steven and Gramling 2013).

5.9.2 SGCN Priority Species

The Taxa Team evaluation considered the level of threat natural system modifications represents to SGCN priority species. Lists of the SGCN and other priority species this threat is expected to have a very high or high impact on can be found in Appendix 3.

5.10 Invasive and Other Problematic Species and Genes

> Threats are from nonnative and native plants, animals, pathogens or microbes, or genetic materials that have or are predicted to have harmful effects on biodiversity following their introduction, spread, and/or increase in abundance. This can include feral animals (e.g., cats, swine); species introduced as biocontrol agents or as part of a management strategy (e.g., Kudzu); native species that can be problematic when populations are overabundant or concentrated (e.g., White-tailed Deer in urban areas); and introduced genetically modified organisms such as plants that can hybridize with native plants or pesticide resistant crops (Salafsky et al. 2008).

Invasive species may be one of the most important and widespread issues in conservation biology today because once established, they are expensive to treat, are typically hard to remove, may become permanent components of the community, and have effects that can be irreversible (Reynolds and Souty-Grosset 2012). Nonnative and invasive species introductions (both plant and animal) continue to pose a threat to native wildlife in North Carolina. The spread of invasive species has been growing over the last decades, with species of all kinds moving higher in latitude and elevation as changing climate conditions facilitate range expansions.

Invasives are particularly threatening to native species with small population sizes and distribution ranges (Vose et al. 2014). Introductions of nonnative species have occurred in a number of different ways, ranging from intended stockings, to range expansions, to accidental and deliberate release of animals purchased through the pet trade. Impacts on native species are equally varied—some exotics out-compete native species (e.g., Kudzu and Japanese Stiltgrass), while others cause hybridization (e.g., Red-eared Sliders breeding with native Yellow-eared Sliders). Still others can cause direct mortalities to our native resources (e.g., red imported Fire Ants, the Hemlock Wooly Adelgid).

The most important concept to remember is that all of the components within a natural community—whether native, introduced, exotic, or invasive—will have synergistic relationships and cumulative impacts on each other, both positive and negative. The species discussed in this section do not represent an exhaustive list of all invasive or problematic species; rather, these are examples that represent widespread concerns or species that may be site-specific.

When considering invasive and other problematic species in North Carolina, it becomes clear that a discussion about one topic often leads to the need to discuss several others. Given this complexity of the topic, the information provided in this section has been organized first by landscapes (aquatic or terrestrial communities), then by category (plants or wildlife). While pathogens may be considered an invasive or problematic species, they are discussed as a separate topic in Section 5.13.

5.10.1 Aquatic Systems – Anticipated Impacts

Freshwater systems have a high degree of connectivity that allows invasive species to spread easily and sometimes rapidly from the source to new areas (Reynolds and Souty-Grosset 2012). Excessive aquatic plant growth can cause many types of impacts but the ones that most often involve local management efforts are habitat degradation, impaired fishing and boating, and blocked hydroelectric turbine intakes (Richardson 2008). Weed management tactics are relatively few and often have limited efficacy, various environmental impacts, and high expense. Management tools include biological, chemical, mechanical, and physical measures, and often require long-term funding commitments to control sources and new occurrences (Richardson 2008).

A partnership of state and federal agencies has developed the North Carolina Aquatic Nuisance Species Management Plan (NCANSMP), which includes an aquatic nuisance species list and policy recommendations. The list includes invasive, nuisance, and nonnative species currently known from North Carolina and those considered at risk of becoming a nuisance though they are not currently known to be in the state, including species that have commercial or recreational value in North Carolina.

Management of invasive aquatic species also needs to include outreach to the public as a means of reducing anthropogenic-related sources (e.g., bait bucket dumps, aquaria and aquaculture releases, hitchhikers on boats and trailers) and involving stakeholders in monitoring and remediation programs. A detailed risk assessment and studies on distribution, ecology, and genetics of known potential invaders can be used to develop prevention and management programs for aquatic invasive species (Reynolds and Souty-Grosset 2012).

Native species introduced into areas where they would not normally be found can create competitive pressures for food and habitat use. Blueback Herring introduced to mountain reservoirs have caused the collapse of walleye populations that now must be maintained by stocking.

The Crayfish Taxa Team identified five crayfish species considered invasive and of concern in North Carolina. In the Mountain ecoregion, the Kentucky River Crayfish has been found in large creeks and small river systems and the Coosa River Spiny Crayfish has been found in the New and Little Tennessee river basins. In the Piedmont ecoregion, Rusty Crayfish and Virile Crayfish have been found in headwater streams, small and large creeks, small and medium rivers, and reservoirs and impoundments. The Red Swamp Crawfish has the most widespread distribution and is found in all freshwater systems throughout the state. Crayfishes that are spread to habitats outside their natural range can affect the distribution of native species as well as the dynamics and biodiversity of the community (Reynolds and Souty-Grosset 2012).

The most commonly occurring groups of freshwater algae are diatoms, green algae, and blue-green algae, which are more correctly known as cyanobacteria. Cyanobacteria refer to a group of microorganisms that possess characteristics of algae (chlorophyll-*a* and oxygenic photosynthesis). They are found in fresh, estuarine, and marine waters in the United States and cyanobacterial blooms can produce highly potent cyanotoxins (USEPA 2014). In North Carolina, two cyanobacteria—Blue-green and Black Mat Algae (*Lyngbya* spp.)—are of particular concern because they produce neurotoxins and paralytic shellfish-poisoning toxins (USEPA 2014).

Invasive and nonnative aquatic plants like Watermilfoil and Hydrilla are economically damaging aquatic weeds (Richardson 2008) and can form dense mats that can clog boat motors and make swimming difficult. Propagation of Hydrilla invades via tubers, turions, plant fragments, and stolons, and is likely spread between lakes by plant fragments attached to boats (Harlan et al. 1985). In locations where Hydrilla mats do not survive winter temperatures, regrowth can occur from residual tubers and turions and germinate in the spring (Harlan et al. 1985).). Public awareness of the need to clean recreational equipment such as boats, water craft, and trailers as well as fishing tackle and gear should be a high priority. Information is available online on proper techniques for cleaning equipment to reduce or prevent the spread of aquatic invasive species (see https://stopaquatichitchhikers.org for specific procedures).

Exotic or invasive aquatic snails in the state include Chinese Mystery Snail, Creeping Ancylid, Giant Rams-horn, Japanese Mystery Snail, Red-rim Melania, and Savannah Elimia. The Red-rim Melania is a host for parasitic trematode worms (e.g., liver flukes and lung flukes) which allows the flukes to complete their life cycle. Trematode flukes affect waterfowl, fish, and other animals and can be transmitted to humans who eat raw or undercooked fish or crab that have been infected or who swim in waters that contain the flukes (Wingard et al. 2008).

Although not currently extant in North Carolina, Zebra Mussels, Bighead Carp, and Silver Carp occur in adjacent states and pose extremely high risks to our aquatic ecosystems. These species are known to alter community dynamics and even extirpate other species.

5.10.2 Terrestrial Systems – Anticipated Impacts

The results of some studies suggest the synergistic effects between climate warming and the presence of invasive species will negatively affect many wildlife species (Saenz et al. 2013). Some studies indicate amphibian declines may be attributed to invasive species becoming established in their habitats (Saenz et al. 2013; Doubledee et al. 2003; Brooks et al. 2004; Brown et al. 2006).

The NC Department of Transportation identifies 74 species in a guide to invasive or exotic trees, shrubs, herbaceous plants, vines, and aquatic plants that are considered a threat, moderate threat, or a watch-list concern in the state. The plant species described in this guide should be considered a priority when addressing problems caused by invasive, introduced, or exotic plants. The guide provides recommendations for management and treatment options as well as resources for additional information and is available for download as a PDF document (see Smith 2012). In addition to the ubiquitous species identified by the NCDOT Roadside Environmental Unit as invasive (Smith 2012), there are others that may not yet be as widespread but are emerging concerns because of their potential negative impacts to wildlife and habitats. These include Cogongrass, Beach Vitex, and various genetically modified organisms (GMOs).

The Emerald Ash Borer (EAB) bores in ash trees, ultimately killing them, and all four of the native ash species (White, Green, Carolina, and Pumpkin [*Fraxinus* spp.]) found in the state are susceptible to attack (NCFS 2015). Mountain Ash (*Sorbus* sp.), which is not considered a true ash, is not susceptible. When EAB is known to be present, there is a risk of long-distance dispersal through transportation of ash wood products from an infested area to an uninfested area. Treatment of infected trees requires destruction of infected wood by cutting down dead or dying trees and chipping, burning, or burying the wood on the site. Quarantines will be placed for areas where EAB has been detected (currently Granville, Person, and Vance counties). The quarantine prohibits the movement of any part of an ash tree, the insect itself, and all hardwood (deciduous) firewood from a quarantined area into an area outside the quarantine. Firewood refers to wood that is cut to less than four feet in length. Additional information is available from the NC Forest Service.

Kudzu is likely the most recognizable example of an introduced nonnative species used for biological control that has become a serious invasive problem. In the case of Kudzu, it was originally planted as a ground cover and control for erosion but is now a widespread invasive that takes extensive and repeated treatment to eradicate on a local level. A more recent example includes the release of a beetle species that specializes in an introduced exotic thistle species. In this case, the beetle has been found to spillover from its weedy invasive host plant onto multiple nontarget native species, which has ultimately resulted in impacts to native thistle populations in some areas of the United States (Louda et al. 1997; Louda 1998; Rand and Louda 2004; Blitzer et al. 2012).

The Nutria is a mammal native to South America that was introduced to North Carolina in the 1950s. Several populations became established in coastal counties by the 1970s. Their populations have grown and Nutria can now be found in Piedmont rivers and large streams. Nutria feed on numerous grasses and wetland plants and can eat approximately 25% of their body weight daily. At high densities and under certain conditions, foraging Nutria can significantly impact natural plant communities. Most damage caused by Nutria comes from overgrazing and burrowing into the banks of impoundments, earthen dams, and other waterbody foundations, which can weaken these structures. In North Carolina, they compete for food and burrows with native muskrats.

Coyotes have naturally spread to North Carolina from their native range in central and western North America. They can be found in a habitats ranging from grasslands to forests, but have also adapted to suburban and urban conditions. Coyotes prey on a variety of animals and plant materials. They will also consume carrion and hunt pets. Their adaptable nature allows them to outcompete foxes and generally replace the niche occupied by wolves. In fact, they have interbred with Red Wolves, jeopardizing efforts to reintroduce that species in eastern North Carolina (Bohling and Waits 2011).

Like Coyotes, the Nine-banded Armadillo has spread throughout much of North America over the past 100 years. The range expansion is not likely due to climate change, but rather to how the lack of predators and land-use changes provide more open conditions. Their omnivorous feeding habits and fast reproduction also contribute to their spread. They compete with other ground-dwelling species, such as skunks and ground-nesting birds. Armadillos can also carry the bacteria that cause leprosy.

Feral Swine can significantly impact plant communities and wildlife habitat because they root through the ground's surface in search of food. Feral Swine destroy agricultural crops and other property and pose a substantial disease risk for both domestic swine and other wildlife.

Pets are exotic predators in the environment and when allowed to roam freely they can significantly reduce small animal populations, especially birds, amphibians, and reptiles, by disrupting nesting and reproduction behavior or by killing wildlife. Dogs allowed to run off-leash impact disturbance-sensitive species such as ground-nesting birds and small mammals and are subject to conflicts and injury from interaction with wild animals. Cats are exotic predators and efficient killers that prey on wild animals. Even well-fed cats will kill small mammals, insects, birds, amphibians, and reptiles — some of which may be species of conservation concern. Exposure to rabies and distemper is a health threat to both dogs and cats when vaccinations are not kept up to date and the animals are allowed to roam freely outside. Support of feral cat colonies should be discouraged, because the number of cats can significantly multiply and impact local wildlife populations. Educating pet owners about the importance of keeping their domesticated animals on a leash or within a fenced yard, or in the case of house cats, keeping them inside to help minimize impacts to wildlife is an ongoing need.

Invasive plants can alter the quality of breeding habitat for some species, such as songbirds, by impacting important demographic traits. For example, the loss of habitat can interfere with migratory patterns of species such as birds and fish, which can have significant impacts to the age structure and dispersal of species that tend to return to their area of natal origin (philopatry) (Ortega et al. 2014). A few research studies have found that animal behavior involving acoustic signals (e.g., birdsong) can be impacted when wildlife abundance is reduced due to habitat degradation (Laiolo and Tella 2005, 2007; Laiolo et al. 2008; Barber et al. 2010; Ortega et al. 2014). Some changes that may be subtle but will have long-term implications to local populations include increased song similarity and reduced song diversity that results from declines in the number of song models available for juveniles to learn (Laiolo and Tella 2005, 2007; Laiolo et al. 2008; Briefer et al. 2010; Ortega et al. 2014).

Single introductions of an invasive species may result in limited genetic variation to an invasive population, whereas multiple introductions of the species may result in an increase in genetic diversity and contribute to its success as an invasive species (Lucardi et al. 2014). It is also widely reported in peer-reviewed literature that integration of invasive plant species into a natural community can disrupt native plant–pollinator relationships and networks (Memmott and Waser 2002; Bjerknes et al. 2007; Morales and Traveset 2009; van Hengstum 2013).

Cogon grass is an invasive perennial grass considered a major weed of forestlands, rights-of-ways, agricultural and disturbed lands, and natural ecosystems in the southeastern United States (Lucardi et al. 2014). It is considered to be one of the top 10 worst weeds in the world and is a federal noxious weed. Rhizomes have sharply pointed tips and form a dense interwoven mat usually within the upper foot of the soil surface. The thick root mat prevents native species from establishing or growing and enables Cogon Grass to out-compete native species for water and nutrient resources.

Beach Vitex is a quickly growing coastal landscape plant tolerant of salt and drought. It can reproduce through seed production (as high as 10,000 to 20,000 seeds per square meter) or broken shoot fragments from established plants that can be washed by storms onto beaches at great distance from each other. It forms dense cover on beach dunes and can inhibit growth of the native species Seabeach Amaranth, which is federally listed as threatened. It can also cover important beach nesting habitat for shorebirds that breed in North Carolina such as the Piping Plover (federally listed as endangered), American Oystercatcher, Black Skimmer, Common Tern, and Least Tern.

Genetically modified organisms (GMOs), also referred to as novel or synthetic organisms, are those in which the genetic material has been altered in a way that does not occur naturally by mating and/or natural recombination (OJEC 2001; Jeschke et al. 2013). Synthetic organisms are completely synthesized by humans and are typically built by assembling short DNA sequences to create new genomes (Preston 2008; Deplazes and Huppenbauer 2009; Jeschke et al. 2013). While it is reported that there are currently no known cases of a synthetic organism becoming established in the wild, GMOs and synthetic organisms can serve as novel hosts for emerging pathogens that can become established (Jeschke et al. 2013). Less diverse ecosystems may be more susceptible to invaders, and likewise, pathogens may be transmitted more readily in ecological communities with reduced diversity (Jeschke et al. 2013). Another concern related to the development and increased cultivation of GMOs is the potential escape of transgenes into native populations and the potential change to the phenotype of an organism and the effects of transgenes on natural ecosystems (Snow et al. 2005; Stewart et al. 2003; Andow and Zwahlen 2006; van Hengstum 2013).

5.10.3 SGCN Priority Species

The Taxa Team evaluation considered the level of threat invasive and problematic species and genes represents to SGCN priority species. Lists of the SGCN and other priority species this threat is expected to have a very high or high impact on can be found in Appendix 3.

5.11 Pollution and Contaminants

> Threats considered in this category are from introduction of exotic and/or excess materials or energy from point (e.g., waste treatment discharge, industrial effluents) and nonpoint sources (e.g., runoff from roads, lawns, golf courses); waterborne pollutants from industrial, resource extraction, energy production, and military sources; agricultural and forestry effluents such as herbicide and fertilizer runoff; garbage and solid waste from landfills, construction debris, and waterborne debris that can entangle wildlife; acid rain, smog and excess nitrogen deposition, radioactive emissions, smoke from fires, and other airborne pollutants; and excess energy sources (e.g., transportation noise, submarine sonar, beach lights) (Salafsky et al. 2008).

In addition to physical alteration of aquatic habitat, sediments and contaminants delivered through point and nonpoint sources magnify the level of threats to aquatic systems (TNC 2000). Point source pollution is delivered primarily in the form of municipal wastewater and stormwater discharges. The majority of water quality problems in North Carolina, however, stem from nonpoint source pollution associated with land-use activities such as development projects, forestry and agricultural practices, and road construction (NCDWQ 2000; SAMAB 1996). Agricultural pesticides, particularly neonicotinoids and fipronil, are having direct and indirect negative nontarget impacts on aquatic invertebrates and vertebrates (Gibbons et al. 2014).

5.11.1 Sewage, Solid Wastes, and Effluents – Anticipated Impacts

The National Pollutant Discharge Elimination System (NPDES) permit program administered by the NC Department of Environment and Natural Resources (NCDENR) regulates the discharge of point source pollution in our state. Permits establish limits on pollutants that must be met before wastewater is discharged to surface waters. Wastewater treatment technologies vary among wastewater treatment plants (WWTP). There is increasing concern over contaminants that are not currently treated by WWTPs or regulated by NPDES limits, such as endocrine-disrupting chemicals (EDCs). EDCs can be found in pharmaceuticals, personal care products, and various industrial compounds.

Stormwater runoff is a non-point pollutant that is mostly unregulated in NC except in larger cities. Stormwater best management practices (BMPs), such as detention ponds, grassed swales, filter strips, and rain gardens slow down stormwater and reduce pollutant input as it travels to surface waters from construction sites, agricultural fields, and paved areas.

Aquatic systems can be impacted by wastewater discharges when effluent fails to meet regulatory limits, accidental spills of untreated wastewater occur, stream baseflows are low and a large percentage of streamflow is comprised of treated wastewater, and WWTPs are not equipped to properly treat all contaminants within wastewater that affect aquatic organisms. EDCs have been shown to affect immune and reproductive systems in freshwater mussels

(Bouchard et al. 2009; Bringolf et al. 2010; Gagné et al. 2011) and in freshwater fish (Blazer et al. 2014; Gagné et al. 2011). Contaminants can lead to population-level impacts to species, including local extirpations.

Without appropriate stormwater BMPs, stormwater runoff following rain events can lead to erosion of cleared fields and construction sites, resulting in increased turbidity and sedimentation of nearby surface waters. Increased turbidity and sedimentation affects foraging and reproduction in streams and lakes and can lead to changes in community composition and species extirpation. Stormwater runoff also affects stream hydrology because there is more surface runoff and less infiltration. As a result, water reaches surface waters quickly, causing flows to increase quickly. An increase in imperviousness causes stream flows to increase more rapidly following rain events and subside more quickly. With less rainfall soaking into the ground, there is less groundwater to contribute to baseflows. This results in a flow regime that differs from the natural flow regime (Poff et al. 1997). These flow regime alterations can cause changes to the aquatic community, including local extirpation of species.

5.11.2 Chemicals and Toxic Compounds – Anticipated Impacts

Pesticides and herbicides are widely used to control pests and unwanted vegetation. However, they can also have unwanted deleterious effects on wildlife, especially if they are used in an unapproved manner. The agricultural insecticide DDT was banned due to environmental impacts; increases in Bald Eagle and Peregrine Falcon populations are partially attributed to the ban on DDT.

Lead shot, such as that used in ammunition and fishing line sinkers, has health implications for wildlife because of the potential for acute toxicosis from ingestion of the lead (Scheuhammer and Norris 1995; Keel et al. 2002; Butler et al. 2005; Clark and Scheuhammer 2003; Samour and Naldo 2005; Fisher et al. 2006; Hunt et al. 2006; Martin et al. 2008; Stevenson et al. 2005; Strom et al. 2005; Thomas et al. 2009; Pierce et al. 2015). Hunting regulations in North Carolina prohibit the use of any shotgun shells containing lead or toxic shot while hunting on any NCWRC posted waterfowl impoundment.

Pesticides and herbicides can impact wildlife that inhabit areas treated or areas adjacent to treated areas that receive overspray or drift, or through runoff from treated areas that reaches surface waters. Pesticides and herbicides can impact wildlife in several ways, such as reducing the foraging or prey base, damaging wildlife habitat, or direct contamination (Freemark and Boutin 1995). Pollutants can have various physiological effects on birds, causing stress and mortality of young and adults (Fry 1995).

Research initially focused on the potential lead poisoning in upland game birds but has expanded to include waterbirds that eat lead pellets or ingest lead sinkers and mammals that scavenge the remains of harvested animals (Thomas 2013). There has been growing awareness and concern about human ingestion of lead fragments from harvested game animals and the potential for serious lead exposure (Dobrowolska and Melosik 2008; Kosnett 2009; Iqbal et al. 2009; Knott et al.

2010; Pain et al. 2010; Thomas 2013). Thomas (2013) suggests that the reluctance of hunters and legislators to support use of nontoxic rifle ammunition may be based on perceptions about availability, price, and effectiveness of substitute ammunition (such as steel, copper, or copper-zinc alloy shot). However, it was reported there are as many as 48 different hunting rifle cartridges manufactured in the United States that contain lead-free ammunition, and they are readily available from national retailers (Thomas 2013).

5.11.3 Airborne Pollutants – Anticipated Impacts

Animals are exposed to air pollutants through breathing, ingestion, or absorption through the skin (in the case of amphibians). The response of an organism depends on many factors, including the type of pollutant and the magnitude and duration of exposure. There are three general pollutant types: gases (e.g., ozone), non-acidic chemicals (e.g., metals, dioxins), and acidic chemicals (e.g., nitrates and sulfates). The burning of fossil fuels releases sulfur dioxide and nitrogen oxides, which are transformed in the atmosphere and returned as acid precipitation.

Gases generally affect animal respiratory systems. Metals may affect their circulatory, respiratory, gastrointestinal, and central nervous systems, particularly the kidney, liver, and brain. Dioxins bioaccumulate, or build up in the body by concentrating in body fat, and are resistant to biological breakdown. A study of earthworms showed they accumulated dioxins up to five times the concentration found in the soil. While not lethal to the worms, it could affect many bird and small mammal species that rely on them as a food source.

Acid rain reduces soil buffering capacity and eventually results in changes to vegetation and acidification of streams and surface waters. Many studies have shown that aquatic invertebrates, fish, and other organisms are greatly affected by low pH conditions, with species composition declining as pH drops. Acid rain impacts on fish are occurring in many countries, including the United States, but evidence in North Carolina is limited. Acid deposition is a possible cause of declines in amphibian populations, particularly those that use ephemeral waterbodies that are susceptible to precipitation events. Reproduction is most vulnerable because early life stages are more sensitive to changes in water chemistry.

Air pollutants also affect wildlife indirectly by causing changes in the ecosystem. Vegetation provides cover for protection from predators and weather, provides breeding and nesting habitat, and also serves as a food source. Therefore, any change in vegetation could indirectly affect animal populations.

5.11.4 Excess Energy – Anticipated Impacts

The most common expression of excess energy is light pollution. It alters and interferes with the timing of necessary biological activities, especially for crepuscular and nocturnal species by exposing them to predators and reducing the time they have to find food, shelter, or mates, and to reproduce.

Excessive lighting has been shown to alter the nesting behavior of sea turtles, causing females to cluster nests in areas shaded from lights, which leads to competition for nesting sites and damage to previously laid eggs (Salmon et al. 1995a). Once the nestlings hatch, light pollution causes them to become disoriented and have difficulty finding their way to the ocean, thus increasing predation and mortality (Salmon et al. 1995b).

Nocturnal animals are adapted to seeing in low light conditions; consequently, lights at night can blind these animals causing disruptions to migrations and local movements. Increased mortality due to roadkill at night is common for species such as Opossum and skunks. Some salamanders show reduced night foraging behavior in the presence of artificial lights.

Of course, light pollution has a dramatic effect on insects, killing or affecting countless numbers. Their altered behavior, in turn, affects animals that feed on them, such as bats and birds like the Common Nighthawk and Whip-poor-will.

Light pollution can send bird migrations off course, which can cause mortality. There are instances of spring migrants such as warblers becoming disoriented by lights in a fog and flying into a building, killing hundreds of the birds.

5.11.5 SGCN Priority Species

The Taxa Team evaluation considered the level of threat pollution and contaminants represents to SGCN priority species. . Lists of the SGCN and other priority species this threat is expected to have a very high or high impact on can be found in Appendix 3.

5.12 Climate Change

> Long-term climatic changes that may be linked to global warming or other severe climatic or weather events outside the natural range of variation are the focus of this threat category. Related concerns are habitat shifts and alterations such as sea-level rise, coral bleaching, and desertification; droughts and sustained periods where rainfall falls below normal ranges; temperature extremes such as heat waves, cold spells, and oceanic temperature changes; and extreme weather events and shifts in seasonality of storms that cause flooding, damage, and can impact wildlife (Salafsky et al. 2008).

The NC Wildlife Resources Commission completed its first Climate Resiliency Strategy (herein referred to as 'the Strategy') in 2024. The Strategy identified ways that the agency undertakes or could undertake to address the shift in ecological regimes and its impact on wildlife distribution. The strategies identified help staff assess climate impacts on habitats and work to implement needed actions to address habitat needs of fish and wildlife in North Carolina. The full Strategy is provided as a reference in Appendix 5 and can be downloaded in PDF format from the NC Wildlife Action Plan webpage (https://www.ncwildlife.gov/ncwrc-climate-strategy-report/open).

Climate shapes the structure and function of natural ecosystems, and increased variability and weather extremes such as drought, heavy rain, and storm events are expected to have greater impacts than temperature alone (Vose et al. 2014). Changes to forests due to dieback, insect outbreaks, and large wildfires may be signals that rapidly changing climate conditions are amplifying ecosystem changes (Vose et al. 2014). Climate change can impact hydrologic processes and water resources directly by altering precipitation, evapotranspiration, groundwater table, soil moisture, or streamflow, and indirectly by degrading water quality or reducing the water available for irrigation.

Climate change also directly affects biodiversity; for example, when environmental conditions change too quickly for species to adapt to them or migrate to areas with more suitable conditions if such areas still exist (Bellard et al. 2012).

The North Carolina Institute for Climate Studies (NCICS) completed the North Carolina Climate Science Report (https://ncics.org/wp-content/uploads/2020/10/NC_Climate_Science_Report_FullReport_Final_revised_September2020.pdf) n 2020. This report provides a scientific assessment of historical climate trends and potential future climate change in North Carolina. This report indicates that North Carolina is very likely to continue to experience warmer temperatures, extreme precipitation events, and more inland flooding. It is likely that North Carolina will experience drought and decreased snowfall and cold temperatures. Sea level rise (SLR) is 'virtually certain.'

The following section provides additional information about three climate change topics expected to impact wildlife: SLR, temperature changes, and precipitation changes.

5.12.1 Sea Level rise - Anticipated Impacts

In simple terms, sea level is the average height of the ocean surface and it is typically measured along a coastline in relation to fixed land positions. Sea level is influenced by several factors, such as ice melt from glaciers and ice masses, and thermal expansion of sea water, which are caused by increased air and water temperatures. Given these influences, sea level naturally fluctuates to some degree on a daily basis because water inputs, ambient temperatures, evaporation, and lunar cycles will vary not only between locations but also on a global scale (NCDCM 2012).

Tide gauge stations located along the coast are used to measure local changes in water elevations and are able to measure changes in land mass that occur from subsidence, shifts, and tectonic plate movements. These types of ocean and land elevation measurements have been collected by the National Oceanic and Atmospheric Administration (NOAA) over time in several locations along North Carolina's coast (Figure 5.12-1).

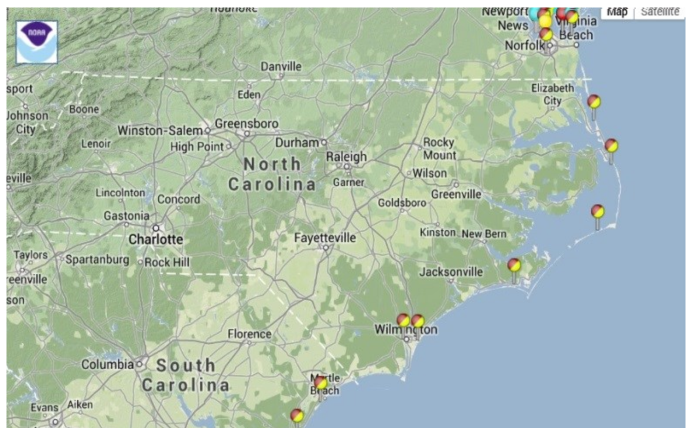


Figure 5.12-1. NOAA National Ocean Service Tides & Currents Stations (North Carolina). Source: http://tidesandcurrents.noaa.gov/products.html

The resulting data are used to derive relative sea level elevations along North Carolina's coast. References are provided at the end of this chapter for additional information on SLR and datasets that are publically available from federal and state agencies and research organizations (NOAA 2013).

Global sea level has increased 20 to 23 cm (8 to 9 inches) since 1880 at a rate of 0.114 to 0.14 cm (0.045 to 0.055 inches) of rise per year to 1993. From 1993 to 2016, the rate of rise doubled to 0.28 cm (0.11 inches) per year, equating to an 8 cm (3 inch) rise (Sweet et al. 2017). Sea level rise along the North Carolina coast is effectively three to four times the global rate due to the Atlantic Meridional Overturning Current along the northeast Atlantic Coast. The associated low-pressure conditions of this current result in increased sea level (Sallenger et al. 2012). Sea level is likely rise by up to almost 1.5 feet on the Atlantic Coast by 2050 (Sweet et. Al 2022).

According to vulnerability assessments (Boruff et al. 2005; Sallenger et al. 2012), North Carolina's coastline is one of the areas considered to have significant vulnerability to SLR. A report by the NC Coastal Resources Commission's Science Panel on Coastal Hazards (NCDCM 2015) notes both geological and tide gauge data provide evidence there is more land subsidence to the north of Cape Lookout than to the south. This contributes to higher measured rates of SLR along the state's northeastern coast (NCDCM 2015). The Science Panel's report compares the range of estimated sea level rise over a 30-year period based on three projection scenarios. The results show the highest and lowest potential increase in mean sea level varies from 2.7 inches at Duck (northernmost area) to 4.5 inches at Southpoint (southernmost area) (NCDCM 2015). This variability is evidence of the uncertainty in predictions, especially at longer time scales, and the spatial differences along the state's coast.

Two of the greatest threats posed by SLR to fish and wildlife in North Carolina are loss of marsh and wetland habitats because of erosion and flooding, and the expected increase in salinity of coastal aquifers, freshwater drainage basins, and estuarine systems because of saltwater intrusion (Neumann and Hearty 1996). DeWan et al. (2010) notes that coastal habitats, such as maritime forests and shrub communities, estuarine communities, tidal swamp forests and wetlands, and beach and dune habitats, will be the most susceptible habitats to the effects of SLR.

Saltwater intrusion into freshwater aquifers and drainage basins can threaten the biodiversity of freshwater tidal marshes and contaminate municipal, industrial, and agricultural water supplies (Marion et al. 2014; Bear et al. 1999). Connectivity between habitats and modified landscapes will become even more important as species are forced to shift their ranges inland because vegetation is converted to open water or dies off from the influence of higher salinity of surface waters. Migratory fishes and the freshwater stream ecosystems they use for portions of their life cycle will be adversely affected by saltwater intrusion, especially if upstream freshwaters where the salt wedge has not historically been recorded becomes brackish (Roessig et al. 2004; Love et al. 2008). Movement upstream to freshwater refugia can be impeded if there are barriers to movement, such as dams and hydraulic conveyances under roadways (i.e., culverts and pipes). Sea turtles and beach-nesting shorebirds will be impacted by SLR through loss of nesting habitats by erosion and inundation and flooding of nests that result in egg mortality (Fuentes et al. 2010).

5.12.2 Temperature Changes – Anticipated Impacts

Higher seasonal and overall temperatures can affect the phenology (seasonal timing) of certain activities, such as migration, breeding, or leaf emergence. Since it can affect species differently, it can result in a mismatch between an animal and its required food source or other essential need. Some plants are producing flowers earlier due to warmer conditions, while others are blooming later because of insufficient duration of necessary cold conditions. So-called false springs have been shown to damage flowers and thus affect wildlife that rely on the fruit. It is not clear, however, if phenological changes are actually damaging to a given species or an adaptation to changing conditions.

Some hunting or fishing harvest seasons have traditionally been timed to coincide with certain life stages of target fish and wildlife. Shifts in phenology can cause a mismatch of the harvest season and the size or condition of the animal (Peer and Miller 2014). Traditional hunting seasons may have to be adjusted not only to benefit the hunter, but also to avoid impacting the wildlife population. For the most part, this is not an issue for freshwater fishing because there typically are no closed fishing seasons. However, there are seasonal considerations for Striped Bass and some marine species.

Sea turtle populations will be affected by erosion of beach nesting areas; sand temperatures that influence sex determination of hatchlings toward females (no male hatchlings); temperatures that exceed the upper limit for egg incubation (34°C) to occur at all; and loss of sea grass bed and coral reef feeding grounds from warming ocean waters.

Growing seasons are becoming longer in the Southeast, nighttime air temperatures are warmer, and precipitation events are becoming more extreme (McNulty et al. 2014; Fischlin et al. 2007). Ground temperatures that are higher than normal winter seasonal ranges are associated with milder winters and may cause earlier onset of spring conditions. There is evidence that plants that have evolved to emerge annually based on persistent soil temperatures are now blooming as many as 10 days earlier than previously documented. Many wildlife species will be affected by a disconnect between availability of food resources and young produced during the spring. Birds that migrate earlier in response to warming temperatures may experience greater competition for food and cover resources when there are disconnects between occurrence and availability.

Climate-change-driven warming could expand the northern ranges for many invasive insect species (Vose et al. 2014). Climate change could also indirectly affect insect populations through impacts on natural enemies, important insect symbionts, host physiology, and host range distributions. Future warmer winter temperatures could remove existing range barriers for some native species. This could result in spread into places where hosts are currently abundant and result in competition between native and nonnative insect species.

5.12.3 Precipitation Changes – Anticipated Impacts

Climate change is expected to directly impact water resources through changes to the amount, form (fog, rain, snow, ice), and timing of precipitation (Marion et al. 2014). These changes will influence the quantity of baseflow and stormflow and the frequency of groundwater recharge and flooding (Marion et al. 2014; Karl et al. 2009). Changes in precipitation amount or storm intensity can affect soil erosion potential by changing the runoff amount, the kinetic energy of rainfall, or the vegetation cover that resists erosion (Marion et al. 2014). Models used by the Intergovernmental Panel on Climate Change (IPCC) show changes in precipitation will strongly influence future variability in wet and dry summer patterns over the southeastern US (Li et al. 2011).

The science of predicting precipitation changes for North Carolina is still young and no clear trends are evident (NCSCO n.d.; Wooten et al. 2014). Recent changes in precipitation in some parts of the state may be related to decadal oscillation (Sayemuzzamana and Jha 2014). Some climate change models indicate that total amounts of precipitation may not change much, but the intensity and duration of events, both storms and droughts, will increase. This could mean that the extreme or infrequent conditions may be a more influential abiotic factor than these habitats and wildlife communities are accustomed to. There are more than 100 years of weather and climate observation records from several locations in the southeast, but there are typically less than 5 years of observation records of ecosystems (Wootten et al. 2014). There is much uncertainty in understanding the relationship between climate change and ecological response because of the lack of overlapping data sets.

With projected decreases in water availability, future population growth will increase stress over water supplies across much of the South by 2060, particularly in developing watersheds (Marion et al. 2014). Projections of water supply demand in the Raleigh–Durham metropolitan area estimate a 14% decrease in water supply from the Upper Neuse River watershed in conjunction with an estimated 21% increase in water demand (Marion et al. 2014).

The amount and timing of precipitation will affect annual amphibian reproduction because most species lay eggs in water, often seasonal and ephemeral wetland systems (Saenz et al. 2013).

Increased drought conditions and warming temperatures will contribute to the potential for increased wildfires in the Atlantic coast in summer and early autumn (Vose et al. 2014). Dynamic vegetation models indicate there will be an increase in the fuel loading in eastern areas of the South (Vose et al. 2014). Long-term drought may result in stress to vegetation.

Projected dryness is expected to influence fire season by increasing duration as much as five months longer in the Appalachian Mountains (Vose et al. 2014). Where development and population growth occur, there will be a greater potential threat to life and property from wildfires. The growing presence of people will also increase the risk of wildfire ignitions from human-ignited wildfires (Vose et al. 2014). Climate change could alter fuel loading by changing plant productivity and decomposition rates, as well as by causing shifts in species distribution. Warmer and drier conditions would result in more fuel being consumed (Liu et al. 2013).

5.12.4 SGCN Priority Species

The Taxa Team evaluation considered the scope and severity the threat of climate change represents to SGCN priority species. Lists of the SGCN and other priority species this threat is expected to have a very high or high impact on can be found in Appendix 3.

5.13 Disease and Pathogens

> This threat focuses on diseases, viruses, bacteria, prions, and other pathogens that can affect wildlife species. Some topics are wildlife-specific while others may not normally infect wildlife but can be carried over from other vectors.

All wildlife species are subject to some type of naturally occurring disease that can cause illness and death to individual animals or in some cases can significantly impact population densities (McLean 2005). It has been reported that disease resistance depends on the interaction of host, pathogens, and environment (Snieszko 1970). This subsection provides information about some of the most serious diseases or emerging concerns that can significantly impact wildlife species or create spillover effects to humans. The following information highlights some of the important concerns and identifies resources for additional information.

In many cases, the spread of disease among and between species is controlled naturally and there is little risk of extinction when mortality occurs within a population. However, management actions to control the incidence and spread of disease may be warranted when disease impacts are so severe that local populations are at risk of becoming extinct; or when mortality from diseases is so severe that it affects ecological processes and/or exceeds the social capacity for acceptance. Management may also be warranted when genetic flow will be disrupted between populations or when there is a risk of spillover to human or domestic animal populations.

Wildlife can serve as a reservoir for diseases and pathogens that naturally occur within wildlife populations with little effect on populations but which have the potential to create spillover effects that affect human health. Examples of diseases that can spillover from wildlife to humans include tickborne diseases (e.g., Lyme disease, *Ehrlichiosis*, Rocky Mountain spotted fever), leprosy, brucellosis, ebola, rabies, and hantaviruses to name a few. Newly introduced diseases can be carried by exotic nonnative species, or captive-raised animals that have been released to the wild. Unnatural high densities facilitated by wildlife feeding and baiting can lead to increased densities of wildlife species and comingling, increasing the prevalence and transmission rates of wildlife disease. When disease in wildlife is associated with human behaviors, steps to educate the public and reduce the incidence of such behaviors should be implemented in an effective way.

In some cases, wildlife may develop diseases or conditions they would not normally have but which are the result of human-induced conditions. Examples include the incidence of pancreatic cancer, diabetes, intersex malformations, and tooth decay. Black Bears have been found with tooth decay likely caused by consumption of bait foods containing high concentrations of sugar. Another example is of freshwater fish species that exhibit intersex characteristics because of exposure to EDCs and hormone-mimicking chemicals found in wastewaters discharged into surface waters.

In North Carolina, certain diseases and conditions are reportable to the Department of Health and Human Services, including diseases that affect wildlife or those for which wildlife can be a vector for human infection. A list of reportable diseases and information on each is available at http://epi.publichealth.nc.gov/cd/lhds/manuals/cd/reportable_diseases.html.

Additional information on wildlife diseases is available from the USGS National Wildlife Health Center (NWHC), which conducts research and publishes information about a number of wildlife disease issues (http://www.nwhc.usgs.gov/disease_information). The Wildlife Disease Association (www.wildlifedisease.org) is a membership organization that acquires, disseminates, and applies knowledge of the health and disease of wild animals in relation to their biology, conservation, and ecology, including interactions with humans and domestic animals.

5.13.1 Amphibians - Anticipated Impacts

Worldwide amphibian population declines have been attributed to numerous causes, primarily anthropogenic, but an increasing threat with significant impacts comes from Chytridiomycota fungus (e.g., chytrid) and Iridoviridae pathogens (e.g., ranaviruses) (Harp and Petranka 2006). Fungal diseases have been linked to the global declines and extinctions in amphibian populations because they often interfere with the animal's ability to regulate body fluids and osmotic pressure, which eventually leads to death (Briggs et al. 2010; Rollins-Smith et al. 2011; McCallum 2012). Stressors such as pollution, habitat changes, and climate change can increase the likelihood of a population being severely impacted by these pathogens. While treatment of individual populations is difficult, protocols are being investigated through various scientific research programs (Rollins-Smith et al. 2011). Current measures to prevent extinction and preserve genetic diversity primarily involve captive breeding of healthy animals for reintroduction to areas where the fungus is not present and protection of populations unaffected by disease through conservation actions.

Batrachochytrium dendrobatidis (Bd) is an infectious fungus that can be introduced to water and soils by infected animals and has been found to affect numerous amphibian species, especially Anurans, including species found in North Carolina (Parris and Beaudoin 2004). This fungus is known to kill from 50% to 80% of the individuals in infected populations, and surviving animals or other host animals can maintain the infection in the population (Gagliardo et al. 2008; Cheng et al. 2011; Blaustein et al. 2012; McMahon et al. 2012; Phillips and Puschendorf 2013; Louca et al. 2014). Some amphibian species are protected from infection by their skin mucus excretions, but exposure to pesticides can alter immune defense and lead to susceptibility to parasites and pathogens (Lannoo 2009; Rohr et al. 2008; Rollins-Smith et al. 2011).

Ranaviruses are associated with diseases in wild and cultured fishes, amphibians, and reptiles (Robert et al. 2007; Gray et al. 2007). They are reported to be most lethal to amphibian larvae with mortality rates as high as 90% or more (Harp and Petranka 2006; Gray et al. 2007). In the United States, there is a high risk of exposure for wild populations to the ranavirus Frog Virus 3 (FV3). Host reservoirs for FV3 include exotic species such as African Clawed Frogs (*Xenopus laevis*), which are commonly raised in captivity for the pet trade and sold across the United States, when they are released into the wild (intentionally or accidentally) (Robert et al. 2007).

The *Regina ranavirus* is highly infectious and can be virulent to Caudata (urodela) amphibians such as the common Tiger Salamander, likely because they lack natural antimicrobial peptides associated with the more evolved immunosystems of other amphibian taxa (Froese et al. 2005; Sheafor et al. 2008). Ranaviruses present at aquaculture facilities can be 2–10 times more lethal than wild strains and can pose a particular risk to frogs in the Ranidae family, thereby contributing to their population declines (Hickling 2011).

5.13.2 Birds – Anticipated Impacts

According to the NWHC, avian vacuolar myelinopathy (AVM) is a recently discovered neurological disease affecting waterbirds, primarily Bald Eagles and American Coots, in the southern United States. AVM has also been confirmed as the cause of death in Mallards, Buffleheads, Ring-necked Ducks, Canada Geese, Killdeer, and a Great Horned Owl. Birds affected with AVM lack muscle coordination and therefore have difficulty flying and swimming. The cause of the disease is unknown but has been linked through the food chain from plants to waterfowl to predators. A cyanobacterium is possibly the root cause.

West Nile Virus (WNV) can infect a number of animals, including humans, horses, and birds. It was first documented in the United States in 1999 and has spread throughout North America. Birds do not normally show any symptoms of WNV infection but serve as natural reservoirs of the virus. However, some avian species, such as crows, appear to be susceptible to the virus. WNV was first documented in raptors in the summer of 2002. Since that time, this disease has been diagnosed in Bald Eagles in South Carolina as well as other states. There is some evidence that WNV has spread globally in part through transmission by migratory birds introducing the virus to other wildlife and humans (Rappole and Huba´lek 2003; Verhagen et al. 2014).

Avian influenza (bird flu) is a disease caused by any one of several influenza subtypes that can affect birds because they are a host reservoir (Alexander 2000; Kilpatrick et al. 2006; Olsen et al. 2006; Munster et al. 2007; Dugan et al. 2008; Verhagen et al. 2014). Research has documented a high prevalence for infection in migratory ducks, geese, and swans (order Anseriformes) and in gulls, terns, and shorebirds (order Characdriiformes) (Webster et al. 1992; Alexander 2000; Olsen et al. 2006; Munster et al. 2007). The prevalence for infection to occur during fall migration may occur because of the large number of birds that occur in concentrated areas and because there are a higher number of immunologically susceptible young of the year in the population (Webster et al. 1992; Hinshaw et al. 1985;

Sharp et al. 1993; Munster et al. 2007). Surveillance to detect the disease and monitoring of infected populations to determine impacts is needed before appropriate management strategies can be developed.

5.13.3 Crayfishes – Anticipated Impacts

Relatively little published research is available concerning crayfish diseases and much of the work is from Australia and Europe. Edgerton et al. (2002) provide a synopsis of crayfish diseases and pathogens. Most disease agents (viruses, bacteria, etc.) cause only limited impacts to crayfish (Longshaw 2011). Disease in freshwater crayfish can result from abiotic factors such as adverse environmental conditions, poor nutrition, and exposure to waterborne toxicants or biotic factors such as viruses, parasites, or microorganisms (Edgerton et al. 2002). Crayfish aquaculture production provides an opportunity to better monitor health status and detect pathogen and disease transmission because population densities allow efficient transfer of disease between individuals.

5.13.4 Mammals – Anticipated Impacts

White-nose Syndrome (WNS) is a disease of hibernating bats that has spread from the northeastern to the central United States. Since the winter of 2007–2008, millions of insect-eating bats in 25 states and five Canadian provinces have died from this disease. The fungus *Pseudogymnoascus destructans* is known to cause WNS in hibernating and colonially roosting bat species. Current estimates of bat population decline in the northeastern United States since the emergence of WNS are approximately 80%. It is suspected that human use of caves is spreading the disease so some jurisdictions have closed or limited entry to caves. Despite these precautions, the disease continues to spread. The ecological consequences of these declines is likely to impact agricultural operations because bats are primary consumers of insects, and a recent economic analysis indicated that insect suppression services (ecosystem services) provided by bats to US agriculture are valued at between 4 and 50 billion dollars per year (USGS NWHC 2013).

Chronic Wasting Disease (CWD) is a disease of the nervous system in deer and elk (family Cervidae) that is characterized by spongy degeneration of brain tissue resulting in emaciation, abnormal behavior, loss of bodily functions, and ultimately death. There currently is no treatment for the disease and it is typically fatal for infected animals. It is not known to infect livestock or humans at the present (USGS NWHC 2013). The US Centers for Disease Control and the World Health Organization indicates there is no evidence that CWD can be transmitted to humans or linked to any neurological diseases of humans (NCWRC 2014).

According to the Chronic Wasting Disease Alliance, CWD has been confirmed in at least 19 states and in Canada but is not yet known in North Carolina. The NCWRC has had a preventative disease management strategy since 2002, when rules were adopted to prevent the introduction of the disease into the state and to minimize the spread of disease should it be found in the state. The strategy includes implementing administrative rules (15A NCAC 10B) on holding deer and elk in captivity and monitoring activities that collect samples from harvest and road-kill deer to find evidence of the disease. In 2014, the NCWRC developed a CWD response plan (currently in draft form) that outlines management actions designed to prevent the introduction or spread of CWD in the state and increase the likelihood of detecting the disease should it occur.

Epizootic Hemorrhagic Disease (EHD) is a virus that causes fluid in the lungs of White-tailed Deer populations. Dead deer are often found by hunters near sources of water, such as lakes, swamps, and wetlands. These wet areas are breeding areas for the gnats and other small biting insects that are carriers for the virus.

Canine Distemper is a disease that occurs in foxes, coyotes, skunks, and raccoons during the spring and fall. Infection typically does not create significant impacts to populations. However, local extinctions can occur when the disease occurs in isolated or remote populations and there is a lack of natural gene flow from other areas. This disease also has a high potential for exposure and spillover to domestic animals, especially unvaccinated dogs that come into contact with infected wildlife. It has been reported that distemper and rabies infections in wildlife can be hard to visually distinguish as early symptoms appear to be similar (salivating, disorientation, lethargy or aggressiveness, aimless wandering) (Stoffregen and Dubey 1991).

Brainworm Disease affects the nervous system of deer and elk (family Cervidae). Anderson (1972) notes that White-tailed Deer are the usual host for the parasitic Meningeal Worm (*Paralaphostrongylus tenuis*) and that larvae of the parasite that are shed in fecal matter can infest terrestrial mollusks (snails and slugs). Deer and elk can become infected by accidentally ingesting gastropods containing small numbers of infective larvae. Several terrestrial snail species found in hardwood forests have been indicated as a potential vector for Meningeal Worm. In North Carolina, snails in the *Anguispira* and *Discus* genus are suspected to be a vector. Little research has been published about transmission and infection of this parasite.

5.13.5 Reptiles – Anticipated Impacts

Snake Fungal Disease (SFD) is an emerging disease in certain populations of wild snakes in the eastern and midwestern United States. The NWHC has diagnosed several species with SFD, including species found in North Carolina such as Northern Water Snake, Eastern Racer, Rat Snake, Timber Rattlesnake, Pygmy Rattlesnake, and Milk Snake. According to the NWHC, population-level impacts of the disease are not yet widely known and are difficult to assess due to the cryptic and solitary nature of snakes, and a general lack of long-term monitoring data.

5.13.6 Freshwater Fishes – Anticipated Impacts

Diseases are a significant threat to the health of free-ranging and hatchery-reared populations of fishes, including a suite of important sport and restoration species (Starliper 2008). Most of the diseases are bacterial and infection can be spread throughout the water column, making it difficult to detect and treat affected populations. Examples of bacterial disease and the species affected include *Renibacterium salmoninarum* (bacterial kidney disease in salmonids); *Aeromonas* spp. (septicemic diseases, furunculosis, in salmonids); *Edwardsiella* spp. (warmwater fishes); *Novirhabdovirus* sp. (petechial hemorrhage, exophthalmia and internal organs congestion in Muskellunge, Yellow Perch, Freshwater Drum, Smallmouth and Rock bass, Redhorse spp.) (Ellis 1997; Austin and Austin 1999; Emmerich and Weibel 1890; McCarthy and Roberts 1980; Millard and Faisal 2012; Diamanka et al. 2014).

In 2014, Brook Trout in several streams were found to be infested with Gill Lice *Salmincola edwardsii*. Then, in 2015, Rainbow Trout in three separate river basins were found to be infected with Gill Lice *S. californiensis*. This was the first time that Gill Lice have been documented in NC waters. Gill Lice, which are actually copepods, attach to a fish's gills, which can traumatize gills and inhibit the fish's ability to breathe. While most fish are able to tolerate a moderate infestation of Gill Lice, if they are suffering from other stressors, such as drought and high water temperatures, fish kills and population impacts are more likely to occur. Relatively little research has been conducted for these two Gill Lice species. A better understanding of their distribution and life history traits will assist the determination of which fish populations may be most at risk of experiencing detrimental effects due to infestation and with mitigating negative consequences of these infections (Vigil et al. 2015).

Three *Flavobacterium* species (*F.psychrophilum*, *F.columnare, and F.psychrophilum*) cause several diseases that result in mortality to freshwater hatchery-reared and wild fishes (Starliper 2011). These particular *Flavobacterium* pathogens are ubiquitous in temperate freshwater aquatic environments, within a wide range of water temperatures from just above freezing to 30°C (86°F) and above (Starliper 2011). *F.psychrophilum* causes bacterial coldwater disease which is usually fatal to coldwater fishes such as trout (Starliper 2011). Chronic inflammation associated with the disease causes spiral or erratic swimming behaviors and/or spinal column deformities that are similar to symptoms associated with whirling disease.

In 2015, whirling disease was detected in the state in Rainbow Trout from the Watauga River. Whirling disease infects young salmonids (i.e., trout, salmon) and is caused by the myxosporean parasite *Myxobolus* [*Myxosoma*] *cerebralis* (Snieszko 1975; Sarker et al. 2015). This parasite causes physical deformities that cause fish to swim in circles and is particularly fatal for young Rainbow Trout (Sarker et al. 2015). The life cycle of the parasite alternates between two hosts, salmonid fishes and an aquatic oligochaete host Sludge Worms (*Tubifex tubifex*). Sludge Worms are a common oligochaete found in stream and lake sediments and are infected by feeding on sediments containing the parasite (Gilbert & Granath 2002; Sarker et al. 2015). Spores developed in the host are released into the water column where they attach and infect fishes. Infected fish can develop skeletal deformaties, may swim in circles, and ultimately will die as a result of the disease. Spores are released back into sediments when fish die, thereby repeating the cycle (Ayre et al. 2014; Sarker et al. 2015). Eutrophic impoundments and organically enriched streams are thought to contribute to the infection cycle (Thompson 2011) because density of *T.tubifex* populations are greater when organic content in sediments are high (Robbins et al. 1989; DuBey and Caldwell 2003; DuBey 2006). McGinnis and Kerans (2013) hypothesized that areas with higher residential, agricultural, and disturbed areas, higher road densities, and lower riparian cover would contribute sedimentation to trout waters that result in favorable habitat for Sludge Worms.

5.13.7 Pollinators – Anticipated Impacts

Introduced pathogens from the commercial bumble bee industry are suspected as potential contributors to significant bumble bee declines throughout North America (Cameron et al. 2011; Colla et al. 2006; Otterstatter and Thomson 2008; Murray et al. 2013). Declines in bumble bee species may be associated with the introduction of pathogens imported on a species of native bumble bee reared in Europe and reintroduced for pollination of crops in the United States (primarily for blueberry, cranberry, and greenhouse tomato production) (Cameron et al. 2011).

5.13.8 SGCN Priority Species

The Taxa Team evaluation considered the level of threat climate change represents to SGCN priority species. Lists of the SGCN and other priority species this threat is expected to have a very high or high impact on can be found in Appendix 3.

Chapter 6
Conservation Goals and Priorities in North Carolina

6

Chapter 6: Conservation Goals and Priorities in North Carolina

Required Element 4: Provide descriptions of conservation actions proposed to conserve the identified species and habitats and priorities for implementing such actions.

6.1 Introduction

Conservation needs and recommendations for specific taxonomic groups, species associations, or individual species were identified and discussed in Chapter 3. Problems affecting important aquatic, wetland, and terrestrial natural communities that provide habitat for North Carolina's wildlife were presented in Chapter 4. Current and emerging conditions that represent the threats most likely to impact fish and wildlife and their habitats were identified in Chapter 5. The information provided in these three chapters has been used to inform the programs and recommendations presented in Chapter 6. During the last decade, these programs have successfully achieved measurable benefits for wildlife and species. The recommendations are intended to be a part of the dialogue for implementing collaborative and cooperative discussions about conservation in the state.

This chapter describes a framework used for establishing conservation goals and objectives and recommends strategies and actions that support this Plan. Examples of objectives, strategies, and priority actions that can be used to develop projects that will implement WAP goals and recommended actions are provided in Appendix 6.

Section 6.2 outlines conservation incentives and programs that can be important tools in the implementation of strategic conservation plans. Program and partnership information for both private and public lands and for outreach and education efforts is outlined in this section.

Section 6.3 provides information about survey, monitoring, and research strategies designed to improve conservation decisions; management practices and cooperative efforts that help partners and others implement projects; and technical guidance that can influence decisions and reduce impacts to species and habitats.

Section 6.4 discusses the conservation programs and initiatives that implement SWAP conservation goals and objectives. NCWRC works collaboratively with many of the federal and state agencies and conservation organizations noted in this section.

6.2 Planning and Implementing Conservation

Goals and objectives should be the founding principles that define a conservation mission. Measurable, project-specific strategies and priority actions are methods by which the conservation mission can be achieved. After conservation goals and objectives have been determined, implementation of strategies and priority actions that include adaptive management concepts can provide a framework for prioritizing actions and modifying strategies based on project results. There are several resources available that describe methods to improve the efficiency and effectiveness of goal-oriented conservation efforts.

Structured decision making is one method that includes strategies for incorporating adaptive management planning (Joseph et al. 2008; Alexander 2008; USFWS 2008; Miller et al. 2009; Newbold & Siikamaki 2009; CMP 2013). It is an iterative process that has been an integral part of the conservation dialogue between NCWRC and conservation partners and was used throughout the WAP revision process.

Figure 6.2-1 provides an example of an iteratively structured decision-making strategy developed by the Conservation Measures Partnership (CMP) for the Open Standards for the Practice of Conservation (CMP 2013). This graphic depicts steps in the iterative process that can be used for developing and refining goal-oriented conservation strategies.

Figure 6.2-1 Example of an adaptive management planning cycle (CMP 2013).

6.2.1 Developing Conservation Goals

As part of the 2015 WAP revision process, a team of biologists and technical staff was tasked with evaluating conservation goals. The team developed recommendations that called for the SWAP conservation goals to focus on species and habitat conservation efforts and to utilize objectives and strategies to address other conservation topics that support achieving these two goals. There was broad consensus that the goals should focus on two primary conservation goals that concentrate on wildlife and natural communities (which are reflected in the first two goals from the original 2005 SWAP). There was also agreement that efforts focused on developing partnerships, education and outreach programs, and rules, regulations, and technical guidance should be used as objectives and strategies to achieve the updated goals, rather than serve as individual goals.

6.2.2 Conservation Goals Framework

The following format represents the revised framework for the revised WAP conservation goals and the relationship between project-specific objectives, strategies, and priority actions that are used to achieve the goals.

- **GOAL** (the overarching concept)
  - **Objective** (what we want to achieve with this goal)
    - **Strategy** (a way to achieve the objective)—these will be project-specific but examples are provided.
      - **Priority Action** (recommended actions that can be general or specific)—these will be project-specific but examples are provided.

Because projects represent many types of conservation efforts, the strategies and priority actions must be project-specific — incorporating adaptive management concepts that address the need for project modification based on results that are measurable. The updated conservation goals and recommended objectives that focus on species and habitats, as well as example strategies and priority actions, are outlined in Appendix 6. The example strategies and priority actions provided in the tables are based on State Wildlife Grant (SWG) funded projects implemented by NCWRC biologists.

6.2.3 Conservation Funding Resources

In Chapter 1 of this SWAP, we outlined how the federal SWG program provides matching grant funds for conservation efforts on behalf of SGCN priority species. The funds can be used for many types of conservation activities, such as surveys, monitoring, research, partnerships and programs, and land acquisition for habitat conservation. In addition to the SWG dollars, money from several trust-fund resources historically has been used in North Carolina to support specific types of land conservation. Successful land acquisition depends on matching site priorities with appropriate trust funds.

Federal- and state-level funding resources that have historically provided grants (as matching funds) that support landscape-level conservation programs include the following programs. However, because these resources are subject to the impacts of economic forces and legislative support, their availability varies annually.

- Land and Water Conservation Fund (LWCF) – This federal fund managed by the National Park Service supports acquisition and development of public outdoor recreation areas and facilities. The program is intended to create and maintain a nationwide legacy of quality recreation areas and facilities. The US Department of the Interior (USDOI) provides the funds and the NC Department of Environment and Natural Resources (NCDENR) administers the program in our state. Since 1965, the LWCF has provided $1.5 million on average per year in matching grants to protect land and support more than 875 state and local park projects in the state. Online at https://www.nps.gov/subjects/lwcf/index.htm.

- North Carolina Land & Water Fund (NCLWF) –Previously known as the Clean Water Management Trust, was originally established in 1996 to protect the state's drinking water sources. In 2013, the NC General Assembly by law (NC General Statute (G.S.) 113A, Article 18) combined the Natural Heritage Trust Fund (NHTF) with the existing CWMTF and expanded the Fund's mission to include conserving and protecting North Carolina's natural resources, cultural heritage, and military installations. The Fund has conserved over 500,000 acres and protected or restored 3,000 miles of streams and rivers. In 2024 the Fund provided $45 million to protect natural areas, waterways, historic sites, and military buffers. Online at https://nclwf.nc.gov.

- Parks and Recreation Trust Fund (PARTF) – This fund primarily supports state and local parks and recreation projects (e.g., recreational trails, greenways, community centers) that serve the general public by providing local governments (counties, incorporated municipalities, and public authorities) with dollar-for-dollar matching grants. The program is managed by the NC Parks and Recreation Authority and administered by the NCDENR, Division of Parks and Recreation. Since 1999, more than $450 million has been awarded ($25 million annually) for 736 projects statewide. Online at https://www.ncparks.gov/about-us/grants/parks-and-recreation-trust-fund.

- Agricultural Development and Farmland Preservation Trust Fund (ADFP) – This fund supports the preservation of NC farmland and depends on annual appropriations from the General Assembly. The fund supports farming, forestry, and horticulture communities within the $77 billion NC agribusiness industry by providing matching grants for the purchase of development rights by recording perpetual or term agricultural conservation easements (on farm, forest, and horticulture lands). The fund also provides matching grants for public and private enterprise programs that promote profitable and sustainable family farms. Grants for agricultural conservation easements give preference to lands with active production of food, fiber, and other agricultural products. Farm and forest landowners must partner with nonprofit conservation organizations or county agencies to apply for funds. In 2023, over 5,000 acres of conservation easements were established at a cost of $12.8 million dollars. Another $2.2 million was provided for county and regional conservation programs for working farms. Online at https://www.ncagr.gov/adfp.

- A number of Natural Resources Conservation Service (NRCS) programs provide funds for environmental improvement and stewardship programs, staff salaries, and conservation easements. Many previous Farm Bill conservation programs were reorganized in 2014 and combine previously available funding into larger programs. Among the biggest changes and newest programs are the Regional Conservation Partnership Program (RCPP) and the Agricultural Conservation Easement Program (ACEP), which can be used to fund conservation easements. Visit the NRCS Conservation Programs website at https://www.nrcs.usda.gov/programs-initiatives for more information.

- The Forest Legacy Program (FLP) is a federal program that supports state efforts to protect environmentally sensitive forest lands. In North Carolina, FLP is administered by the NC Forest Service (NCFS) to help landowners, state and local governments, and private land trusts identify and protect environmentally important forest lands that are threatened by present and future conversion to non-forest uses. The most important part of forest legacy are private landowners who want to conserve the special values of their land for future generations. Owners can do this in trust with the state government and receive a fair price for the commitment. Online at https://www.fs.usda.gov/managing-land/private-land/forest-legacy.

- NC Tax Checkoff for Nongame and Endangered Wildlife – The largest and most significant source of state funding for the NCWRC Wildlife Diversity Program. Anyone filing an NC income tax form and receiving a tax refund can designate any portion of the refund to fund the Wildlife Diversity Program. These are tax-deductible contributions for the next tax year. The deduction is generally made by checking line 31 on the form (exact line number is subject to tax form revision) and indicating the dollar amount of the contribution to be withheld from the tax refund. Since 1984, the Tax Checkoff program has provided $10,432,469 for conservation efforts. The average annual donation amount is $347,748, with the lowest in its first year in 1984 of $51,006 and the highest in 1991 of $510,269.

- NC Wildlife Diversity Endowment Fund – Interest earned from donations to this fund is spent on programs that benefit nongame species (i.e., animals not hunted or fished). Every dollar in donations given to the fund is matched with federal and other grants, so donated dollars actually count twice. Contributions are tax deductible and can be made through donations directly to the fund (including memorial contributions) or through a bequest from a will or living trust. This is a new fund designed to allow contributions toward programs benefitting nongame species. Online at https://www.ncwildlife.gov/donate#Diversity_Fund.

- NC Wildlife Endowment Fund – An investment and conservation program funded by fees paid for lifetime licenses and specified contributions. Contributions are tax deductible and can be made through donations directly to the fund (including memorial contributions) or through a bequest from a will or living trust. Online at https://www.ncwildlife.gov/donate#Diversity_Fund.

- NC Wildlife Conservation Account – Through partnership with the NC Division of Motor Vehicles, funds are generated through purchase and renewal of a Wildlife Resources personalized license plate for a vehicle, camper, or trailer. Since 2000, the personalized license plate program has provided more than $300,000 for wildlife conservation. Visit the NCDMV website to order a special plate https://payments.ncdot.gov.

- NCWRC's Green Growth Toolbox program has developed Partners for Green Growth to provide cost-share funding to local governments to assist them in enhancing priority wildlife habitat conservation through land-use planning. Details about this funding resource can be found online at Online at https://ncwildlife.gov/wildlife-habitat/conservation-restoration-programs/green-growth-toolbox/partners-green-growth-cost-share.

- North Carolina has 21 local land trusts that work with landowners to ensure critical lands are protected for clean drinking water, recreation, tourism, healthy forests, and working farms that produce fresh, local foods. Land trusts range from small groups run by dedicated volunteers to large and complex organizations. These groups reflect the communities they serve — protecting a single river or open space within a town, building urban trails, or saving thousands of acres to create a new park. The one trait shared by all is a passion for protecting North Carolina's unique natural heritage. Find a land trust by visiting Preservation North Carolina online at https://www.presnc.org/nc-land-trusts-conservation-organizations.

6.2.4 Conservation Tools and Data Resources for NC

Conservation occurs across the landscape on many different scales and there currently is no single resource that maps where land conservation occurs. Several Geographic Information

System (GIS) and map viewer tools representing different aspects of conservation in North Carolina are available on the internet. This section highlights a few of the mapping tools that are beneficial to conservation planning. Some of the tools rely on others to provide spatial data, and as such, the benefits from using the tool will rely on the quality of data provided.

6.2.4.1 NC OneMap Geospatial Portal

NC OneMap is the geospatial backbone supporting NC data and map service users. It is an organized effort of numerous partners throughout North Carolina, involving local, state, and federal government agencies, the private sector, and academia. NC OneMap is an evolving initiative directed by the NC Geographic Information Coordinating Council (GICC). GICC adopted this comprehensive initiative in partnership with county, municipal, state, and federal data providers. Available online at https://www.nconemap.gov.

The program promotes a vision for geospatial data standards; data currency, maintenance, and accessibility; data documentation (i.e., metadata); and a statewide GIS inventory. Thirty-seven priority data themes were selected as the initial focus, and critical information captured in geospatial datasets includes aerial imagery, land records, transportation, regulatory data, demographics, governmental boundaries, and marine and natural resources.

6.2.4.2 NC Natural Heritage Data Explorer

The NC Natural Heritage Data Explorer provides interactive access for viewing most of the conservation data available statewide and all of the data compiled and managed by the NC Natural Heritage Program (NCNHP). The data comprise maps of the best natural areas with the highest quality habitats for rare plants and wildlife in our state. NCNHP provides training on how to use the Data Explorer. More information is provided on the NCNHP web page https://ncnhde.natureserve.org.

6.2.4.3 Green Growth Toolbox (GGT)

The Green Growth Toolbox, coordinated by NCWRC, is a free technical assistance tool (program?) for local and regional governments, planners, advisory boards, and developers. The toolbox helps plan for growth in a way that will conserve natural assets — fish, wildlife, plants, streams, forests, fields, and wetlands. A handbook and GIS datasets provide mapping data, land-use planning methods, habitat conservation recommendations, and case studies for conservation of priority wildlife habitats through local land use planning, policy-making, model ordinance language, and development design. Biologists provide technical assistance to local governments to encourage and support community conservation efforts. Information about the program is available online at https://www.ncwildlife.gov/wildlife-habitat/conservation-restoration-programs/green-growth-toolbox.

6.2.4.4 NC Gap Analysis Project (NC-GAP)

NC-GAP is the state-level representative of the National Gap Analysis Program sponsored by the Biological Resources Division of the US Geological Survey (USGS). The mission of the program is to conduct regional assessments of the conservation status of native terrestrial vertebrate species and natural land cover types, and to facilitate the application of this information to land management activities. The goal of the NC-GAP project is to assess the distribution and conservation status of biodiversity in the state under existing land ownership and management regimes. More information is available on the NC State University Biodiversity and Spatial Information Center website at http://www.gapserve.ncsu.edu.

Additionally, the NC-GAP Geo-Data Server was developed to provide access to species distribution, stewardship, and land cover data in an interactive map format. Data in Esri ArcInfo (www.esri.com) data format (grids and coverages) can be downloaded through the Geo-Data Download interface. All data can be viewed through the GAP Online Tool (http://www.gapserve.ncsu.edu/ncgap/ncgap/). Geo-data can be downloaded from the NCGAP website online at http://www.basic.ncsu.edu/ncgap/DataServer.html.

6.2.4.5 Data Basin

Data Basin is a science-based mapping and analysis platform that supports learning, research, and sustainable environmental stewardship. Datasets are spatial information, typically created using a GIS. Datasets contain local, regional, and global geospatial information. Biological, physical, and socioeconomic information also is available. A dataset could be coordinates where a bird species has been observed, boundaries of land managed in various ways, a thematic image of vegetation types, or the results of a model that shows changes in the habitat distribution of a species under different climate change scenarios. The web page is online at https://databasin.org.

The core of Data Basin is free and provides open access to thousands of scientifically grounded, biological, physical, and socioeconomic datasets. A large and continually growing body of datasets, including both raw data (e.g., monitoring data on temperature and precipitation, road networks) and analytical results (e.g., projected changes in suitability for a species or ecosystem, interpretations, or recommendations), is included.

6.2.4.6 Southeast Conservation Blueprint

The Southeast Conservation Blueprint (Blueprint) is a spatially explicit living plan that describes the places and actions needed to meet the shared conservation objectives of the Southeast Conservation Adaptation Strategy (SECAS) and partners in the face of future change. As a living plan, it can be updated to respond to future changes like urban growth, sea level rise (SLR), and climate change. More than 300 people from 85 organizations were actively involved in developing the current version of the Blueprint. The SECAS website is online at . https://secassoutheast.org/blueprint.html.

The Blueprint is accessed through a simple web-based interface that informs conservation decisions through exploration of data on priority areas, recommended actions, and landscape context. The interface is a map that identifies habitats of particular concern and prioritizes them using a hierarchical system. The map uses a color matrix to depict conservation priorities in a hierarchy of highest, high, and low priorities, and indicates which areas need further investigation to understand conservation needs. The web-based Blueprint map is hosted through Data Basin (see 6.1.3.5), which facilitates uploading digital files with spatial data or downloading maps that delineate particular areas of interest. The 2024 version of the Blueprint Explorer online map tool is available at https://apps.fws.gov/southeastblueprint.

6.2.4.7 USGS State Wildlife Action Plans

The US Geological Survey (USGS) provides national information about State Wildlife Action Plan (SWAP) publications data, and guidance. For example, the website provides a national database that compiles all the SGCN lists from 56 states, US territories, and districts, encompassing action plans spanning from 2005 to 2022. A list of SGCN data can also be downloaded for use in Microsoft Excel formats. The website is online at https://www.usgs.gov/search?keywords=State+Wildlife+Action+Plans.

6.3 Conservation Opportunities and Incentives

Successful wildlife habitat conservation ultimately involves effective partnerships forged among private landowners, public land managers, local governments, developers, and transportation and development planners. Strong partnerships among agencies, organizations, academics, and industries are critical to implementing these strategies and actions, both statewide and in regional settings. Examples of objectives, strategies, and priority actions to achieve the goals outlined in this chapter are provided for these measures.

The conservation issues, strategies, and actions discussed in this section represent only a fraction of North Carolina's conservation needs and are intended to be a starting point for discussions about how best to accomplish wildlife and habitat conservation in the state.

6.3.1 Private Lands and Conservation Incentives

Conservation programs can seem complex. Private landowners can be unaware of programs for which they are qualified, and lacking information about administrators of such programs. From a programming standpoint, private land programs need to be more streamlined, better coordinated, and more effectively presented to the public. Key agencies and organizations involved in private lands programming in North Carolina should strive for better program coordination, with the goal of providing clear and consistent leadership on options and benefits to landowners.

Conservation programs, incentives, and partnerships should be utilized to the fullest extent to preserve high-quality resources and protect important natural communities. Landowners should be introduced to available cost-share programs (e.g., Farm Bill programs) and habitat improvement advice (e.g., Forest Stewardship Program, Forest Landbird Legacy Program) that fit their needs. The NC Forest Service (NCFS) and NCWRC provide technical guidance to assist private landowners with sustainable management of the natural resources on their property.

It is recommended that priority wildlife habitat management on private lands implement silvicultural management practices at appropriate locations to enhance ground forb and grass understory development; provide regeneration and habitat for disturbance-dependent species or early successional species; and enhance mature forest conditions in young to middle-aged pure stands. Quality early successional habitats should be developed and maintained through a combination of management strategies and appropriate practices (including prescribed burning, timber harvest, grazing, herbicide use, or other practices) on both public and private lands.

6.3.1.1 Strategies and Recommendations

The following strategies and recommended actions highlight land conservation and management considerations with a goal of conserving wildlife of conservation concern, improving hunting and fishing opportunities for all regions of the state, and improving wildlife habitat in general. These strategies can be implemented through partnerships with private landowners and should be incorporated where appropriate in management of public lands.

- Introduce private landowners to available programs that fit their needs, such as cost-share programs (e.g., Farm Bill programs) and technical guidance on habitat improvement (e.g., Forest Stewardship Program, Forest Landbird Legacy Program).
- Inform landowners about Present Use Value Programs to encourage the maintenance of working lands.
- Ensure that priority wildlife habitats are ranked appropriately in Farm Bill Incentive Programs.
- Incorporate forest habitat management that benefits priority wildlife species in Forest Stewardship Plans.
- Ensure that partners implementing CREP have access to up-to-date data and maps of priority riparian and wildlife conservation areas.
- Use agriculture cost-share programs to target protection of priority watersheds. See Chapter 4 Habitats, Section 4.5 River Basins for maps of priority watersheds. .
- Assist conservation partners (including land trusts) with purchasing or acquiring easements on land with priority habitats. Rural lands around urbanizing areas is a critical priority.
- Develop large-scale incentive programs designed to improve wildlife stewardship by corporate landowners. Include measures that support prescribed burning on private and corporate timber lands.

6.3.1.2 Incentives and Programs

Cost-share and tax incentive programs can reduce tax rates and the cost of establishing new conservation practices for private landowners, thereby encouraging them to implement better habitat and natural resource management on their lands. Examples that can benefit private landowners include the following North Carolina and federal agency programs.

Wildlife Land Conservation Program (WLCP) is a NCWRC program that allows private landowners who have owned their property for at least five years and want to manage for protected wildlife species or priority wildlife habitats to apply for a reduced property tax assessment. A site visit by NCWRC is made to verify that the landowner has at least 20 acres of defined priority wildlife habitat. The legal framework for the program can be found in NC G.S. Section 105-277.15. These lands are assessed by the county in which they are located at a reduced value and landowners participating in WCLP can apply to their county tax office for a property tax deferment. Other present-use tax reduction programs exist in North Carolina for private lands actively managed for forestry or agriculture; however, benefits cannot be combined from multiple programs. More information is available online at https://www.ncwildlife.gov/wildlife-habitat/private-lands-management/wildlife-conservation-land-program.

NC Forest Service (NCFS) offers forest and tree conservation technical assistance and incentives for landowners. A forest management plan approved by a representative of NCFS is required. NCFS Forester also utilizes all of the forestry programs and incentives outlined in this chapter. There are different qualification standards for different forest types.

- The NC Forestry and Agriculture Present-Use Value Program can reduce property taxes for qualifying farm and forest landowners. See the NCFS web page, Managing Your Forest, for detailed program information. Available online at https://www.ncagr.gov/divisions/nc-forest-service/managing-your-forest/puv.

- The NC Forest Stewardship Program provides technical assistance to enhance wildlife habitat management on private forest lands. Information about the program is available online at https://www.ncagr.gov/divisions/nc-forest-service/managing-your-forest/forest-stewardship.

- The NC Forest Development Program is a reforestation, afforestation, and forest stand improvement cost-sharing program run by NCFS. The goals of the program focus on timber production and the creation of the benefits associated with active forest management. Information is available online at https://www.ncagr.gov/divisions/nc-forest-service/managing-your-forest/fdp.

Farm Bill programs, administered by the USDA Natural Resources Conservation Service, offer many conservation incentive cost-share funds. These programs are subject to change depending on modifications to the Farm Bill. There are numerous programs that improve management of wildlife habitat and water quality for lands in agricultural and forestry production. The USDA website is available at https://www.usda.gov/farming-and-ranching/farm-bill.

The USDA's Conservation Reserve Enhancement Program (CREP) and the NC Department of Agriculture and Consumer Services's (NCDACS) Agriculture Cost-Share Program (ACSP). These programs are joint efforts among state and federal agencies administered by the NC Division of Soil and Water Conservation to address water quality problems. They are voluntary programs that seek to protect land currently in agricultural production along watercourses. Details about the CREP program can be found online at https://www.fsa.usda.gov/resources/programs/conservation-reserve-enhancement-program-crep.

The USFWS Safe Harbor and Candidate Conservation Agreements are voluntary agreements between USFWS and cooperating nonfederal (private and government) landowners. They are designed to benefit federally endangered and threatened species by giving landowners assurances that at no future time would USFWS impose restrictions on their land as a result of conservation actions on their part. In other words, these agreements essentially relieve landowners of liability under the Endangered Species Act if conservation practices on their land attract and/or perpetuate federally listed species. To date, nearly 3 million acres of land have been enrolled in Safe Harbor Agreements, benefiting a variety of listed species. In North Carolina, Safe Harbor Program agreements have been used to benefit the endangered Red-cockaded Woodpecker. Information about Safe Harbor Agreements is available online at https://www.fws.gov/service/safe-harbor-agreements. Information about the Candidate Conservation Agreements is on the USFWS website at https://www.fws.gov/service/candidate-conservation-agreements.

Sustainable Forestry Initiative (SFI) is an independent collaboration of individuals and organizations that work together to improve forest management and promote responsible fiber sourcing. Certification of sustainable forest management can provide a tangible incentive to timber companies to improve their natural resource management practices. The SFI website is online at https://forests.org/buy-sfi.

Timber Investment Management Organizations (TIMOs) – Timber investments occupy a considerable landmass in our state. Conservation ethics should be integrated into the decision-making process of the parent financial organizations through working with TIMOs, or other appropriate contracting organizations, to influence TIMO land management practices to include considerations for wildlife and habitats. Information about this type of investment is available online at https://forestry.com/economic-impact/investment-opportunities/timber-investments-guide.

6.3.2 Public Land Stewardship

Public lands include state and federal lands as well as municipal and local government parks and open space. Maintaining natural public lands and natural open space within urban areas will help to make cities more livable and may reduce the pressure to develop rural farms and woodlands. There is overwhelming public endorsement of conserving the land along with documentation of associated economic benefits. According to the outdoor recreation industry, more than $3.3 billion is spent annually on wildlife-related recreation in our state.

There is a continuing need to protect corridors between conservation lands to provide sufficient connectivity that facilitates species movement and gene flow across the landscape. It is critical to provide corridors and protect connections in urban areas, especially in the Piedmont ecoregion where development and urbanized areas continue to expand.

6.3.2.1 State-owned Public Lands

North Carolina has more acreage of managed game lands than all states east of the Mississippi, with the exception of Florida and Michigan, both of which include lake and ocean frontage as managed land. Through cooperative agreements with federal and state agencies and private landowners, NCWRC manages over 2 million acres of land for conservation of fish and wildlife species and broad expanses of public recreational opportunities, especially public hunting, trapping, and fishing opportunities. Information about game lands managed by NCWRC is available online at https://www.ncwildlife.gov/wildlife-habitat/conservation-restoration-programs/game-lands-program,

NCWRC land conservation objectives include expanding existing game lands to connect them better with other wildlife conservation areas. This will improve connectivity of priority habitats and buffer natural communities from encroaching development and land uses that could limit use of prescribed fire as a conservation tool. Other objectives are to provide public hunting and fishing access and wildlife observation opportunities that benefit all regions of the state, and to preserve wildlife migration and movement corridors. More information about public hunting access can be found online at https://www.ncwildlife.gov/hunting/where-hunt-shoot. Where to fish information is available online at https://www.ncwildlife.gov/fishing/where-fish-north-carolina.

State game lands are managed using science-based practices and are critical to the preservation of endangered, threatened, and rare species. Currently, there are 64 game lands representing over 812,000 acres of state-owned land. There are another 40 game lands representing over 1.2 million acres owned by others (e.g., national forest and park lands, conservation easements) that are managed by NCWRC. Several game lands have management plans that implement conservation actions for the endangered, threatened, and rare species that occur in the landscape. Game land management plans can be downloaded from the NCWRC website online at https://www.ncwildlife.gov/hunting/where-hunt-shoot/game-land-management-plans.

In the Coastal Plain ecoregion, Holly Shelter Game Land (Pender County) is home to 13 endangered, threatened, or rare species, including the federally endangered Red-cockaded

Woodpecker, Golden Sedge, and Rough-leaf Loosestrife, and several state listed species, including Carolina Gopher Frog, Cooley's Meadowrue, and Venus Flytrap. The Sandhills Game Land (Hoke, Moore, Richmond, Scotland counties) contains one of the largest and most intact remnants of Longleaf Pine ecosystems in the state and has several state and federal listed species such as Red-cockaded Woodpecker, Michaux's Sumac, Rough-leaf Loosestrife, and Sandhill's Lily.

Prescribed fire is a management tool used on game lands to maintain the understory of the Longleaf Pine and wet pine savanna communities essential for Red-cockaded Woodpeckers. Game lands include the largest intact and least disturbed bottomland forest ecosystem in the mid-Atlantic Region and some of the oldest Cypress-tupelo trees on the East Coast — many at least 800 years old. Other benefits include:

- One of the largest, most intact remnants of Longleaf Pine ecosystems in North Carolina, a high-priority wildlife habitat in the Lands Management program. Among the species dependent upon this type of habitat are Northern Bobwhite Quail, a variety of songbirds, Eastern Fox Squirrels and the federally endangered Red-cockaded Woodpecker;

- The densest populations of Black Bear, White-tailed Deer, and Turkey, and the highest density of nesting birds in the state. Most of our 32 Black Bear sanctuaries are on game lands;

- A system of floating waterfowl blinds, 19 public hunting blinds for disabled sportsmen, 32 public boating access areas, 33 public fishing areas, 6 wildlife observation platforms, and 4 public WRC shooting ranges with plans to build and manage more as opportunities occur; and some of the finest examples of multiple conservation collaborations in the country.

The NCFS manages the 10,400-acre DuPont State Recreational Forest in Henderson and Transylvania Counties. This forest also is found in the NCWRC game lands program. NCFS operates a system of six Educational State Forests (ESFs) designed to teach the public — especially school children — about forest environments. In some cases, forest restoration projects are used to promote the importance of the state's unique natural communities. For example, the Clemmons ESF (Johnston County) is restoring the original Longleaf Pine stands, which will eventually cover as much as 400 acres of the forest and benefit many species that rely on this type of habitat. Turnbull Creek (Bladen County) is located amongst natural Carolina bays and natural Longleaf Pine savannah habitat is being restored on the site.

North Carolina Division of Parks and Recreation (NCDPR), a part of NCDENR, works to conserve and protect representative examples of the natural beauty, ecological features, and recreational resources of statewide significance; to provide outdoor recreational opportunities in a safe and healthy environment; and to provide environmental education opportunities that promote stewardship of the state's natural heritage. Numerous state parks are notable for their natural resources:

- Grandfather Mountain State Park in the Mountain ecoregion is home to 70 known rare and endangered species and 16 distinct natural communities.
- Eno River State Park in the Piedmont ecoregion is home to several state and federally protected species. The park is a scenic wilderness corridor encompassing 14 miles of river, and featuring multiple cultural history sites.
- The Longleaf Pine forests of Weymouth Woods Sandhills Nature Preserve in the Sandhills ecoregion are home to rare and endangered species including the Red-cockaded Woodpecker and Pine Barrens Tree Frog.
- Lake Waccamaw State Park in the Coastal Plain ecoregion features one of the largest natural Carolina bays in the state where it is home to several unique plants and animals — some of which exist only at this location.

6.3.2.2 Federally Owned Public Lands

USFWS manages the National Wildlife Refuge System, a national network of lands and waters for the conservation, management, and where appropriate, restoration of fish, wildlife, and plant resources and their habitats. Managing these habitats is a complex process of controlling or eradicating invasive species, using fire in a prescribed manner, assuring adequate water resources, and assessing external threats such as development or contamination.

National wildlife refuges are home to more than 380 of the nation's 1,311 endangered or threatened species. So far, 11 of those species have been removed from the list due to their recovery, and conservation efforts have resulted in 17 others being downlisted from endangered to threatened status. More than 500 listed species are now stable or improving. Fifty-nine national wildlife refuges have been created specifically to help imperiled species. North Carolina has 11 national wildlife refuges, including one of the newest, Mountain Bogs National Wildlife Refuge.

USFS manages public lands in national forests and grasslands. North Carolina falls within the Southern Region of the Forest Service (Region 8). There are four National Forests in North Carolina: Croatan, Uwharrie, Nantahala, and Pisgah. Each has its own Land and Resource Management Plan (LRMP), a document that provides direction for the future management of the forest and its resources. Information is available on the USFS website at https://www.fs.usda.gov/managing-land. Information about National Forests in NC can be found online at https://www.fs.usda.gov/r08/northcarolina.

The National Park Service (NPS) manages several public lands scattered across the state. Cape Hatteras and Cape Lookout national seashores protect more coastal acreage, including beaches, maritime grasslands, and maritime forests, than do any other managed areas in the state. The Great Smoky Mountains National Park and the Blue Ridge Parkway protect several hundred thousand acres of mature forests in the Mountain ecoregion, including some of the best examples of spruce-fir forests. Information about NPS locations in NC is available online at https://www.nps.gov/state/nc/index.htm.

6.3.2.3 Municipal Parks and Open Space

The Statewide Comprehensive Outdoor Recreation Plan suggests a link between access to open space and the overall mental and physical health of nearby residents (NCDPR 2015). Many city and county parks in North Carolina have been developed with human recreation as the top priority, but opportunities also exist to improve habitat management and wildlife-related recreation and education on these public lands. An urban wildlife program can serve to maximize biodiversity within urban areas, build critical public support for conservation efforts, and assist in guiding development pressures to help ensure the conservation of species and habitats in presently rural areas. Technical guidance assistance is available from state and federal agency partners to help develop appropriate management options.

The Mecklenburg County Parks and Recreation Department is a prime example of a parks system that has made natural resources management a priority by conserving habitat integrity and educating the public by offering guided hikes and programs about the environment. It serves as a model for other parks and recreation programs that wish to better integrate natural resources management into traditional programming methods.

Recommendations for conservation and management of both private and public lands that will benefit fish and wildlife resources and their habitats and education and outreach opportunities that will connect natural resource agencies and organizations to the broader conservation community are provided in the next section.

6.3.2.4 Strategies and Recommendations

The following strategies and recommended actions highlight land stewardship strategies that can be implemented through partnerships with federal, state, and local government land owners and should be incorporated where appropriate in management of public lands.

- Improve management for wildlife on existing public lands through technical assistance programs. Many city and county parks in North Carolina have been developed with human recreation as the top priority, but opportunities also exist to improve habitat management and wildlife-related recreation and education on these public lands.

- Promote conservation of open space and coordinate with regional open space and land-use planning initiatives.

- Promote development and management of greenways as natural areas that are not landscaped and manicured, especially in urban areas. Studies suggest greenways between 100 and 300 meters wide (roughly between 330 and 985 feet) provide the best wildlife habitat and corridors for dispersal when maintained in native vegetation and adjacent to canopy cover (NCWRC 2012).

- Provide technical guidance that supports preserving intermediate canopy layers and understory vegetation to benefit wildlife species that utilize open space in urban settings. Wide trails that are frequently maintained to remove vegetation and canopy cover may disrupt sensitive species or habitats by creating breaks in the forest cover as well as introducing human intrusion.

- Protect and adequately buffer high priority habitats, especially riparian forests, floodplains, isolated wetlands, and sites with known sensitive or listed species occurrences located in urban settings or areas subject to development.

- Support stream restoration in priority watersheds and in areas with sensitive species or significant aquatic resources (e.g., trout waters).

6.3.3 Education and Outreach

Effective conservation can only be an integral feature of human society when it is a priority for most of its citizens. As North Carolina’s population centers become increasingly urban, there appears to be a growing disconnect between people and the outdoors, nature, and wildlife, which can lead to misconceptions, distrust, and fear. Education, outreach, and recreation opportunities are important tools to engage citizens in conservation and improve understanding of our wildlife resources among the general public and conservation stakeholders.

A goal of public education and outreach in urban and suburban areas is to increase awareness of and appreciation for wildlife-related issues in the urban landscape and to inspire people to take action toward protecting their local environment. Some citizens want to learn more about the impacts their homes and yards have on wildlife and how to create backyard oases for species. These programs can increase awareness of and appreciation for local wildlife species and habitats and create a connection between urbanites and nature. Local connections can be emphasized by promoting to the audience an awareness of where they live in their watershed and how their actions affect the world around them.

Limited funding, personnel, and resources are challenges when trying to meet education, outreach, and associated recreation needs, especially when there are more imminent needs associated with species and habitat protection. Some may view these types of activities as more expendable when balancing limited budgets and manpower. There is a critical link to be made between education, outreach, and recreation initiatives that can help address conservation problems.

Developing appropriate education and outreach efforts requires identifying different target audiences and understanding their respective attitudes and needs in the context of wildlife and natural community conservation. Human dimensions surveys should be used to collect information on attitudes toward wildlife and open space, conservation issues and management options. Further, human dimensions surveys need to identify actions that different audiences are willing to take or have their governments take on behalf of wildlife conservation. In light of the state's population growth and changing demographics, the perceived needs and desires of the public for wildlife education programs must be evaluated at regular intervals to ensure that needs are being met.

The Commission-published magazine, *Wildlife in North Carolina*, is an important outlet for information dissemination about fish and wildlife conservation projects and initiatives across the state. The WRC offers other publications such as a Wildlife Diversity newsletter, news releases, photos, species fact sheets, technical, conservation and management guides. Education and outreach needs specific to particular species groups (see Chapter 3 NC Species) or habitats (see Chapter 4 Habitats) are addressed within the appropriate natural community or river basin sections of this Plan. Other education and outreach information is available on the NCWRC website at https://www.ncwildlife.gov/education.

6.3.3.1 Public Education

Education, outreach, and recreation initiatives are components of successful wildlife conservation because they provide a way to connect natural resource agencies and organizations to citizens that comprise the broader conservation community. This community includes students and educators, public and private landowners, urban and rural residents, special interest and user groups (e.g., birders, hikers, paddlers, sportsmen and women), as well as local governments, corporations, and other natural resource stakeholders. State fish and wildlife agencies have a mandate to manage shared public wildlife resources for this broad constituency.

The NCWRC's Wildlife Education program provides publications and resources through which the general public and educators can learn about wildlife, natural history and outdoor skills. The NCWRC runs the John E. Pechmann Fishing Education Center in Fayetteville (NC) to provide family-oriented fishing experience and education. Distance learning opportunities and in-service training opportunities are regularly offered online; visit the Education information website at . https://www.ncwildlife.gov/education/classes-workshops-events.

Outdoor skill experiences that are hands-on, participatory training can increase a person's ability to enjoy and experience wildlife resources (e.g., orienteering, fly fishing, cooking game). Women who are interested in connecting with the outdoors can take advantage of the NCWRC's Outdoor Skills Academy. This program is designed for adventurous women aged 18 and up, as a hands-on experience that empowers you to explore, learn, and thrive in the great outdoors. Expert-led workshops in shooting, hunting, fishing, and conservation are designed to boost confidence and independence in nature. Information about the program is available online at https://www.ncwildlife.gov/education/outdoor-skills-academy.

Improved public education is critical to reducing human-induced threats and impacts to sensitive species and habitats. Humans have great influence and impact on sensitive environments such as coastal beaches, dunes, and estuarine habitats. Residential development in coastal areas can create impacts such as beach lighting and beach management practices (e.g., fencing, dredging, beach renourishment) that affect beach-nesting sea turtles and birds. Commercial and recreational activities such as boating and fishing (which can cause collisions, ghost line impacts, by-catch concerns) disturb and threaten coastal wildlife such as Diamondback Terrapins, sea turtles, and marine mammals. Education about human impacts on other sensitive environments such as isolated wetlands, bogs, caves and mines, and rock outcrops will be critical for the continued protection of these sites.

Prescribed burning is used as a forest management tool to reduce fuels and the risk of wildfire, and for ecosystem restoration, oak regeneration, understory control, and wildlife conservation. The importance of continued use and reintroduction of prescribed fire as a habitat management tool is critical to several natural communities. Public attitudes about fire have been greatly influenced by decades of Smokey Bear's effective fire prevention messages that emphasize the destructiveness of wildfire. Although anti-wildfire messages did not extend to prescribed burning, many people are unable to distinguish between "good" and "bad" fire (NCCES n.d.). Support for prescribed fire practices will require effective education and outreach to the communities and private landowners affected by this management practice.

6.3.3.2 Citizen Science Outreach

Citizen science projects help to involve the public in a hands-on way and create a sense of ownership and accomplishment among participants. Continued expansion of citizen science projects involving water quality monitoring, watershed restoration, wildlife conservation, and cleanup efforts are important in North Carolina. These efforts do a great deal to connect citizens to natural resources and water quality conservation and help them understand human impacts on these resources at the local level.

In the western part of the state, the Hiwassee River Watershed Coalition sponsors volunteer water quality monitoring programs and supports local watershed restoration work that protects water quality. In the densely urbanized central Piedmont, the Lake Norman Wildlife Conservationists (an NC Wildlife Federation partner) actively works toward protection and enhancement of wildlife habitats in the Lake Norman area.

Other programs provide citizens with the opportunity to contribute to the base of scientific knowledge about wildlife. The NCWRC supports citizen science initiatives by conducting outreach and training for certain programs.

- The NC Calling Amphibian Survey Program (CASP) is a volunteer-based monitoring program that is part of the NC Partners in Amphibian & Reptile Conservation program and is administered by NCWRC The CASP survey data contributes to information on the distribution and relative abundance of frogs and toads in North Carolina over time. This NC data will also be pooled with data from other states to investigate regional and national trends in frog distribution and changes in frog populations. Understanding these trends will provide us with a better understanding of the status and health of our frog and toad populations, and will enable us to protect critical habitats for our frog and toad species. Information about the CASP program is online at https://ncparc.org/casp.

- The National Audubon Society sponsors two annual citizen science bird count programs. The Christmas Bird Count (CBC) engages tens of thousands of birders in three weeks of organized group spotting events. The goal of CBC is to collect the most complete and accurate picture of bird populations across the world. This volunteer-driven citizen science event has been conducted for more than 100 years and is the most complete historic record of our bird populations over time. A second, less formal version is the Great Backyard Bird Count (GBBC) held each February while many birds are on their wintering grounds. Participants can count birds for as few as 15 minutes and record species they observe in the international eBird database. Information about these opportunities is available online at https://www.audubon.org/community-science.

- The NC Bird Atlas project is an online portal that collects systematic survey information from volunteers working statewide. The project is linked to eBird, one of the world's largest biodiversity-related science projects with bird sightings contributed annually by birdwatchers from around the world. Details about the NC Bird Atlas are available online at https://ebird.org/atlasnc/about/why-an-atlas.

During spring and fall migration, millions of birds pass through North Carolina, often flying at night. Because they are attracted to the lights of tall buildings, birds like the Wood Thrush are at risk of becoming fatigued and suffering window collisions. The Lights Out North Carolina initiative provides citizen science opportunities in Winston-Salem, Charlotte, and Raleigh that include monitoring for injured birds or working with local officials and building owners to turn off lights during peak migration times.

6.3.3.3 Connecting with Wildlife

Although promoting some outdoor activities, such as birding or canoeing, may not directly result in species delisting or reverse habitat loss trends, these types of activities can create strong supporters for broader conservation goals. These initiatives are often the only opportunity for members of an urbanized area to make a personal connection with the natural environment.

Some species have adapted to coexist with humans and even prosper in their presence while others need additional assistance as their natural habitat is altered. Loss of natural habitats can result in wildlife adapting to use human structures, such as Chimney Swifts roosting in smokestacks and chimneys, bats roosting in house attics, Barn Owls nesting in sheds and barns, or Purple Martins using hanging gourds for nests. Local populations can be impacted as man-made structures are removed or wildlife viewed by residents as a nuisance is removed.

Conservation organizations such as the Chimney Swift Conservation Association and Bat Conservation International encourage construction of artificial roost habitats. Other activities to benefit wildlife species using man-made and urban structures include preserving old chimneys for Chimney Swifts; identifying buildings used by Peregrine Falcons for nesting and foraging and protecting these areas from disturbance; identifying, enhancing and protecting structures used for bat roosts; and promoting installation of bird boxes of various sizes and shapes for Eastern Bluebirds, American Kestrels, Wood Ducks, Purple Martins, Barn Owls, and other cavity nesters.

Wildlife conservation in urban areas necessarily relates to managing human-wildlife interactions. Wildlife disturbance by people can cause wildlife to abandon habitats and is more common in developed and developing areas.

Nuisance wildlife problems can occur when wildlife is attracted to human dwellings for food or shelter, when wildlife populations are enhanced by the presence of humans, and when wildlife is displaced by human development. Wildlife species that can be compatible with human development include some bats, foxes, Raccoons, Opossums, squirrels, deer, pigeons, European Starlings, House Sparrows, Canada Geese, and Chimney Swifts, among others. Many wildlife damage problems can be addressed by changing the perceptions and expectations of homeowners with regard to living with wildlife.

Many human-wildlife conflicts can be addressed by changing the perceptions and expectations of homeowners who live with wildlife. Though most nuisance wildlife issues may not relate directly to a conservation concern (e.g., a listed species or an endangered habitat), our efforts to solve nuisance wildlife problems are critical to improving the perception of urban wildlife issues in general. The Commission has developed nuisance wildlife recommendations and guidelines on some issues (e.g., resident Canada Geese, Black Bear).

Nuisance guidelines developed by the US Department of Agriculture (Hygnstrom et al. 1994) are another key source of information used by Commission outreach specialists for wildlife damage-related inquiries. Certified damage control agent programs should be supported and periodic reevaluation of the methods used for the removal of sensitive or tracked species (such as bats and some snakes) may be necessary to ensure the most appropriate handling of these sensitive species.

Wild animals can be reservoirs or hosts for diseases that can be transmitted to humans and domestic animals, such as rabies, distemper, tuberculosis, and leprosy. When there is contact between humans, domestic animals, and wildlife, there will be more risk for transmission of some zoonotic diseases (Bosch et al. 2013; Sharma et al. 2013; Schrenzel 2012; Calver et al. 2011; Loughry et al. 2009; Infectious Disease News 2008). Outdoor pets are at increased risk of contracting diseases from infected wildlife. Public service announcements, wildlife and hunter education programs, and coordination with local public health agencies are important avenues for sharing information about safety practices and local pet vaccination programs.

The NCWRC, NCSU Cooperative Extension Service, USDA Wildlife Services, and county and local wildlife control officers all play a role in responding to wildlife damage problems (e.g., crop depredation, flooding). Continued coordination and improved sharing of resources among these entities will make response efforts more effective.

6.3.3.4 Strategies and Recommendations

There are many conservation, management, education, outreach, and recreation programs. Substantial progress has been made towards meeting many of the program priorities identified in the 2005 Plan (e.g., the Commission now has a wildlife education and nature centers in each region of the state). Still, some have not been fully realized to-date and where possible, priorities should be addressed within the context of other recommendations identified within this Plan. Continuing efforts should develop and foster partnerships that incorporate targeted conservation topics into existing programs. As unmet needs are identified, new projects should be developed and implemented through cooperative efforts. Emphasis should be on local programs, where individuals have the opportunity to have personal experiences that may foster greater appreciation and concern for local or regional conservation issues. Important needs for NCWRC and our partners include the following topics.

Wildlife Education Programs

- Develop and improve guides for construction/development of outdoor classrooms.
- Develop demonstration projects for wildlife education programs.

- Develop citizen education programs about impacts from homes on wildlife, coexisting with wildlife, and having a wildlife-friendly landscape.
- Work with developers, local government staff, and elected officials on ways to minimize impacts (e.g., impervious surface effects on stormwater drainage).
- Develop programs and involve the public through volunteer and citizen science opportunities.
- Works toward better coordination among biologists and educators to develop effective education and outreach materials for endangered/rare species and implement workshops that highlight high priority species, species groups, and habitats.
- Promote and expand cooperative projects between partners and other organizations with an aim to improve efficiency and effectiveness at reaching shared goals.

Wildlife Educational Materials

- Develop and distribute wildlife educational materials to public school systems.
- Develop public informational materials on wildlife species, management programs, and habitat conservation.
- Distribute educational materials about reducing homeowner impacts to natural communities.
- Incorporate education/outreach goals, priorities, and ideas from existing conservation plans, such as the North American Bat Conservation Partnership Strategic plan and the Partners in Flight Landbird Conservation Plan.

Engaging the Public

- Conduct human dimension surveys to understand attitudes toward wildlife better and to use information to develop appropriate education and outreach programs and materials for the public.
- Provide learning opportunities such as the ForestHer NC program which aims to support, educate, and empower a community of women landowners and natural resources professionals to engage in forest conservation and stewardship in North Carolina.
- Develop structures and stations for fish and wildlife viewing and photography.
- Use media relations to highlight conservation issues and success stories and make a local connection with the public through media outlets.
- Use agency websites, magazine and social media platforms to engage public directly on various conservation issues and success stories.
- Participate in and support citizen science and wildlife monitoring programs that offer hands-on opportunities to learn about wildlife while helping these programs accomplish their conservation objectives. Examples include the Box Turtle Project; statewide

amphibian calling surveys; Backyard Bird Survey, Christmas Bird Count, and other bird survey programs; Carolina Herp Atlas; and the Sea Turtle Stranding Network.

Connecting Recreation and Wildlife

- Develop and maintain access points (at piers, docks, etc.) to accommodate kayaks, canoes, and other paddle (non-motorized) boats accessing aquatic systems.
- Develop and maintain marked canoe trails along major streams and rivers.
- Support and assist with maintenance to the Mountain-to-Sea Trails and the Rails-to-Trails systems as well as connections to local greenway systems.
- Develop and maintain hiking trails on state-owned game lands and provide interpretive materials to educate users about local wildlife and conservation needs.
- Develop and maintain hiking trails and viewing sites associated with state-maintained campgrounds, picnicking areas, and visitor centers.
- Develop wildlife-related displays and educational materials at state-owned campgrounds, picnicking areas, and visitor centers.
- Produce wildlife-related educational programs at state-owned campgrounds, picnicking areas, and visitor centers.
- Develop and maintain Coastal, Piedmont, and Mountain Birding Trails development projects that support and promote the North Carolina Bird Trail initiative (www.ncbirdingtrail.org).
- Assist with the organization, promotion, and operation of local birding or wildlife festivals.
- Develop Birding Guides to North Carolina species and Birding Lists for significant public-owned properties.
- Establish demonstration areas for backyard wildlife habitat improvements and promote schoolyard habitat programs.
- Educate the public about human impacts on sensitive sites, such as isolated wetlands, bogs, caves and mines, and rock outcrops.

Education and Training Opportunities

- Support NC Division of Parks and Recreation educational opportunities provided through the Environmental Education Learning Experiences (EELE), which include workshops for educators and information for student activities.
- Support the Environmental Education Certification Program offered by the Office of Environmental Education. This program provides teacher guides, state curriculum guides, guides to environmental education centers around the state, and adult education programming.

- Support courses on plant identification, native plant propagation, and maintenance as well as wildlife identification, ecology, and habitat protection/creation. Examples include programs offered by the NC State University Cooperative Extension Service.

6.3.4 Technical Guidance, Rules, and Regulations

The availability of technical guidance can be a limiting factor, both in the amount of initial guidance available and in the ability to follow up on management efforts. There is a significant need for increased and targeted outreach and technical guidance to private landowners to help them understand the different types of assistance and management practices available and to encourage participation in conservation programs.

There is also a need for interagency cooperation to serve the needs of landowners better with multiple or varying objectives (e.g., for landowners wishing to manage their property for wildlife, wildlife biologists should be on hand to provide advice, in addition to foresters or agricultural extension agents). Protection measures that utilize existing regulatory frameworks to protect habitats and species should be incorporated where applicable.

Wildlife species that can adapt to human development (e.g., foxes, some bats, Raccoons, Opossums, squirrels, deer, Canada Geese, Chimney Swifts, some snakes, and small rodents) are often the source of human-wildlife conflicts. NCWRC has developed wildlife recommendations and guidelines on avoiding and controlling nuisance issues. Evaluation of the methods used for the removal of sensitive or tracked species (such as bats and some snakes) may be necessary to ensure the most appropriate handling of these species. Nuisance guidelines developed by USDA are a key source of information used by Commission outreach specialists handling wildlife damage-related inquiries (Hygnstrom et al. 1994).

Currently, North Carolina considers venomous reptiles, large constricting snakes, or crocodilians to be dangerous animals (see NCGS 14). Regulations require owners to have a written safety protocol and escape recovery plan that includes emergency contact information, identification of the local animal control office, and first aid procedures. Escapes must be reported to local law enforcement immediately. Specialized training is needed for law enforcement personnel, first responders, and animal handlers who may encounter dangerous or venomous animals as part of their work (e.g., animals that have escaped, are part of personal property seizures, or have been abandoned by the owners). Resources to support and coordinate emergency medical services, such as distribution and type of antivenom available, resources for exotic species identification, and facilities for temporary or long-term handling need to be identified and funded.

NCWRC offers free education programs for hunters and anglers that cover ethics and responsibilities as well as conservation and wildlife management information. Wildlife enforcement officials work with local law enforcement, federal and state agencies, wildlife biologists, and others to investigate and prosecute illegal activities. Illegal activities can range from hunting outside of season limits or taking a larger harvest than allowed by bag or creel limits; holding wild animals in captivity without permits; capturing wild animals without appropriate collection permits; harassing or harming protected species; or setting artificial lures or baits for animals and other unapproved harvest methods. Information about classes and workshops is available online at https://www.ncwildlife.gov/education/classes-workshops-events.

6.3.4.1 Strategies and Recommendations

Outreach. Target outreach and technical guidance to private landowners to help them understand the different types of assistance and management practices available, to get participants enrolled, to provide initial and ongoing management guidance.

- Work with key landowners and groups who are influential in their communities and are likely to influence participation by other landowners.
- Develop and offer incentives for corporate landowners to effect positive on-the-ground changes on the considerable corporate landholdings in the state.
- Coordinate with partner agencies that work with private landowners to increase awareness and interest in programs that benefit species and habitats on private lands.

Land Management. Identify resources and take action when appropriate to implement programs that control, suppress or eradicate invasive species threats. Facilitate conservation of large, contiguous tracts of land under multiple ownerships as a means to conserve wildlife and habitat on a landscape scale.

- Continue to coordinate placement of dredge materials to benefit beach nesting birds, foraging shorebirds, and sea turtles.
- Increase the number and availability of private contractors available to conduct prescribed burns on private and corporate lands.
- Highlight and support opportunities for ongoing land management and restoration efforts on protected lands through coordination, protection, management assistance programs, and stewardship funding.
- Provide information and implementation guidance about land management practices that effectively maintain suitable habitat for species.
- Assist in the planning, development, and management of greenways.
- Promote the use of native plants in landscaping, publicizing native plant nurseries and partnering with UNC Botanical Garden and North Carolina Exotic Pest Plant Council.

Development. Expand technical guidance to promote site design techniques that minimize impacts and maximize benefits to wildlife and habitat (e.g., development, roads, utilities).

- Ensure that Best Management Practices (BMPs) are robust enough to protect aquatic habitats and water quality.
- Encourage adoption of BMPs by landowners by demonstrating benefits and linking use with eligibility to other landowner assistance programs.
- Implement NCWRC recommendations to minimize cumulative and secondary impacts during initial site design and environmental review process (NCWRC (2002, 2012).
- Encourage local government ordinances to streamline the environmental review process through reduction of development impacts.
- Support the EPA's Low Impact Development approaches (US EPA 2002).
- Use the Green Growth Toolbox Program to encourage higher density development within existing urban boundaries and around existing infrastructure; discouraged development on urban fringes and in high diversity or ecologically sensitive areas.
- Work with home builders and developers to adopt voluntary conservation guidelines; promote the principles of "conservation design" outlined in the Green Growth Toolbox and Wildlife Friendly Development Certification programs.

Rules and Regulations. Coordinate with partners to develop policies and programs that address the presence and movement of nonnative and exotic invasive species. Work with local municipalities (commissions, planning boards, and other government entities) to promote ordinances that protect natural resources and improve water quality.

- Continue coordination with regulatory agencies that enforce wetlands regulations, Migratory Bird Treaty Act, and the Endangered Species Act.
- Support and encourage public comment to local officials or commissioners to voice their opinions on natural resources issues.

6.3.5 Partnerships and Cooperative Efforts

Partnerships and cooperative efforts among natural resource agencies, organizations, academia, private industry, and landowners that focus on common goals and objectives are key to reducing redundant efforts. These partnerships provide the basis for programs and projects that implement species, habitat, and ecosystem conservation and provide public recreation opportunities, preserve open space, protect water quality, and buffer military activities.

Sections 6.4 through 6.9 highlight federal and state agencies, organizations, and initiatives that are key partners for implementing the conservation goals of this Plan.

6.4 Federal Conservation Partners

The NCWRC works with several federal partners on important conservation measures to benefit both wildlife and their habitats. The information provided in this section about the federal partners and their programs is current as of early 2025. However, some agencies and programs are experiencing dynamic changes and loss of staff to the extent that some of the information provided in this section may be out of date before the end of 2025.

6.4.1 US Fish and Wildlife Service (USFWS)

The mission of USFWS is working with others to conserve, protect, and enhance fish, wildlife, plants, and their habitats for the continuing benefit of the American people. USFWS includes National Wildlife Refuges, National Fish Hatcheries, Law Enforcement, Ecological Services offices, and Migratory Birds offices.

In North Carolina, there are two Ecological Services offices that oversee listing and recovery of federally endangered and threatened species in the state.

- The Asheville Ecological Services field office serves western NC and southern Appalachia (https://www.fws.gov/office/asheville-ecological-services).

- The Eastern NC Ecological Services office serves the Piedmont, Sandhills, and Coastal Plain ecoregions with an office located in Raleigh and a suboffice in Manteo (https://www.fws.gov/office/eastern-north-carolina-ecological-services). They also provide fish and wildlife expertise to large-scale planning efforts in the areas of energy, transportation, and water and coastal development.

The National Coastal Program is one of the USFWS's most effective resources for restoring and protecting fish and wildlife habitat on public and privately-owned lands. The North Carolina Coastal Program works with willing partners to restore and conserve coastal waters and wetlands.

There are 11 wildlife refuges across the state, each with Comprehensive Conservation Plans. These refuges are Alligator River, Cedar Island, Currituck, Mackay Island, Mattamuskeet, Mountain Bogs, Pea Island, Pee Dee, Pocosin Lakes, Roanoke River, and Swanquarter.

USFWS faces the greatest challenges to fish and wildlife conservation in its history: the Earth's climate is changing at an accelerating rate that has the potential to cause abrupt changes in ecosystems and contribute to widespread species extinctions. In response, the USFWS's Climate Change program (https://www.fws.gov/climate-change)was developed as a blueprint for action in a time of uncertainty. It calls for the agency and the larger conservation community to employ adaptation, mitigation, and engagement to conserve our nation's fish and wildlife resources in the years to come.

6.4.2 US Forest Service (USFS)

USFS, an agency within USDA, manages public lands in national forests and grasslands. The mission of USFS is to sustain the health, diversity, and productivity of the nation's forests and grasslands to meet the needs of present and future generations. There are nine geographical regions and North Carolina falls within USFS Southern Region 8. There are four national forests in North Carolina, the Nantahala, Pisgah, Croatan, and Uwharrie National Forests. Together they provide 1.25 million acres of public lands from the mountains and the coast.

Each National Forest has a Land Management Plan, commonly referred to as a forest plan. The forest plan provides strategic direction for the forest and guidance for project and activity-level decision making. The plan describes desired ecological, social, and economic conditions of the forest and provides constraints that focus management activities toward maintaining or achieving those conditions over time. Each forest plan also includes a plan monitoring program to evaluate whether the plan is being implemented properly, whether it is effective at guiding management toward long-term outcomes, or whether changes need to be made.

- The Forest Service released the final revised Nantahala Pisgah Forest Plan (R8-MB-160) in January 2023. This Plan will guide future management of the national forests in western North Carolina.

- The Croatan National Forest Plan was published in 2002 and since then the USFS adopted a new planning rule that requires the forest monitoring program to meet new monitoring requirements and transition the forest to a biennial monitoring report, with a first report due in 2018.

- The Uwharrie National Forest Land and Resource Management Plan (R8-MB 140A) was published in May 2012.

- A Biennial Monitoring Evaluation report for the Uwharrie and Croatan National Forests was published in September 2020.

The Land Management Plans and biennial monitoring reports for each National Forest in the state is available online at https://www.fs.usda.gov/r08/northcarolina/planning.

The Southern Region 8 identifies non-native invasive plant species as a critical threat to national ecosystems. A regional goal is to reduce, minimize, or eliminate the potential for the introduction, establishment, spread, and impact of non-native invasive species across all landscapes and ownerships. To achieve this goal the region has developed the Southern Region

Framework for Non-Native Invasive Species. To address the problem, the USFS developed a National Strategy and Implementation Plan for Invasive Species Management (FS-805) that addresses prevention, early detection and rapid response, control and management, and rehabilitation and restoration. The strategy document is available online at https://www.fs.usda.gov/invasivespecies/documents/Final_National_Strategy_100804.pdf.

6.4.3 National Park Service (NPS)

The National Park Service (NPS) is a bureau within US DOI. As of 2012, NPS managed 12 sites in North Carolina: Appalachian National Scenic Trail, Blue Ridge Parkway, Cape Hatteras National Seashore, Cape Lookout National Seashore, Carl Sandburg Home National Historic Site, Fort Raleigh National Historic Site, Great Smoky Mountains National Park, Guilford Courthouse National Military Park, Moores Creek National Battlefield, Overmountain Victory National Historic Trail, Trail of Tears National Historic Trail, and Wright Brothers National Memorial.

The mission of NPS is to preserve, unimpaired, the natural and cultural resources and values of the national park system for the enjoyment, education, and inspiration of this and future generations. NPS cooperates with partners to extend the benefits of natural and cultural resource conservation and outdoor recreation throughout this country and the world.

6.4.4 Natural Resources Conservation Service (NRCS)

The NRCS is an agency within USDA that provides assistance to land users for developing and implementing conservation plans on their lands. To complete its mission, NRCS offers a variety of incentives-based programming aimed at species and habitat conservation, including the Longleaf Pine Initiative and Farm Bill programs like the Wetlands Reserve Program, Wildlife Habitat Incentives Program, and Conservation Reserve Program, among others (NRCS 2013). This information is available online at https://www.nrcs.usda.gov/programs-initiatives.

The National Resources Inventory (NRI), a nationwide survey conducted annually by NRCS, is the federal government's principal source of information on the status, condition, and trends of soil, water, and related resources in the United States. The NRCS conservation priorities in North Carolina are highlighted below and information about programs and resources that support these priorities is available online at https://www.nrcs.usda.gov/nri.

- Provide leadership in a partnership effort to conserve, maintain, and improve our natural resources and environment.
- Provide conservation planning and technical consultation about natural resource management.
- Support conservation implementation through installation of conservation practices and systems that meet established technical standards and specifications.

- Conduct natural resource inventories and assessments by collecting, analyzing, and providing natural resource data.
- Develop and distribute a wide array of technology pertaining to resource assessment, conservation planning, and conservation system installation and evaluation.
- Provide financial assistance to encourage the adoption of beneficial land-treatment practices that conserve and protect our nation’s valuable natural resources.

6.4.5 National Oceanic and Atmospheric Administration (NOAA) Fisheries

The National Oceanic and Atmospheric Administration (NOAA) Fisheries unit (formerly known as the National Marine Fisheries Service) is the federal agency responsible for the stewardship of the nation’s living marine resources and their habitat. NOAA Fisheries is responsible for the management, conservation, and protection of living marine resources within the United States’ Exclusive Economic Zone (waters 3 to 200 miles offshore). North Carolina is part of the Southeast Region, which operates a research lab in Beaufort.

NOAA Fisheries works to promote sustainable fisheries and to prevent lost economic potential associated with overfishing, declining species, and degraded habitats. NOAA Fisheries strives to balance competing public needs and interest in the use and enjoyment of our oceans’ resources. Using the tools provided by the Magnuson-Stevens Act, NOAA Fisheries assesses and predicts the status of fish stocks, ensures compliance with fisheries regulations and works to reduce wasteful fishing practices. Under the Marine Mammal Protection Act and the Endangered Species Act, NOAA Fisheries recovers protected marine species (e.g., whales, sea turtles) without unnecessarily impeding economic and recreational opportunities.

NOAA Fisheries research and conservation priorities in North Carolina are carried out by the Southeast Fisheries Science Center facility in Beaufort. The programs highlighted below represent work they focus on. Information about their programs and resources that support these priorities is available online at https://www.fisheries.noaa.gov/about/southeast-fisheries-science-center.

- Collect and analyze data describing the individual and population biology of living marine resources, with emphasis on exploited fish species (e.g., snappers and groupers), coral reefs (e.g., fish spawning aggregations), and protected resources (e.g., marine mammals and sea turtles).
- Conduct research to understand the structure and function of the southeast US continental shelf large marine ecosystem.
- Assess fish stocks, primarily in the Atlantic.
- Work to understand fisheries’ ecosystems, primarily in the Atlantic.
- Assess population and health of sea turtles and dolphins, primarily in the Atlantic.
- Conduct aging of reef fishes.

- Collect data and samples and conduct assessments with commercial menhaden fisheries and recreational headboat fisheries in the Atlantic and Gulf of Mexico.

6.4.6 US Environmental Protection Agency (USEPA)

North Carolina is part of USEPA Region 4, which encompasses eight southeastern states and six federally recognized Native American tribes. The mission of USEPA is to protect human health and the environment and is accomplished through activities such as regulations, grant funding, research, and partnerships. More information is available online at https://www.epa.gov/aboutepa/about-epa-region-4-southeast.

USEPA Region 4 is committed to operating an effective Environmental Management System (EMS, https://www.epa.gov/ems) as part of an integrated framework for sustainable environmental stewardship. An EMS is a continual cycle of planning, implementing, reviewing, and improving the processes and actions that an organization undertakes to meet its operational and environmental goals. It is a set of processes and practices that enable an organization to reduce its environmental impacts. This includes nonregulated environmental impacts like energy use, carbon dioxide emissions, and purchase and use of products that have less impact on the environment.

With an EMS, the organization’s environmental impacts become the responsibility of all employees and managers. EMS is integrated with EPA’s mission and is accomplished through setting targets for environmental stewardship, reducing or preventing pollution, and preserving environmental resources and enforcing environmental protection in conjunction with other governmental agencies. The USEPA initiatives in North Carolina are accomplished through the actions identified above. Key programs and resources that support conservation priorities are described throughout this Plan.

6.4.7 US Geological Survey (USGS)

As the sole science agency for DOI, USGS provides natural science expertise and shares earth and biological data holdings with partners and customers. It is the largest water, earth, and biological science and civilian mapping agency and is responsible for collecting, monitoring, analyzing, and providing scientific understanding about natural resource conditions, issues, and problems. The diversity of scientific expertise enables USGS to carry out large-scale, multidisciplinary investigations, and provide impartial scientific information to resource managers, planners, and other customers.

The mission of USGS includes providing reliable scientific information to describe and understand the Earth as well as managing water, biological, energy, and mineral resources. This mission is accomplished through various types of programs, partnerships, and cooperative agreements with other agencies and organizations.

- The USGS South Atlantic Water Science Center works cooperatively with other agencies and organizations to collect and interpret water-resource information in North Carolina. The hydrologic data collected through their network of 243 monitoring stations provides valuable data on stream flow (discharge, water height, depth to water level, water temperature). Information is online at https://www.usgs.gov/centers/sawsc/about.

- The NC Cooperative Fish and Wildlife Research Unit is jointly sponsored by USGS, NCWRC, NCSU, and the Wildlife Management Institute. The Cooperative Unit focuses on the identification, assessment, interpretation, and alleviation of the effects of current or potential environmental changes or perturbations on fish and wildlife resources. Information about the unit is available online at https://cals.ncsu.edu/applied-ecology/programs-centers/fish-wildlife-research-unit.

6.4.8 US Army Corps of Engineers (USACE) – Wilmington District

As the nation's environmental engineer, USACE (or Corps) manages one of the largest federal environmental missions: restoring degraded ecosystems; constructing sustainable facilities; regulating waterways; managing natural resources; and cleaning contaminated sites affected by past military activities. There are two main federal laws that grant the Corps with the authority to regulate the nation's waterways: Section 404 of the Clean Water Act (https://www.epa.gov/cwa-404/overview-clean-water-act-section-404) and Section 10 of the Rivers and Harbors Act of 1899 (https://www.epa.gov/cwa-404/section-10-rivers-and-harbors-appropriation-act-1899).

The Wilmington District (https://www.saw.usace.army.mil) is responsible for two deepwater ports and more than 300 miles of federal navigation projects along the Atlantic coast stretching from Norfolk, Virginia, to Little River, South Carolina; coastal storm damage reduction; water management and multi-purpose reservoirs; Section 404 and Section 10 regulatory permit programs for waters and wetlands in North Carolina; and ecosystem restoration programs, as well as other responsibilities. Materials from dredging projects are used to create and maintain dredge spoil islands that provide nesting and roosting habitat for shorebirds. Examples include South Pelican, Ferry Slip, Goat, and Bird islands.

The Wilmington District has four field offices (Wilmington, Washington, Raleigh, Asheville) and several district lake and dam facility offices located around the state. USACE works in partnership with other federal and state agencies, nongovernmental organizations (NGOs), and academic institutions to find innovative solutions to challenges such as sustainability, climate change, endangered species, environmental cleanup, ecosystem restoration, and more.

The mission of USACE is to deliver vital public and military engineering services, partner in peace and war to strengthen our nation's security, energize the economy, and reduce risks from disasters. Environmental Operating Principles were developed to ensure that the Corps' missions include totally integrated sustainable environmental practices and provide corporate direction to ensure responsibility for sustainable use, stewardship, and restoration of natural resources across the nation and through the international reach of its support missions.

6.4.9 Department of Defense (DOD)

The Department of Defense's (DOD) Natural Resources program supports the military's testing and training mission by protecting its biological resources. The NR program provides policy, guidance, and oversight for management of natural resources on approximately 28 million acres nationwide of military land, air, and water resources owned or operated by DOD. North Carolina DOD facilities include:

- Marine Corps Installation East (https://www.mcieast.marines.mil)
  - Marine Corps Base Camp Lejeune
  - Marine Corps Air Station Cherry Point
  - Marine Corps Air Station New River
- Fort Bragg Army Base (https://home.army.mil/bragg)
  - Pope Army Airfield
  - Camp Mackall Army training facility
- Seymour Johnson Air Force Base (https://www.seymourjohnson.af.mil)
- Sunny Point Military Ocean Terminal (https://www.sddc.army.mil/SitePages/MOTSU.aspx)
- Harvey Point Defense Testing Activity

The DOD's NR program's goal is to support the military's combat readiness mission by ensuring continued access to realistic habitat conditions, while simultaneously working to ensure the long-term sustainability of our nation's priceless natural heritage. The program implements several initiatives and management strategies to conserve and protect federally listed species, provide climate change tools and workshops, address invasive species, and conserve and protect pollinators found on military installations. The North Carolina Sandhills Conservation Partnership and the Onslow Bight Conservation Forum (described in Section 6.8) support NR Program conservation initiatives. Key DOD programs and resources that support conservation priorities described throughout this Plan are

6.5 State Conservation Partners

Since the 1800s, North Carolina has taken steps to protect the state's natural resources through science-based stewardship and management programs that address not only land and water quality issues but also agricultural and forestry functions. In addition to NCWRC efforts, the mission of NC Department of Environmental Quality (NCDEQ, https://www.deq.nc.gov), a cabinet level agency, is the lead stewardship agency for the protection of North Carolina's environmental resources. This mission is accomplished through collaboration among agency partners and stakeholders across the state and through legislation enacted by the NC General Assembly. Several divisions and organizational units within the NCDEQ organization focus on management and protection of various natural resources. Key programs for these units are highlighted in this section.

The NC Department of Agriculture and Consumer Services (NCDACS, https://www.ncagr.gov) is a cabinet level agency. NCDACS divisions have responsibilities in regulatory and service areas covering agronomy; animal health; crop and livestock statistics; USDA commodity distribution; state farm operations; research station operations; nursery and plant pest eradication activities; agricultural environmental issues; soil and water conservation; forest management and protection; and many other related topics. The agency's mission is to provide services that promote and improve agriculture, agribusiness and forests; protect consumers and businesses; and conserve farmland and natural resources for the prosperity of all North Carolinians. Key programs are highlighted in this section.

6.5.1 NC Wildlife Resources Commission (NCWRC)

The NCWRC (or Commission, https://www.ncwildlife.gov) is the state agency created by the General Assembly in 1947 to conserve and sustain the fish and wildlife resources of the state. The agency has a much broader responsibility than just the regulation of hunting, trapping, fishing, and the management of game lands. As a result, the Commission enforces other rules, conducts research, and collaborates with many other agencies and organizations on projects that include nongame wildlife. Nongame animals are defined in the General Statutes as all wild animals except game and fur-bearing animals (see Chapter 3 and Glossary for definitions).

The mission of NCWRC is to conserve, protect, manage, restore, and regulate the wildlife resources of the state. Toward this mission, Commission biologists conduct a variety of management and conservation activities, ranging from surveys and inventories to habitat management, to land acquisition. The agency is organized by divisions that are responsible for specific aspects of wildlife and habitat management and conservation.

- The Inland Fisheries Division oversees the state's inland (freshwater) and joint (coastal) fisheries, fish hatchery facilities, aquaculture propagation, boating and public fishing access. The division manages public mountain trout waters, a community fishing program, stocking sport fish, and the conservation efforts of aquatic nongame species. The division evaluates and develops fishery regulations Inland fishing waters are managed under the authority of the North Carolina Wildlife Resources Commission and include all inland waters except private ponds, and all waters connecting with or tributary to coastal sounds or the ocean extending inland from the dividing line between Coastal Fishing Waters and Inland Fishing Waters as agreed upon by the North Carolina Marine Fisheries Commission and the North Carolina Wildlife Resources Commission (see 15A NCAC 03Q .0102) (NCMEF 2025).

- The Wildlife Management Division oversees and manages the state's terrestrial game, nongame, and furbearer species. The division evaluates and develops hunting and trapping regulations through rule-making processes. Biologists develop, coordinate, and evaluate data collected through survey and research programs for all terrestrial species. They also implement the Wildlife Conservation Lands Program that helps landowners who enroll in this statewide property tax deferment program to manage their land for the benefit of wildlife. District biologists work regionally to provide technical assistance to private landowners as well a partners. The division also advises the public on coexisting with wildlife through several programs, including the national BearWise program, deer management assistance, beaver management assistance, and others.

- Biologists in the Habitat Conservation Division work to protect, manage, and conserve aquatic, wetland, and upland habitats for the benefit of fish and wildlife populations through technical guidance. The division's biologists assess impacts and provide recommendations to avoid or minimize those impacts through permit and environmental document review; provide technical guidance regarding habitat conservation to governmental and private agencies and to individuals; and encourage adequate mitigation for losses of fish, wildlife, their habitats, and uses thereof resulting from land and water developments. The Habitat Conservation Division is responsible for the Wildlife Action Plan, Green Growth Toolbox (see Section 6.2.4.3), and Wildlife Friendly Development Certification programs so users can implement conservation priorities an measures that reduce wildlife and natural resource impacts.

- The Law Enforcement Division provides proactive law enforcement that conserves wildlife resources and promotes safe and responsible boating, hunting, and trapping. They are the only state agency responsible for enforcing boating laws and regulations on the state's waters. Officers work cooperatively with other agencies and regulatory authorities to protect species statewide from poaching and persecution. The division also provides assistance through search and rescue efforts of citizens during natural disasters, boating accidents and missing persons, and other types of public safety support.

- A standing Nongame Wildlife Advisory Committee (NWAC) is a board established by the state legislature (General Statutes 113-335 and 113-336) and comprised of North Carolina citizens. The members are volunteers representing specific types of expertise or representing certain organizations. They provide advice to NCWRC on nongame wildlife conservation issues and are responsible for convening Scientific Councils of species experts to evaluate conservation status for species and recommend aquatic and terrestrial wildlife for state listing protection.

The Wildlife Friendly Development Certification was developed through collaboration between NCWRC, NCWF, and the NC chapter of the American Society of Landscape Architects, and was designed to recognize residential land developers who promote the conservation of wildlife habitat while using environmentally sound construction practices. The program benefits wildlife by protecting existing habitats onsite that provide food, water, cover, and places to raise young — the four components of suitable wildlife habitat.

In 2011, science-based recommendations for conservation of priority wildlife habitats were developed and published in the guide *Conservation Recommendations for Priority Terrestrial Wildlife Species and Habitats in North Carolina*. The recommendations were developed to assist local governments, developers, and other stakeholders in conserving and managing terrestrial wildlife habitats and species for future generations, particularly in North Carolina's urbanizing landscapes. The recommendations, if implemented, should increase the probability that these habitats will support most of the priority species associated with them. The priority habitats described in the document are wetland habitats, riparian and floodplain habitats, upland forests, early successional habitats, and rock outcrops, caves, and mines.

6.5.2 NC Museum of Natural Sciences (NCMNS)

The NC Museum of Natural Sciences (NCMNS) is a division within NC Department of Natural and Cultural Resources (NCDNCR). The mission of NCMNS is to enhance the public's understanding and appreciation of the environment in ways that emphasize the natural diversity of North Carolina and the southeastern United States and relate the region to the world as a whole. In support of this mission, the NCMNS scientific staff maintains the state's extensive natural sciences research collections, conducts primary research in the natural sciences, collaborates on research projects with area universities, state and federal agencies, and international organizations, and interprets natural history to the public through a variety of outreach initiatives and programs.

In addition to the paleontology and geology collections, zoological collections are maintained for terrestrial and aquatic invertebrates, crustaceans, fishes, amphibians, reptiles, birds, and mammals. These extensive Research Collections, and the data associated with them, are invaluable sources of information, are available to the larger scientific community for academic research and often serve to inform policy makers on environmental issues. NCMNS offers online access to certain collections on its website (https://naturalsciences.org/research-collections/collections).

6.5.3 NC Natural Heritage Program (NCNHP)

North Carolina's Natural Heritage Program (NCNHP), established in 1976, is a unit of the Office of Land and Water Stewardship within NCDNCR. Its mission is to provide the scientific knowledge and motivation for appropriate stewardship of the significant natural areas in North Carolina. The office is an integral part of the state's conservation efforts and seeks to maintain a positive relationship with communities through partnerships with local, state, and federal agencies, industries, organizations, and private citizens.

The NCNHP inventories, catalogues and facilitates protection of rare and outstanding elements of the natural diversity of North Carolina. These elements of natural diversity include plants and animals which are so rare, or natural communities which are so significant, that they merit special consideration as land-use decisions are made.

NCNHP is part of the NatureServe Network Program and follows methodology developed by The Nature Conservancy and shared by the Natural Heritage Network and NatureServe. By consolidating information about hundreds of rare species and natural communities, the program is able to ensure that the public is able to get the information needed to weigh the ecological significance of various sites, and to evaluate the likelihood and extent of ecological impacts resulting from land-use activities. This information supports informed evaluations of the trade-offs associated with biological diversity and development projects.

Finally, NCNHP data can be used to help set priorities for the protection of North Carolina's most important natural areas. The NCNHP information database is easily reached online and can be used to produce reports about rare species, high-quality natural communities, and areas managed for conservation. Written reports, including rare plant and animal lists, are also available from the NCNHP website (https://www.ncnhp.org).

6.5.4 NC Division of Marine Fisheries (NCDMF)

The NC Division of Marine Fisheries part of NCDEQ and is the state agency dedicated to ensuring sustainable marine and estuarine fisheries and habitats for the benefit and health of the people of North Carolina. The NCDMF jurisdiction encompasses all coastal waters and extends to 3 miles offshore. The NCWRC and NCDMF share joint jurisdiction over the waters where coastal and inland freshwaters converge as defined by legislative action (see 15A NCAC 03Q.0202).

Agency policies are established by the nine-member Marine Fisheries Commission (MFC) and the Secretary of NCDEQ. North Carolina is a member of the Atlantic States Marine Fisheries

Commission, the Mid-Atlantic Fishery Management Council, and the South Atlantic Fishery Management Council. Key components of the NCDMF mission include:

- Enforcing marine fisheries statutes and rules fairly and consistently,
- Ensuring healthy, sustainable marine and estuarine fisheries and habitats through management decisions based on sound data and objective analyses, and
- Monitoring and evaluating coastal waters for the safe harvest of molluscan shellfish and recreational uses to safeguard the public health of shellfish consumers and recreational bathers.
- Issuing coastal water advisories (e.g., swimming, shellfish harvest) based on water quality that exceeds health standards.

The NC General Assembly charged NCDEQ to develop, adopt, and implement plans and strategies to protect and restore fisheries habitats (see G.S. 143B-279.8). The plans are to be drafted by the agencies responsible for managing fisheries, water quality, and coastal management, with NCDMF as the lead agency for development of the plans. These strategies and supporting scientific background information are reported in the NC Coastal Habitat Protection Plan (CHPP), which is organized across six key estuarine and marine fisheries habitats. Each chapter includes a characterization of the habitat, its distribution, fish use, ecological benefits, status, trends, and threats, as well as management and research needs.

The CHPP is reviewed and approved by the CHPP Steering Committee, which consists of two members of the Environmental Management Commission, Coastal Resources Commission, and the various Marine Fisheries Councils. After the CHPP Steering Committee approves of the plan, each associated full commission has the opportunity to review and approve. The CHPP Steering Committee also meets regularly to enhance communication and discussion of cross-cutting and emerging coastal habitat issues, review the CHPP biennial implementation plans, and discuss progress on implementation actions. The plan was initially completed and then approved in late 2004 and 2010, respectively, and will continue to be updated in five-year cycles. NCWRC voluntarily joined as a participating commission in 2006 due to common issues regarding migrating fish species that utilize both coastal and inland waters.

6.5.5 NC Division of Coastal Management (NCDCM)

The NC Division of Coastal Management is part of NCDEQ and works to protect, conserve, and manage North Carolina’s coastal resources through an integrated program of planning, permitting, education, and research. North Carolina’s coastal zone includes 20 coastal counties that in whole or in part are adjacent to, adjoining, intersected, or bounded by the Atlantic Ocean or any coastal sound. NCDCM carries out the state’s Coastal Area Management Act (CAMA), the Dredge and Fill Law, and the federal Coastal Zone Management Act of 1972 in the 20 coastal counties using rules and policies established by the Coastal Resources Commission

(CRC). The NCDCM provides staffing services to the CRC, implements CRC rules and issues CAMA permits.

NCDCM is home to the NC Coastal Reserve (NCCR) and NC National Estuarine Research Reserve (NCNERR), a network of 10 protected sites established for long-term research, education, and stewardship. NCCR and NCNERR together protect more than 44,000 acres of estuarine land and water, which provide essential habitat for wildlife, offer educational opportunities, and serve as living laboratories for scientists. Information about these resources is available online at https://www.deq.nc.gov/about/divisions/coastal-management/nc-coastal-reserve.

While NCDCM is part of NCDEQ, it also works with the Office of Ocean and Coastal Resource Management (https://coast.noaa.gov/states/stories/?redirect=301ocm), part of NOAA. Additionally, NOAA administers the Federal Coastal and Estuarine Land Conservation Program (CELCP) that offers coastal states cost sharing for land conservation efforts, with the funds provided through an annual competitive process among eligible states. The NC Coastal and Estuarine Land Conservation Plan provides an assessment of priority conservation needs and guidance for nominating and selecting land conservation projects. More information is available on the NOAA website at https://coast.noaa.gov/czm/landconservation.

NCDCM is also responsible for several oversight and conservation programs, including permitting and enforcement, CAMA land-use planning, public beach and waterfront access, North Carolina Coastal Reserves, and Clean Marinas and Pump-out grants program. Staff of NCDCM also collect and analyze data for oceanfront erosion rates and recently completed an inventory of the state's entire estuarine shoreline.

In 2014 NCDCM published a Living Shorelines Strategy to advance alternatives to vertical erosion control structures to minimize erosion, improve water quality, and provide wildlife habitat (NCDCM 2014). The Coastal Nonpoint Pollution Control Program seeks to improve coordination between state coastal zone managers and water quality experts to reduce polluted runoff in the coastal zone. These are just a few of the several programs designed to protect and conserve North Carolina's coastal resources.

6.5.6 NC Division of Water Resources (NCDWR)

The North Carolina Division of Water Resources (NCDWR) is the state agency responsible for statewide regulatory programs in surface water and groundwater protection. The mission of NCDWR is implemented through water quality monitoring programs, efficient permitting, responsible management, fair and effective enforcement, and excellence in public service. NCDWR accomplishes these goals by collaborating with other agencies to develop appropriate management strategies, assuring equitable distribution of waste assimilative capacity, evaluating the cumulative effects of pollution, and improving public awareness and involvement.

NCDWR's planning group is responsible for producing an integrated basinwide water quality and water quantity plan, which is a nonregulatory, basin- and watershed-based approach to identifying, quantifying, restoring, and protecting North Carolina's water resources. Basinwide water resource plans are available for each of the 17 major river basins (https://www.eenorthcarolina.org/resources/river-basin-map-and-gis-resources) and are proposed to be presented in a dynamic online format.

Implementation of the plan protection and restoration recommendations requires the coordinated efforts of many agencies, local governments, and stakeholder groups in the state. These cooperative efforts help achieve the goals of basinwide planning, which are to:

- identify and quantify the state's water resources,
- evaluate the current, near-term (20 years into the future) and long-term (50 years into the future) basinwide water use needs,
- identify sites where ecological integrity for planning purposes may not be met,
- identify water quality problems and restore full use to impaired waters,
- identify and protect high value resource waters, and
- protect unimpaired waters while allowing for reasonable economic growth.

NCDWR is also responsible for monitoring aquatic toxicology through support of the USEPA National Pollutant Discharge Elimination System (NPDES) program; evaluating water quality of streams and rivers using the fish and benthic macroinvertebrate communities as a measure of environmental condition to assign bioclassifications to surface waters; and collecting and analyzing biological, chemical, and physical data from a variety of surface waters using a statewide network of sampling sites.

6.5.7 NC Division of Mitigation Services (NCDMS)

The mission of NC Division of Mitigation Services]is to restore, enhance, and protect the state's wetlands, streams, and streamside buffers, with an aim to improve the state's compensatory mitigation process for unavoidable impacts to wetlands and streams. NCDMS will identify and implement projects within the context of a watershed approach based on multiple scales of planning, provide functional replacement based on watershed needs through stream, buffer, and wetlands projects, and provide watershed planning and project implementation in advance of impacts.

The NC Watershed Restoration Plans are key to NCDMS efforts (https://www.deq.nc.gov/about/divisions/water-resources/water-planning/nonpoint-source-planning/319-grant-program/nc-watershed-restoration-plans).

6.5.8 NC Division of Energy, Mineral and Land Resources (NCDEMLR)

The NC Division of Energy, Mineral and Land promotes the wise use and protection of North Carolina's land and geologic resources. The division regulates and provides technical assistance related to mining, dams, sediment and erosion control and stormwater management. The Energy Section is responsible for oil and shale gas management, transportation, renewables, and the implementation of the State Energy Program and Weatherization Assistance Program. The NC Geological Survey is part of the Division and is responsible for performing scientific investigations, providing technical assistance and maps of the state’s geological resources. The Division as a whole supports public geoscience education.

6.5.9 NC Division of Parks and Recreation (NCDPR)

The North Carolina Division of Parks and Recreation (https://www.ncparks.gov) administers a diverse system of state parks, natural areas, trails, lake, natural and scenic rivers, and recreation areas. The Division also supports and assists other recreation providers by administering grant programs for park and trail projects, and by offering technical advice for park and trail planning and development. The Division administers the North Carolina Trails System, North Carolina Natural and Scenic Rivers, and the Parks and Recreation Trust Fund. The mission includes inspiring all citizens and visitors through conservation, recreation, and education.

The division's Natural Resources Program provides field staff, planning staff, and construction staff with technical expertise on issues such as resource stewardship, scientific research, environmental review and compliance, and landscape planning. The primary goal of natural resource management is to minimize human impacts on the natural environment and to ensure the long-term protection of state parks as intact, naturally evolving ecosystems.

The primary goal of cultural resource management is to protect and preserve historically significant features. The program is currently working with a number of agencies, universities and cooperative extension program to control exotic species in the state park system. Exotic species are seen as one of the greatest threats to rare species, high quality communities and biodiversity. Over the past several years the Natural Resources Program has been working with field staff to develop a natural resources database. The database is available online at auth1.dpr.ncparks.gov/nrid/public.php.

6.5.10 North Carolina Aquariums

The NC Aquariums were established in 1976 to promote an awareness, understanding, appreciation, and conservation of the diverse natural and cultural resources of North Carolina’s ocean, estuaries, rivers, streams, and other aquatic environments. They incorporate conservation into daily activities and long-term programs. This is also integral to maintaining accreditation with the Association of Zoos and Aquariums. Collections conservation ensures the health of our captive population. North Carolina has three aquariums: Roanoke Island, Pine Knoll Shores, and Fort Fisher.

The aquarium setting provides a unique opportunity for scientific research aimed at sustaining and restoring native aquatic animals, plants, and their habitats. Veterinary research is carried out in partnership with the NCSU College of Veterinary Medicine, our partner in caring for aquarium animals. Applied research projects are often done in coordination with research institutions.

6.5.11 NC Zoological Park (Zoo)

The NC Zoo is a 1,500-acre tract of land in the Uwharrie Mountains. Approximately 500 acres of this property have been developed into one of the largest “natural habitat” zoos in the United States. The Zoo’s conservation mission includes initiatives and programs to improve the quality of our environment and the health of our state and participation in international efforts to protect animal habitats and help people understand the value of wild animals and wild places. The Zoo is active in a number of regional initiatives to protect plants and wildlife in the central Piedmont, preserve the state’s resources, and minimize negative impacts throughout the southeastern United States.

The Valerie H. Schindler Wildlife Rehabilitation Center at the Zoological Park was established for the care and husbandry of injured and orphaned native wildlife, until they are ready for release back into the wild, as well as caring for education animals housed at the park.

6.5.12 Office of Environmental Education and Public Affairs

The Office of Environmental Education and Public Affairs (Environmental Education) was established in 1993 to balance NCDENR’s regulatory functions with a commitment to environmental literacy and environmental education outreach. The mission of the Office of Environmental Education is to encourage, support, and promote environmental education programs, facilities, and resources in North Carolina for the purpose of improving the public’s environmental literacy and stewardship of natural resources through planning, policy development, community involvement, innovative partnerships, and collaboration.

The Environmental Education section works to increase environmental literacy and natural resource stewardship in North Carolina by encouraging, promoting, and supporting environmental education programs, facilities, and resources throughout the state. It serves as the clearinghouse for all of the environmental education resources in the state. The office also manages a nationally recognized professional development program that certifies educators in environmental education. The NC Environmental Educator Certification Program provides enrollees with outdoor teaching skills, science and nature content knowledge, and environmental education methods.

Since 2005, the Office of Environmental Education has been a key partner in a 10-state consortium that has developed an interactive, web-based database that allows us to share resources and opportunities. This greatly increases the capacity for environmental education in North Carolina and allows sharing of grants, resources, and job opportunities with the people of the state.

6.5.13 NC Forest Service (NCFS)

The NC Forest Service (NCFS) is a division with NCDACS. The mission of NCFS is to protect, manage, and promote forest resources for the citizens of North Carolina. NCFS accomplishes its mission through management of existing resources, development and creation of new and better forests, and protection of these valuable resources. NCFS is directly involved with forest management assistance to private landowners, reforestation services, forest fire prevention and suppression, and insect- and disease-control programs.

The NCFS Forest Action Plan is a strategic plan that defines the goals and objectives that guide the agency’s efforts in meeting its mission. It is a complementary plan to the WAP. The NCFS is also involved in the operation of tree seedling nurseries, long-range forestry planning and technical development, water quality controls, urban forestry assistance, training and support to volunteer fire departments, and forestry education. The primary emphasis in conducting the programs under these objectives is directed at the 664,000 forest landowners who collectively own nearly 70% of more than 16 million acres of the state’s privately owned forest land.

6.5.14 Plant Conservation Program (PCP)

The mission of the NCDACS Plant Conservation Program (PCP) is to conserve the native plant species of North Carolina in their natural habitats, now and for future generations. To accomplish its mission, PCP develops regulations, voluntary programs, and cooperative partnerships to help protect imperiled species and their habitats. PCP’s responsibilities include maintaining the list of imperiled species and the development of conservation programs to protect these species permanently.

PCP’s conservation goal is to ensure protection of the two best populations of each of the more than 400 imperiled species where they naturally occur. To meet this goal, the program has determined that there are 134 of the best imperiled-plant locations (about 51,000 acres) in need of protection. An additional 120 locations (about 245,000 acres) are partially protected and/or lack appropriate conservation-oriented management. PCP employs a host of methods and procedures to perpetuate native plants and their ecosystems, including the acquisition and management of important plant sites and habitats. PCP works with various partners to identify the most important sites for protecting imperiled plant species and with local land trusts and landowners to protect these sites as Plant Conservation Preserves in perpetuity. The most significant funding source for these preserves has been the Natural Heritage Trust Fund (now part of the Clean Water Management Trust Fund, see Section 6.1).

PCP's regulatory activities involve administering the state's Ginseng (*Panax quinquefolius*) harvest monitoring system to comply with federal and international mandates related to the trade of this species. Other regulatory activities involve permitting actions affecting the listed imperiled species and investigating violations of relevant portions of the Plant Protection and Conservation Act. In addition to laws specific to ginseng, there are rules and regulations protecting the listed imperiled plant species. Staff at PCP issues permits for a variety of matters involving imperiled plants. Scholars, plant enthusiasts, and NCDOT have worked with PCP to minimize impacts of activities on imperiled plants.

6.5.15 Division of Soil and Water Conservation (S&WC)

A seven-member Soil and Water Conservation (S&WC) Commission provides oversight, rules, and policy for the state soil and water conservation programs. These programs are voluntary and emphasize a locally led approach to improving and protecting water quality and natural resources for a wide range of land uses. The S&WC mission is to foster voluntary, incentive-driven management of soil, water, and related natural resources for the benefit of the environment, economy, and all citizens. This division provides programs, technical services, and educational outreach promoting voluntary natural resource management and conservation on the private lands of the state through a nonregulatory, incentive-driven approach.

S&WC cooperates with federal and local partners to administer a comprehensive statewide program to protect and conserve the state's soil and water resources. It is recognized as having one of the nation's top soil and water conservation programs for private lands. This effort is achieved through a conservation partnership composed of the state division, local soil and water conservation districts, and NRCS, as well as private and nonprofit entities. Cost-share programs offer BMPs targeted to meet specific program goals to address agricultural, rural, and urban water resource issues.

6.5.16 Plant Industry Division, Apiary Program

The mission of the NC Department of Agriculture and Consumer Services Plant Industry Division is to ensure seed and fertilizer and other soil additives offered for sale in North Carolina meet prescribed standards and are truthfully labeled; to protect the state's agriculture and natural environment from introduced plant pests, including insects, diseases, and noxious weeds; and to enhance and protect the state's endangered and threatened plants. To meet this mission, the division regulates the movement of agricultural or related items capable of spreading harmful insects, diseases, and other pests.

The mission of the Apiary Program is to promote and protect the state's beekeeping industry. The Apiary Program provides disease and disorder inspections and fumigation services to control diseases and pests of the beekeeping industry. Additionally, the Apiary Program provides educational workshops to educate the state's beekeepers on the biology and treatment of mite and disease pests of honey bees and Africanized bees. The division works in partnership with the NCSU Apiculture Program to promote bee conservation by combating the spread of pathogens, mites, and other hive pests and to promote bee pollination services.

6.5.17 NC Department of Transportation (NCDOT)

NCDOT's mission is to connect people and places in North Carolina safely and efficiently, with accountability and environmental sensitivity. To fulfill this mission, NCDOT adopted an Environmental Stewardship Policy that calls for a safe and well-maintained transportation system that meets the needs of the traveling public and supports the development of sustainable, vibrant communities while striving to preserve and enhance the state's natural and cultural resources. NCDOT has the responsibility to comply with all rules and regulations described in the Sedimentation Pollution Control Act and all requirements stipulated in the program delegation from NCDENR.

The NC Board of Transportation, which has oversight of NCDOT, formed an Environmental Planning and Policy Committee (EPPC). NCDOT and EPPC are working to integrate environmental stewardship into decision making; engage the public and resource agencies early in the project-development process; build trust and effective working relationships; develop mutual goals related to transportation and the environment with local, state and federal partners; use context-sensitive design and maintenance strategies; and continually improve processes, among other initiatives.

It is the intent of NCDOT to forge more effective and efficient working relationships through partnerships with agencies and organizations. NCDOT and its partners strive to serve as a national model for interagency partnerships for environmental stewardship and streamlining.

6.6 Native Americans

Long before European explorers landed on North American shores there were Indigenous people who lived on North American land. They are the original stewards of the species, ecosystems, and landscapes. Their populations lived as both separate and intermingled communities or tribes and had their own cultures, languages, beliefs, social structure, and political ways of life. They are all independent nations with inherent powers for self-determination.

Common terms used to refer collectively to these sovereign nations and their members include American Indians, Indigenous Americans, First Nations, Indigenous Nations, Indian Tribes, Native Americans, Native Nations, or some combination. It is with respect we use the term Native Americans to collectively refer to all indigenous people and the term Indian Tribe to identify communities with shared cultural, social, or governance histories.

Whether Native Americans are members of an Indian Tribe recognized by federal or state governments or not, they are valued members of our communities and deserving of respect as individuals; every Tribal Nation is equally deserving of respect and autonomy.

6.6.1 Federal History and Indian Tribe Recognition

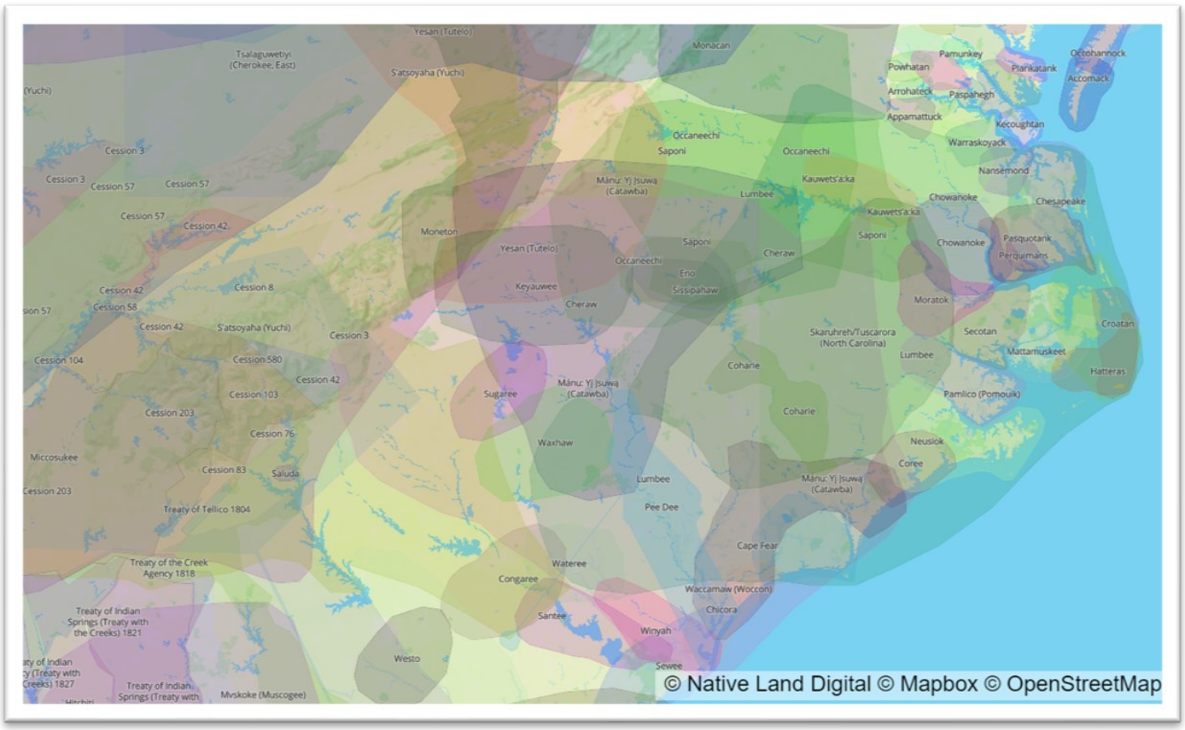
Indian Tribes have the sovereign power to govern themselves based on pre-existing sovereignty that has been recognized or acknowledged by treaties, statutes, executive orders, and U.S. Supreme Court decisions (USFWS 2011). The U.S. Department of the Interior, Bureau of Indian Affairs is the federal agency established to fulfill trust responsibilities to American Indian and Alaska Native tribes and individuals (USDOI 2025).

There is extensive history of the U.S. Federal government treatment and relationships with Native Americans. Much of that history is unpleasant and derogatory toward the Native Americans and their Sovereign Nations. National policy has been inconsistent or contradictory, either idealistic or less than altruistic (USFWS 2011). We recognize this as something that should not be forgotten.

American Indian lands are neither federal nor public lands (not part of the public domain) and are not subject to federal public land laws. The lands were retained by Indian Tribes or were set aside for tribal use pursuant to treaties, statutes, judicial decisions, or executive orders or agreements. These lands are managed by the tribes in accordance with tribal goals and objectives, within the framework of applicable laws. Many locations have remained untouched by conventional land-use practices and therefore are islands of high-quality ecosystems and retain many sensitive species (USFWS 2013).

This section acknowledges there are historic and Federal legislation that currently guides recognition and government-to-government relationships between Native Americans and the U.S. Federal government. The U.S. Federal government has officially recognized 567 American Indian tribes. Not all Indian Tribes historically living in the U.S. have been recognized by the U.S. government, however these non-recognized tribes may have state government recognition. The Eastern Band of Cherokee Indians (EBCI) are currently the only federally recognized tribe in North Carolina. Figure 6-1 represents an estimate of overlapping ancestral boundaries of Indian Tribe communities historically occurring in North Carolina (Native Land Digital 2024).

Figure 6-1. Ancestral Indian Tribe Territories in North Carolina (Native Land Digital 2024)**.**

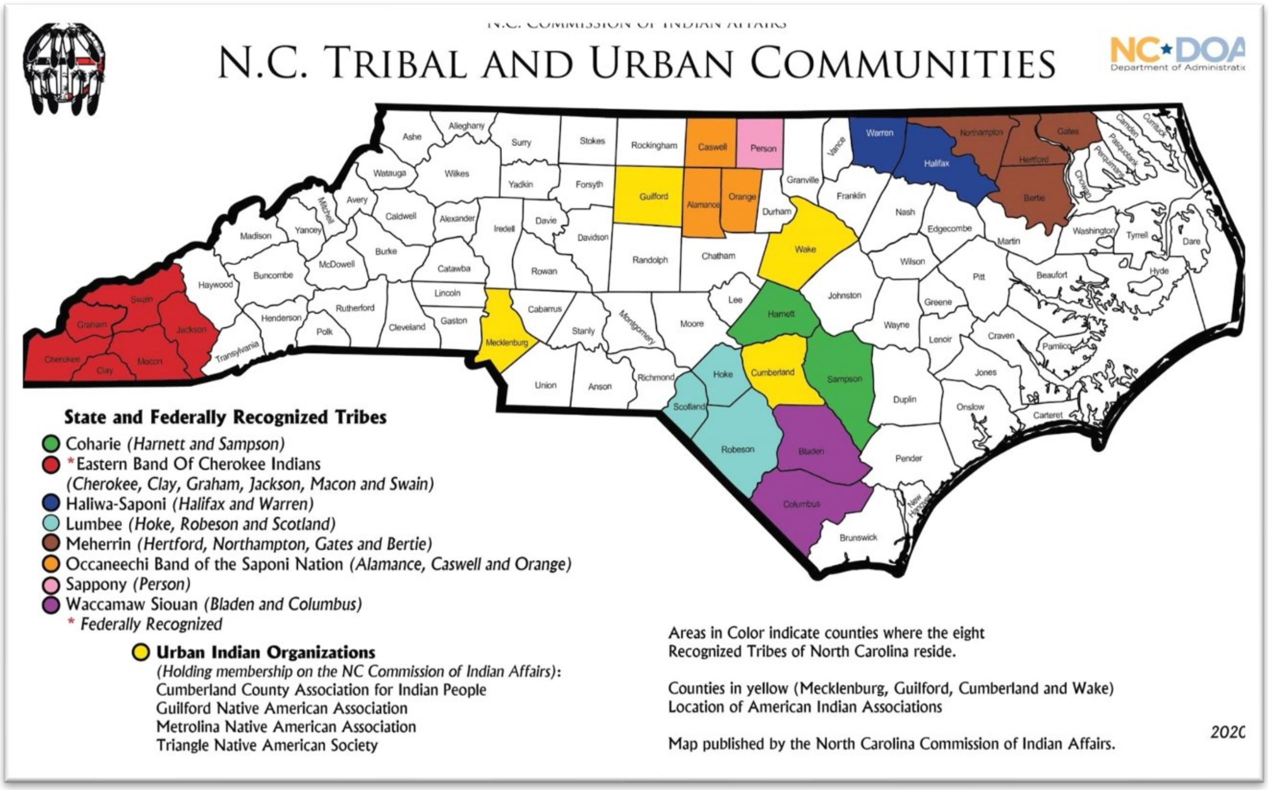


6.6.2 North Carolina's Indigenous People

The North Carolina Commission on Indian Affairs (NCCIA) was established in 1977 with a purpose of dealing fairly and effectively with American Indian affairs; bringing resources together for the benefit of the state's Indian citizens; providing aid, protection, and prevent undue hardships; providing social assistance and economic development assistance; promoting recognition of Indian rights to pursue cultural and religious traditions that are sacred and meaningful; and holding land in trust for the benefit of state recognized tribes (does not apply to federal recognized tribes). See NC General Statute Part 15 Sections 143B-404 to -411 and NC Administrative Code 01 NCAC 15 Sections .0200 to .0214. The NCCIA website https://www.doa.nc.gov/divisions/american-indian-affairs/map-nc-tribal-communities provides more information.

Figure 6-2 shows the current locale in North Carolina that represents the counties with state-recognized Tribal communities. This does not imply that individual members of any tribe live only in these areas; the map recognizes established communities where they have established centers of governance.

Figure 6-2. Recognized Indian Tribes in NC and Their General Community Locations (NCCIA 2020)



The federal Bureau of Indian Affairs (BIA), an agency within the US Department of the Interior, maintains a directory of federally recognized Tribes on their web page https://www.bia.gov/service/tribal-leaders-directory. In addition to federal-recognition of tribes, there are state-recognized Indian Tribes in North Carolina (see Table 6-1).

Table 6-1. NC Federal and State Recognized Tribes (NCCIA 2025)

Tribe	Tribal Center (City or Ancestral Location)	Counties
Coharie	Clinton	Harnett, Sampson
Eastern Band of Cherokee Indians	Cherokee (Qualla Boundary)	
Haliwa-Saponi	Hollister (The Meadows)	Halifax, Warren

Table 6-1. NC Federal and State Recognized Tribes (NCCIA 2025)

Tribe	Tribal Center (City or Ancestral Location)	Counties
Lumbee	Pembroke	Robeson
Meherrin	Ahoskie	Bertie, Gates, Hertford, Northampton
Occaneechi Band of the Saponi Nation	Mebane	Alamance, Orange
Sappony	Virgilina, VA (High Plains)	Person, Halifax (VA)
Waccamaw-Siouan	Bolton	Bladen, Columbus

6.6.2.1 Coharie Tribe

Headquartered in Clinton (NC), the Coharie Indian Tribe descends from the aboriginal Neusiok Indian Tribe on the Coharie River in Harnett and Sampson counties. The community consists of four settlements: Holly Grove, New Bethel, Shiloh and Antioch. The Coharie have over 3,000 members with about 20 percent residing outside the tribal communities. Early records indicate the tribe sought refuge from hostilities from both English colonists and Native peoples, moving to this area between 1729 and 1746 from the northern and northeastern part of the state. Since then, they have lived continuously around the Little Coharie River (NCCIA 2025, Coharie Tribe 2025).

The Great Coharie River is a significant source of subsistence and traditions for the Coharie people. The Great Coharie River Initiative began in 2015 as an effort by volunteer members from several tribes and non-tribal affiliated local residents to remove fallen trees, beaver dams, storm debris, and trash to restore and maintain free flow of a 13 mile stretch of the river (NCCIA 2025, Coharie Tribe 2025). The Coharie Tribe website is at https://coharietribe.org.

6.6.2.2 Eastern Band of Cherokee Indians

The Eastern Band of Cherokee Indians (EBCI) are a federally recognized Tribe in North Carolina. As noted in the EBCI Wildlife Action Plan (2022), "Cherokee aboriginal territory historically encompassed hundreds of thousands of square miles across eight southeastern U.S. states. Lands stretched from southern Appalachian mountaintops to productive Tennessee River valleys providing for a rich agricultural and subsistence lifestyle. The wide range of elevations, diverse landforms, mild temperatures, and abundant rainfall found on aboriginal Cherokee lands provided for diverse and productive aquatic and terrestrial habitats (Vick 2011).

The Cherokee people possess a long history of natural resource stewardship dating back thousands of years. Traditional management actions such as the use of fire to improve habitat, wildlife-friendly agricultural practices, and traditional hunting and fishing methods were implemented to improve natural resource conditions and sustain resources. The fish, wildlife, and plants found within this land base were intricately tied to cultural identity and the livelihood of the Cherokee people (EBCI 2013)."

In 1838 the United States government made the Cherokee people leave their homelands. The forced march of the Cherokee to Oklahoma became known as the Trail of Tears. A small group of Cherokee who were allowed to remain in the North Carolina mountains became the Eastern Band of Cherokee. EBCI's primary lands are known as the Qualla Boundary and is located on 56,000-acres adjacent to the Great Smoky Mountains National Park. The Qualla Boundary is not a reservation, but rather a land trust supervised by the US Bureau of Indian Affairs. EBCI also owns, holds, or maintains additional lands in the vicinity, and as far away as 100 miles from the Qualla Boundary. However, it is acknowledged this represents an extremely diminished land base in comparison to ancestral lands (NCCIA 2025, EBCI 2022).

As a federally recognized tribe the EBCI are eligible for federal matching grant funds provided through the Tribal and State Wildlife Grant Program (see Chapter 1). Conservation priorities are described in the EBCI Wildlife Action Plan (WAP) (2022), including definitions for cultural and ecological priorities and species-specific management priorities. The NC SWAP incorporates the priorities of the EBCI as documented in their WAP and Legacy documents (see Appendix 3 Reference 3-3). Information is available on the Tribe's web site at https://www.ebci.gov.

Comprehensive planning and implementation efforts to prevent species of greatest conservation need and species of significant cultural importance from becoming endangered are documented in the Tribal Wildlife Action Plan.The EBCI have established conservation targets based on Cherokee government approvals and natural resource codes and laws; Federal laws, regulations, and statutes that are applicable to Native American Trust lands; and guidance from the Cherokee community (elders advisory boards, hunters, Cherokee language). While all animals often possess multiple cultural values and uses, Cherokee Species of Concern (CSC) have primary and secondary cultural or ecological values, are essential and are designated using specific criteria outlined in the EBCI WAP.

Wildlife population and habitat surveys are conducted in support of a comprehensive Tribal Wildlife Management Program on the Qualla Boundary. The goal is to enhance habitat for a variety of wildlife, including migratory birds, Black Bear, Elk, and the native Southern Appalachian Brook Trout. Management and restoration activities are implemented for species of federal concern and of cultural importance to the Cherokee on their lands. Wildlife species of federal concern that occur within the Qualla Boundary include Indiana and Grey Bats and the Carolina Northern Flying Squirrel. The goal of these activities is to protect rare species and to implement habitat improvements identified in recovery plans and avoid high-priority habitat in tribal economic development planning (USFWS 2013).

6.6.2.3 Haliwa-Saponi Tribe

Members of the Haliwa-Saponi Tribe are direct descendants of the Saponi, Tuscarora, Tutelo, and Nansemond Indians and is the third largest tribe in North Carolina. Tribal members live primarily in the northeast Piedmont area traditionally known by their elders as “The Meadows.” This area encompasses most of the southwestern part of Halifax County and southeastern part of Warren County. Members also live in adjoining Franklin and Nash counties (NCCIA 2025, Haliwa Saponi Indian Tribe 2025). The tribe’s website is online at https://www.haliwa-saponi.org.

6.6.2.4 Lumbee Tribe

The ancestors of the Lumbee were mainly Cheraw and related Siouan-speaking Indians who were first observed in 1724 on the Drowning Creek (Lumbee River) in present-day Robeson County. In 1887, the state established the Croatan Normal Indian School, which is today the University of North Carolina at Pembroke (NCCIA 2025).

The Lumbee Tribe is the largest tribe in North Carolina, the largest tribe east of the Mississippi River and the ninth largest in the nation. The Lumbee Tribe takes their name from the Lumber River, originally known as the Lumbee, which winds its way through Robeson County (NCCIA 2025). More information is available from the tribe’s website at https://www.lumbeetribe.com.

6.6.2.5 Meherrin Tribe

According to the NCCIA (2025), “the Meherrin People, also known as Kauwets’a·ka (People of the Water), are an Iroquois Nation closely related to the Tuscarora, also known as Skarù·rę? (Hemp - Splitters), with whom they share a language, cultural ties, and a history of once being part of a people who long ago traveled East to the rising sun and took up residence in North Carolina. These people would go on to be known as Kahtehnuʔá·ka·ʔ (People of the Submerged Pine Tree), and it is from these people that the Nations of Kauwets’a·ka and Skarù·rę? would emerge.

In 1680 Meherrin Chiefs Ununtequero and Horehannah signed an Addendum to the 1677 Treaty of Middle Plantation, which established two reservations for the Meherrin: Kauwitzihocken (Cowinchawkon), and Menderink. Over time, the Meherrin relocated downstream to the Meherrin towns of Unote and Tawarra, and eventually settled in present-day Maneys Neck, formerly known as Meherrin Neck. In 1726, the North Carolina General Assembly assigned a reservation to the Meherrin, and in 1729, “An Act for the More Quiet Settling the Bounds of the Meherrin Indian Lands” expanded their reservation to include the confluence of the Chowan and Meherrin Rivers.”

The Merrin Indian Tribe website (https://meherrinnation.org) and the NCCIA website (2025) reports that the Meherrin Tribal members primarily reside in Hertford, Bertie, Northampton and Gates Counties, NC.

6.6.2.6 Occaneechi Band of Saponi Nation

The Occaneechi Band of the Saponi Nation (OBSN 2025) descend from several small Siouan speaking tribes who were living in the Piedmont of North Carolina and Virginia when the first European explorers arrived in the 1600s. The Occaneechi are a confederation of Saponi, Occaneechi, Eno, Tutelo, and Cheraw communities (OBSN 2025). The OBSN are the smallest of the officially state-recognized tribes, but its members are active in their community and in statewide Indian events.

Tribal members live primarily in Alamance, Caswell and Orange counties, with Tribal Grounds located in the Little Texas Community in Alamance County NC. The Tribe's website is online at http://www.obsn.org.

6.6.2.7 Sappony Tribe

The NCCIA (2025) notes that members of the Sappony Tribe (2023) have made the Piedmont Highlands their home for countless generations. The Sappony descend from seven main families, or clans - Coleman, Epps, Johnson, Martin, Shepherd, Stewart/Stuart and Talley. Historically, the town of Christie was the center of their traditional homelands known as the High Plains. Prior to European colonial contact the Sappony were living in five villages along the James River as the Indians of Monassukapanough, which became known as Sappony (Sappony 2023). The tribe's website has more information at https://www.sappony.org.

6.6.2.8 Waccamaw-Siouan Tribe

According to the Waccamaw Siouan Tribe website (https://waccamaw-siouan.org), the "first written mention of the Waccamaw Siouan Indians appeared in historical records of 1521 by the Spanish explorer, Captain Francisco Gordillo, while visiting the South Carolina coast." The Waccamaw were once known as the Waccommassus and are considered "People of the Fall Star."

The present day Waccamaw Siouan Tribal Office is located in Columbus and Bladen counties. The tribal homeland of the Waccamaw Siouan is situated on the edge of the Green swamp, about 37 miles west of Wilmington and 7 miles from Lake Waccamaw, NC.

6.6.3 Federal Resources

Native American Fish and Wildlife Society (NAFWS) is a national Native American non-profit organization that serves as an informative communication network between Tribal, federal, and state fish and wildlife management entities. NAFWS maintains a database of Tribal Natural Resource Departments staff.
https://www.nafws.org/

National Conference of State Legislature (NCSL) represents the legislatures in the states, territories and commonwealths of the United States. Its mission is to advance the effectiveness, independence and integrity of legislatures and to foster interstate cooperation and facilitate the exchange of information among legislatures. NCSL also represents legislatures in dealing with the federal government, especially in support of state sovereignty and state flexibility and protection from unfunded federal mandates and unwarranted federal preemption. The conference promotes cooperation between state legislatures in the U.S. and those in other countries. More legislatures are recognizing the benefits of having dedicated committees on Indian affairs or state-tribal relations.
https://www.ncsl.org/quad-caucus/state-committees-and-commissions-on-indian-affairs

6.6.4 State Resources

NC Commission on Indian Affairs (NCCIA) operates various programs to service the needs of NC American Indians. The Commission of Indian Affairs consists of 28 members: 21 representatives of the American Indian community, two representatives appointed by the General Assembly, and one representative or their designee appointed by the secretaries of DHHS, DOA, Commerce, DEQ & DOL each.
https://www.doa.nc.gov/divisions/american-indian-affairs.

Cumberland County Association for Indian People (CCAIP) was incorporated in 1973 to enhance the socioeconomic, legal, political, and cultural well-being of the Indian people of Cumberland County. Through various programs and initiatives, the organization aims to improve the lives of American Indians in the county. It may collaborate with other organizations and agencies to provide services and resources, and advocate for the rights and interests of the American Indian community. They have a web site at https://www.countyoffice.org/cumberland-county-association-for-indian-people-fayetteville-nc-916.

Guilford Native American Association (GNAA) was incorporated in 1975 to assist Native Americans living in Guilford and surrounding counties in achieving social and economic self-sufficiency. Their website is https://www.guilfordnative.com.

Metrolina Native American Association (MNAA) was incorporated in 1976 to promote cultural awareness, economic development, employment training, and work experience for Native Americans living in Mecklenburg and surrounding counties.
https://www.metrolinanatives.com.

Triangle Native American Society (TNAS) was founded in 1984 to promote and protect the identity of Native Americans living in Wake, Johnston, Durham, Orange, and Chatham counties by providing educational, social, and cultural programs. TNAS seeks to foster a local Native community while bridging the various cultural and traditional practices members bring from their respective home tribal communities. https://www.trianglenative.org.

North Carolina Native American Youth Organization (NCNAYO) was established in 1979 to support all American Indian youth in the state of North Carolina. https://ncnayo.weebly.com.

University of North Carolina (UNC), American Indian Center has a vision to make the University of North Carolina at Chapel Hill a leading public university for American Indian scholarship and scholars. We aim to make Native issues a permanent part of the intellectual life of the University. https://americanindiancenter.unc.edu.

6.7 Land Trusts and Private Conservation Organizations

6.7.1 Audubon North Carolina

The mission of the National Audubon Society's NC state office is to conserve and restore natural ecosystems, focusing on birds, other wildlife, and their habitats for the benefit of humanity and North Carolina's biological diversity. The Important Bird Areas (IBA) program is key to this mission. The IBA program operates under two objectives:

- To identify places that are essential to sustaining the diversity and abundance of naturally occurring populations of birds in North Carolina; and
- To protect or ensure the appropriate management of these sites for the long-term conservation of birds and their habitats.

Audubon North Carolina is a key partner for beach-nesting bird and colonial waterbird conservation efforts in the state. They have identified 96 IBAs that cover 4.9 million acres statewide. There are several regional Audubon Chapters across the state. For more information about their conservation efforts visit the website (http://nc.audubon.org).

6.7.2 North Carolina Wildlife Federation (NCWF)

The mission of NCWF is to be the leading advocate for all NC wildlife and its habitat. The goals of NCWF are:

- To advocate the conservation and enhancement of all wildlife and its habitat;
- To advocate ethical and biologically sound hunting, fishing, and other outdoor activities;
- To advocate education, for children and adults, that increases public awareness of wildlife, its dependence on habitat, and the importance of both to human existence;
- In affiliation with member organizations, to communicate, cooperate, and partner with the NC General Assembly, state resource agencies, corporations, and other interested groups to advance the well-being of wildlife and its habitat; and
- In affiliation with the National Wildlife Federation, to support national and international issues of mutual interest.

NCWF was instrumental in the creation of the Wildlife Resources Commission in the mid-1940s and it continues to be a key advocate for wildlife and wildlife-related policy in North Carolina. Additional information is available from its website (www.ncwf.org).

6.7.3 The Conservation Trust for North Carolina (CTNC)

CTNC was created to help protect North Carolina's land and water resources, both by direct action and by assisting private, local land trusts, other community groups, and private landowners. CTNC is the statewide land trust working with communities, landowners, local land trusts, and other conservation organizations to protect North Carolina's natural and cultural resources. CTNC works cooperatively with land trusts across the state to help landowners protect natural resources through voluntary conservation methods. Visit its website to learn more (www.ctnc.org).

6.7.4 The Nature Conservancy (TNC)

The Nature Conservancy's mission is to conserve the lands and waters on which all life depends. This mission is carried out through partnerships, alliances, and collaborations with a variety of state and federal agencies, land trusts, and conservation groups. North Carolina falls within three of The Nature Conservancy's defined ecoregions (the Mid-Atlantic Coastal Plain, the Piedmont, and the Southern Blue Ridge) — each with its own ecoregional plan that identifies priority conservation areas within the ecoregion.

The Nature Conservancy has developed a strategic, science-based planning process, called "Conservation by Design," which is used to help identify the highest-priority places — landscapes and seascapes that, if conserved, promise to ensure biodiversity over the long term. Visit the TNC website for more information about their work in North Carolina (www.nature.org/ourinitiatives/regions/northamerica/unitedstates/northcarolina).

6.7.5 North Carolina's Land Trusts

Land trusts are community-based, nonprofit organizations that actively work to conserve land by acquiring land or conservation easements from willing landowners. Land trusts also manage or restore land once it has been conserved. Many of the land trusts in North Carolina are members of the Land Trust Alliance (LTA, https://landtrustalliance.org) which supports local land trusts and acts as an advocate on issues that affect organizations.

North Carolina land trusts are community-led and supported and protect lands and waters that help the entire state. NCWRC works collaboratively with numerous land trusts and conservation organizations. According to the LTA, land trusts in the state have increased the amount of land protected by 19% since 2010. A list of land trusts working in North Carolina is available on the LTA website at https://landtrustalliance.org/land-trusts/gaining-ground/north-carolina#demographics.

6.8 Local and Municipal Programs

There are 100 counties in North Carolina and hundreds of municipal and local governments that range from large cities like Charlotte and Raleigh to small communities such as Banner Elk and Navassa. Local government programs can participate in funding programs through the Open Space Institute (https://www.openspaceinstitute.org/states/north-carolina) or other funding programs specific to North Carolina (see Section 6.2.3).

Some local government programs have implemented their own riparian buffer and floodplain protection programs in compliance with National Flood Insurance Programs and as a means to protect nutrient-sensitive waters. Other programs work with landowners, nonprofit agencies, public agencies, and other stakeholders in the protection of important farmlands, natural resources, and waterways.

An example is the Charlotte-Mecklenburg County Park and Recreation's Division of Nature Preserves and Natural Resources (https://parkandrec.mecknc.gov/places-to-visit/nature/natural-resources) is a regional environmental leader and willingly partners with other public agencies and non-profit organizations on preservation, conservation and educational endeavors. Nature preserves protect the county’s biological resources and natural areas, while providing opportunities for environmental education, nature-based programs, and outdoor recreation. Natural Resources staff use controlled burns to improve wildlife habitat. An example of a fire dependent natural community in Mecklenburg County is Shuffletown Prairie Nature Preserve.

Durham County’s Farmland Protection Program represents a collaboration among Durham’s Soil and Water Conservation District, Open Space Program, City-County Planning, the Farmland Protection Advisory Board, County Manager, and the Board of County Commissioners to protect farmland. This collaboration has succeeded in communicating with landowners on farmland preservation options and in leveraging significant state and federal funds to match local dollars for the purchase of agricultural conservation easements. As of 2022, Durham County has received over $6.9 million in federal and state grant awards to support its farmland preservation efforts. The Durham County Open Space Program website provides more information at https://www.dconc.gov/county-departments/departments-a-e/engineering-and-environmental-services/open-space-and-real-estate-division/durham-county-open-space-program.

Another example of local conservation efforts is Orange County’s Lands Legacy Program. This program works with landowners, land trusts, and other conservation partners to leverage local funds and state and federal dollars for the acquisition and protection of important natural and cultural resource lands in the county. Since 2000, the program has helped to protect more than 3,000 acres that include natural areas, prime farmlands, and watershed riparian buffer lands. The 2024-2027 Lands Legacy Program Action Plan is available online at https://www.orangecountync.gov/DocumentCenter/View/7662/Lands-Legacy-Action-Plan-2024-2027.

In Wake County, the Open Space Program protects valuable open space by purchasing land or conservation easements in areas targeted for protection. The Wake County Consolidated Open Space Plan was developed to guide decisions about protection and conservation of county land and water for current residents and future generations. The Open Space Program also provides matching funds to partners for purchase of land or conservation easements.

The Community Conservation Assistance Program (CCAP) works at the county level with urban, suburban, and rural landowners interested in reducing their contributions to nonpoint source pollution. Both Durham County CCAP and Rockingham County CCAP provide assistance for installation of qualifying BMPs (e.g., rain gardens, riparian buffers, stormwater wetlands, stream restoration, permeable pavement, and other conservation measures).

6.9 Other Statewide Conservation Partners and Initiatives

North Carolina is home to several esteemed university and research colleges that are important partners in accomplishing the conservation goals outlined in this Plan. Research projects often involve partnerships with universities and organizations located outside the state. Some of the notable partnerships and initiatives are outlined in the following sections.

6.9.1 Albemarle-Pamlico National Estuary Partnership (APNEP)

APNEP is a cooperative effort jointly sponsored by NCDENR and USEPA, in partnership with the Virginia Department of Environmental Quality. The mission of APNEP is to identify, protect, and restore the significant resources of the Albemarle-Pamlico estuarine system. APNEP pursues this mission with guidance and support from its overarching Comprehensive Conservation and Management Plan (CCMP), advisory bodies, and regional partners. The program area extends across most of the Albemarle-Pamlico watershed, including the Neuse, Tar-Pamlico, Roanoke, Chowan, lower Roanoke, and parts of the White Oak River basins.

In collaboration with partners, APNEP supports implementation of CCMP, which has a 10-year planning horizon, through development and implementation of annual work plans. APNEP also supports several important initiatives, including a brownwater rivers floodplain inventory conducted in cooperation with NCNHP; the Defense Coastal and Estuarine Research Program conducted in cooperation with the DOD; peatland restoration projects with TNC and the North Carolina Coastal Federation; and the submerged aquatic vegetation (SAV) partnership that operates under a Memorandum of Agreement between numerous federal and state agencies, universities, and conservation organizations. NCWRC and APNEP partner in a statewide SAV signage program. Additional information about APNEP is available from its website (www.apnep.org).

6.9.2 Appalachian Mountains Joint Venture (AMJV)

AMJV is one of 18 habitat joint-venture partnerships in the United States. It comprises state and federal government agencies, NGOs, universities, and industries that work together to prioritize and coordinate bird conservation activities using an adaptive management framework that builds upon the best available science. AMJV is a self-directed partnership governed by a management board representing its partners, with NCWRC having a seat on the board.

AMJV’s mission is to restore and sustain viable populations of native birds and their habitats in the Appalachian Mountains. It does so by coordinating and assisting partners in prioritizing which species and habitats to conserve, working with researchers and resource managers to design and implement effective conservation projects for native bird species throughout their annual life cycles, and capitalizing on funding opportunities relevant to partnership priorities.

Their work in the Appalachian Region of western North Carolina focuses on enhancing and maintaining young forest habitat for Golden-winged Warblers and other young forest species, improving mature forest habitat for forest interior species such as Cerulean Warblers and Wood Thrush, and restoring high elevation spruce-fir forests.
Key partners to AMJV in North Carolina include NCWRC, USFS, USFWS, NRCS, NPS, Audubon NC, National Wild Turkey Federation, and Southern Appalachian Highlands Conservancy. Additional information about AMJV is available from its website (www.amjv.org).

6.9.3 Atlantic Coast Joint Venture (ACJV)

The mission of ACJV is to provide a forum for federal, state, regional, and local partners to coordinate and improve the effectiveness of bird conservation planning and implementation. ACJV is one of 18 habitat joint-venture partnerships in the United States and brings together partners focused on the conservation of habitat for native birds in the Atlantic Flyway, from Maine south to Puerto Rico.

ACJV was originally formed as a regional partnership focused on the conservation of waterfowl and wetlands under the North American Waterfowl Management Plan (NAWMP) in 1988 and has since broadened its focus to the conservation of habitats for all birds consistent with major national and continental bird conservation plans under the framework of the North American Bird Conservation Initiative formed in 1999.

Under the framework of NAWMP and NABCI, ACJV plans and implements bird conservation in the Atlantic Flyway through these major initiatives and planning efforts:

- Waterfowl: North American Waterfowl Management Plan; ACJV Waterfowl Implementation Plan
- Waterbirds: Waterbird Conservation for the Americas; Southeast US Region Waterbird Conservation Plan; Northwestern Atlantic Marine Bird Conservation Cooperative; Integrated Waterbird Management and Monitoring Plan;
- Shorebirds: US Shorebird Conservation Plan; Northern Atlantic Regional Shorebird Plan; Western Hemisphere Shorebird Reserve Network; Atlantic Flyway Shorebird Business Strategy
- Landbirds: Partners In Flight Bird Conservation Plans
- NABCI Bird Conservation Plans (BCR Plans); South Atlantic Migratory Bird Initiative (eastern portion of BCR 27 – Southeastern Coastal Plain), New England/Mid-Atlantic Coast (BCR 30), Atlantic Northern Forest (BCR 14), Lower Great Lakes-St. Lawrence Plain (BCR 13), Piedmont (BCR 29), Peninsular Florida (BCR 31).*****
- Single Species Planning efforts: National Bobwhite Conservation Initiative, North American Grouse Management Strategy, Woodcock Management Plan, Atlantic Brant Management Plan

*****Note*: BCR Plans synthesize information of all these planning efforts for each bird initiative on an ecoregional scale, integrating the planning and implementation vision for all of these species/initiatives into a single BCR plan. Additional information about ACJV is available from its website (www.acjv.org).

6.9.4. Blue Ridge Forever Coalition

Blue Ridge Forever is a coalition of the 10 land trusts in Western North Carolina, that have partnered for over a decade of conservation successes in the region. The partners include: Blue Ridge Conservancy, The Conservation Trust for North Carolina, New River Conservancy, The Nature Conservancy, Highlands-Cashiers Land Trust, Foothills Conservancy, Pacolet Area Conservancy, Southern Appalachian Highlands Conservancy, Mainspring Conservation Trust, the Trust for Public Land, Riverlink, and Carolina Mountain Land Conservancy. The coalition works to engage the public and raise financial resources to safeguard land and water in the southern Blue Ridge for present and future generations. A region-wide conservation vision guides the connection of protected lands on a landscape scale with attention to places containing important wildlife habitat, water quality, scenic value, and cultural, economic, and agricultural significance. http://www.blueridgeforever.info.

6.9.5 Cape Fear Arch Conservation Collaborative (CFACC)

The Cape Fear Arch is a region distinguished by unusual geology and the greatest biological diversity along the Atlantic Coast north of Florida. It is located between Cape Lookout in North Carolina and Cape Romain in South Carolina and extends inland beyond Fayetteville to the Sandhills region of the Carolinas. In North Carolina, the Cape Fear Arch includes the watersheds of the lower Cape Fear and Waccamaw rivers. The area is under great development pressure, which requires infrastructure that often eliminates habitat for important wildlife species.

CFACC is a nonprofit partnership of organizations and individuals created in 2006 to enhance cooperation and communication regarding regional conservation issues within the CFA landscape. The participating organizations represent a broad spectrum of land managers and land conservation advocates with differing missions. All are dedicated to sustainable natural resource management, providing for human needs while retaining the natural heritage of the region.

A conservation plan was developed in 2009 that identifies, evaluates, and prioritizes an interconnected network of essential core ecosystems in the Cape Fear Arch region and identifies gaps in the existing network for protection and restoration priorities. The Cape Fear Arch Conservation Plan was published in 2009 and is a tool for informing planning at regional and local levels. Additional information about CFACC is available from its website (http://capefeararch.org).

6.9.6 Cape Fear River Partnership (CFRP)

The Cape Fear River Partnership was formed in 2011 to restore and demonstrate the value of robust, productive, and self-sustaining stocks of migratory fish in the Cape Fear River. The partnership includes key federal, state, local, academic, and other organizations in the region that are working together on a multi-year action plan to provide long-term, habitat-based solutions for the most pressing challenges for migratory fish. The Cape Fear River Basin Action Plan for Migratory Fish published in 2013 outlines problems related to the health of migratory fish stocks and recommends actions to restore fish passage and improve habitat and water quality to revitalize fish populations and improve overall condition of the river.

The partnership evaluates its efforts through goals and objectives associated with: increased fish populations (as measured by catch-per-unit efforts, improved age structure, and other techniques); increased recreational fishing success for Shad, Striped Bass, and River Herring (as measured by creel surveys); and a reopened native Striped Bass and River Herring harvest in the Cape Fear River. The partnership successfully got underway through the US Army Corps of Engineers' construction of a new fish passage structure at Lock and Dam 1 on the Cape Fear River near Wilmington. Additional information about CFRP is available from its website (http://www.capefearriverwatch.org).

6.9.7 Chatham Conservation Partnership (CCP)

The mission of CCP is to develop and implement strategies for a community conservation vision that builds awareness, protection, and stewardship of Chatham County's natural resources. CCP is a partnership of government agencies, local land trusts, local conservation organizations, colleges, private businesses, and landowners who share the common interest of developing a sustainable county focused on the preservation of its natural resources and rural and agricultural heritage.

To achieve its goals, CCP provides a forum for public discourse on sustainable land use, serves as an educational resource on land conservation and management tools, facilitates collaborative efforts among members to achieve common conservation objectives, and promotes the role science plays in responsible sustainable land use. CCP has created an innovative tool, the Comprehensive Conservation Plan, to help with land protection and development decisions in Chatham County. Additional information about CCP is available from its website https://www.chathamconservation.org.

6.9.8 Eastern Brook Trout Joint Venture (EBTJV)

This fish habitat partnership includes state fish and wildlife agencies, federal resource agencies, academic institutions, and private sector conservation organizations that have adopted a formal management structure and signed an MOU. The partnership works to conserve Eastern Brook Trout and their habitats and has produced a range-wide population assessment of brook trout; completed extensive work that identifies key threats to brook trout and their habitats; and developed conservation strategies to protect, enhance, and restore brook trout.

A conservation strategy, which was published in 2011, is a goal-oriented, science-based action plan that explicitly states EBTJV principal goals, presents guidance for decision making, and provides methods for evaluating success. In addition, there are 12 state-level conservation action plans that prioritize the specific strategies needed for brook trout conservation within each state. Additional information about EBTJV is available from its website http://easternbrooktrout.org.

6.9.9 Greater Uwharrie Conservation Partnership (GUCP)

GUCP is a collaboration of diverse partners that works cooperatively to conserve wildlife, habitats, and associated natural resources in the Greater Uwharries region of south-central Piedmont in North Carolina. Partner organizations are: NHP, NCPCP, NCWRC, NCMNS, NC Zoological Park, Piedmont Land Conservancy, USFS, NRCS, USFWS, Central Park NC, Environmental Defense Fund, The Land Trust for Central NC, and The Nature Conservancy.

Since its founding in 2006, the partnership has permanently conserved more than 6,500 acres and enhanced habitat on more than 3,400 acres for high-priority wildlife and rare plant habitat. Other work includes biological surveys on 230 sites leading to the discovery of a 1,000-acre significant natural heritage area in Anson County with the largest population in the world of river sedge, a rare plant. Partners have contacted more than 200 private landowners in the region’s most valuable natural areas, to offer technical guidance about conservation options and cost-share programs, resulting in cooperative working relationships with 64 of these landowners.

6.9.10 NC Longleaf Coalition

The mission of the NC Longleaf Coalition is to promote the maintenance and restoration of North Carolina’s Longleaf Pine ecosystem, including its cultural and economic values, by forming a collaborative network of diverse stakeholders to provide strategic leadership across the historic range while also supporting local restoration activities. The Coalition was formalized in 2010 and aims to provide the state/local level leadership called for in the regional plan.

Participants in the Coalition include multiple state agencies (NCFR, NCWRC, and NCNHP) and federal agencies (USFWS, USFS, NRCS, and the NC Commander’s Council, representing multiple military services). The Coalition is rounded out by multiple nonprofits, consulting foresters/landowners, academics, and other Longleaf proponents. The Coalition coordinates closely with on-the-ground restoration efforts including the NC Sandhills Conservation Partnership, the Onslow Bight Conservation Forum, and the CFA. Additional information is available from its website http://nclongleaf.org.

6.9.11 NC Partners in Amphibian and Reptile Conservation (NCPARC)

NCPARC is North Carolina's chapter of Partners in Amphibian and Reptile Conservation, which has the mission of conserving amphibians and reptiles and their habitats. Members include academia, state and federal agencies, research facilities, nature education centers, land trusts, municipalities, zoos, veterinary fields, forest products industries, energy cooperatives, conservation organizations, herpetological societies, pet trade industries, museums, and even communities and neighborhoods.

NCPARC believes that the successful conservation of amphibians and reptiles can only be accomplished by joining forces to combine the expertise and resources of a multitude of individuals and organizations. This effort includes technical working groups that facilitate herpetological conservation by addressing research, inventory and monitoring needs, policy, regulation and trade issues, and education and outreach objectives.

NCPARC is a unique conservation network because it includes conservation of all reptiles and amphibians; is focused on conserving the habitats required for survival; includes all individuals, organizations, and agencies that have an interest in reptile and amphibian conservation; and focuses not only on endangered and threatened species but also on keeping common native species common. Additional information is available from its website https://ncparc.org.

6.9.12 NC Partners In Flight (NCPIF)

NCPIF is North Carolina's chapter of Partners In Flight, a cooperative effort involving partnerships among federal, state, and local government agencies, philanthropic foundations, professional organizations, conservation groups, industry, the academic community, and private individuals. NCPIF is a statewide initiative that brings together government, private, and public organizations, and individuals in an effort to further migratory bird conservation through habitat protection, management, monitoring, professional training, and education. NCPIF is also part of the Southeast PIF Work Group. Additional information is available from its website http://ncpartnersinflight.org.

6.9.13 NC Prescribed Fire Council

Fire is a natural part of North Carolina's ecosystem. Low-intensity fire historically occurred across the state to maintain some ecosystems. Today, prescribed burning is essential to the perpetuation, restoration, and management of many plant and animal communities.

The mission of the NC Prescribed Fire Council is to foster cooperation among all parties in North Carolina with an interest or stake in prescribed fire. The goal is to optimize burning opportunities for the benefit of natural ecosystems and wildlife and to reduce the risk of damage from wildfires. This will be accomplished by encouraging the exchange of information, techniques, and experiences among practitioners of prescribed fire in North Carolina. Another goal is to promote public understanding of the regional importance and benefits of prescribed fire. Goals and objectives are described in the Council's 2025–2030 Strategic Plan (https://ncprescribedfirecouncil.org/wp-content/uploads/NC-PFC-Strategic-Plan-Final-December-2024.pdf).

Council members represent federal and state agencies, organizations, corporations, institutions, or private landowners with an interest in prescribed fire and whose goals are consistent with the Council's mission. The Council advocates for increased expertise in prescribed fire through the sharing of technical and biological information; promotes safety, training, and research in the art and science of prescribed fire; reviews prescribed fire practices, regulations, and policies, and suggests improvements; and promotes BMPs that minimize smoke and air quality impacts from prescribed fires. The Council is affiliated with the Coalition of Prescribed Fire Councils. Additional information is available from its website https://ncprescribedfirecouncil.org.

6.9.14 NC Sandhills Conservation Partnership (NCSCP)

The NCSCP was created in 2000 with the mission to protect, enhance, and restore the unique Sandhills environment. The Partnership facilitates collaboration between various federal, state, and nonprofit conservation groups for the purposes of conserving the vanishing Longleaf Pine ecosystem and recovering the endangered Red-cockaded Woodpecker in the NC Sandhills. The NCSCP seeks input from more than 18 stakeholder organizations and has developed a landscape-level strategic conservation plan for the Sandhills. In addition to traditional natural resource and land conservation organizations, the Partnership includes the US Army, a key partner in the region.

Examples of successes that have been achieved as a result of the NCSCP include: more than 20,000 acres protected through collaborative land conservation efforts and leveraging of funds; the development of GIS data layers identifying the lands and waterways most important to natural resource conservation and management; the expansion and sharing of resources to improve land management including prescribed burning and invasive plant control; the development of a strategic plan that includes threat assessments, implementation strategies, and monitoring; increased communication and collaboration between partners; the training of several local government land-use planning staff in the use of conservation data; and the recovery of the NC Sandhills population of the endangered Red-cockaded Woodpecker to levels identified in the national recovery plan.

In addition, results compiled through a 10-year review conducted in 2010 indicate that NCSCP provides partners with invaluable opportunities to build their personal and professional networks, to bolster internal capacity and support for accomplishing conservation objectives, and to demonstrate the success of the collaborative approach to conservation. Additional information is available from its website https://www.ncscp.org.

6.9.15 Onslow Bight Conservation Forum

The Onslow Bight is a unique geographic landform located along the mid-coast region of North Carolina and includes all or portions of 13 coastal counties. The landscape stretches from the lower Northeast Cape Fear River to the Pamlico River and from offshore waters to approximately 40 miles inland. The Onslow Bight contains large federal- and state-managed areas including three Marine Corps installations, the Croatan National Forest, and the Holly Shelter and Angola Bay state game lands. The landscape contains rare and unusual animal and plant life such as the Red-cockaded Woodpecker, Venus Flytrap, and Carolina Gopher Frog. The region includes barrier islands, marshes, riverine wetlands, pocosins, Longleaf Pine savannas, and many other Coastal Plain and coastal habitats.

The Onslow Bight Conservation Forum facilitates collaborative partnership between organizations and individuals dedicated to conservation within the Onslow Bight landscape while helping to preserve mission-compatible land use adjacent to the military installations. The Forum fosters a strong collaborative relationship among regional military installations, federal, state, and local agencies, and a wide array of environmental groups.

The mission of the Onslow Bight Conservation Forum is to allow open communication between the collaborating partners to achieve forum goals for the conservation, protection, and restoration of the Onslow Bight landscape.

6.9.16 Piedmont Prairie Partnership

The Piedmont Prairie Partnership is a group of natural resource professionals and landowners who joined forces to explore opportunities and techniques for the restoration and enhancement of native prairies throughout North Carolina. Piedmont Prairies, also known as grasslands, early successional habitat, savannas, or xeric hardpan forests contain a whole suite of native bird and rare plant species such as Schweinitz’s Sunflower and Smooth Coneflower, which are both federally listed endangered species.

The Partnership implemented the Piedmont Prairie Restoration Program, which began with collaboration between Mecklenburg County, USFWS, NCDOT, and University of North Carolina at Charlotte faculty. Since it was first organized in 1994, several Piedmont prairie restoration projects have been implemented, including Mecklenburg County’s McDowell Nature Preserve prairie restoration (150 acres), Latta Plantation Nature Preserve prairie restoration (40 acres), Gar Creek Nature Preserve (36 acres), Shuffletown Prairie Nature Preserve (18 acres), and the City of Greensboro's Meadowlark Sanctuary Piedmont Prairie (23 acres) at Price Park.

6.9.17 Robust Redhorse Conservation Committee (RRCC)

The Robust Redhorse Conservation Committee (RRCC) was created in 1995 to improve the status of Robust Redhorse throughout its former range. RRCC is a cooperative, voluntary partnership formed under an MOU between state and federal resource agencies, private industry, and the conservation community. Members of the RRCC MOU are working collaboratively to conserve an imperiled species and its habitat in lieu of listing the species for protection under the Endangered Species Act. Current RRCC members include: Georgia Department of Natural Resources, NCWRC, South Carolina Department of Natural Resources, USFWS, USGS, USFS, Duke Energy, Georgia Power Company, South Carolina Electric and Gas Company, Georgia Wildlife Federation, and the South Carolina Aquarium.

The Robust Redhorse is a large, long-lived species that occurs in Atlantic Slope rivers from the Altamaha River drainage in Georgia to the Yadkin-Pee Dee River drainage in North and South Carolina. The RRCC is facilitating recovery efforts and conservation measures by conducting research to answer scientific questions and address management needs including habitat use and movement, early life history, population dynamics, and genetics. Work has also focused on discovery of additional populations, supplemental stocking of existing populations, reestablishment of historical populations, and public education.

The RRCC's Conservation Strategy, which establishes short- and long-term conservation goals and management actions, was adopted in 1999 and revised in 2003. We are currently very close to meeting the goal of establishing or maintaining at least six self-sustaining populations distributed within a significant portion of its historic range. Wild populations exist in the Oconee River (Georgia), Savannah River (Georgia and South Carolina), and Pee Dee River (North and South Carolina). Successful stockings in the Broad, Ogeechee, and Ocmulgee rivers in Georgia, and the Broad and Wateree rivers of South Carolina, have reestablished historical populations. Detailed information, reports, and publications on the Robust Redhorse are updated online at www.robustredhorse.com.

6.9.18 Southeast Aquatic Resources Partnership (SARP)

SARP is a regional collaboration of natural resource and science agencies, conservation organizations, and private interests developed to strengthen the management and conservation of aquatic resources in the southeastern United States. The mission is to work with partners to protect, conserve, and restore aquatic resources including habitats throughout the Southeast for the continuing benefit, use, and enjoyment of the American people. This mission is achieved through the support and facilitation of on-the-ground and in-the-water science-based action to improve and protect aquatic habitats and resources. Efforts are focused on habitat assessments, restoration actions, monitoring, and evaluation of some of the nation's most economically and socially significant aquatic habitats. Additional information is available from the SARP website http://southeastaquatics.net.

6.9.19 Upper Neuse River Basin Association (UNRBA)

This association was formed in 1996 to provide a forum for cooperation on water quality protection and water resource planning and management within the 770-square-mile watershed. Seven (of the eight) municipalities, six counties, and local Soil and Water Conservation Districts in the watershed voluntarily formed UNRBA.

The mission of UNRBA is to preserve the water quality of the Upper Neuse River Basin through innovative and cost-effective pollution reduction strategies, and to create a forum to cooperate on water supply issues within the basin by forming a coalition of units of local government, public and private agencies, and other interested and affected communities, organizations, businesses, and individuals to secure and pool financial resources and expertise; collecting and analyzing information and data, and developing, evaluating, and implementing strategies to reduce, control, and manage pollutant discharge; and providing accurate technical, management, regulatory, and legal recommendations regarding the implementation of strategies and appropriate effluent limitations on discharges into the Upper Neuse River Basin. Visit the UNRBA website for more information http://unrba.org.

6.9.20 Upper Tar Collaboration

Anchored by the Tar River Land Conservancy (TRLC), the Upper Tar Collaboration includes a multitude of corporate, agency, nonprofit, and private partners dedicated to preserving and managing riparian buffers and wetlands to help protect the incredible aquatic biodiversity that resides in the Upper Tar River Basin. This basin is nationally recognized as one of the most important watersheds along the East Coast because it harbors 14 federal and state rare and endangered species, including the federally endangered Tar Spinymussel and Dwarf Wedgemussel. Information is available online at https://www.tarriver.org.

6.9.21 WakeNature Preserves Partnership

The WakeNature Preserves Partnership brings together natural resource professionals from local governments, NCSU, state agencies, and nonprofit organizations to build capacity among Wake County's local governments to identify the most valuable natural resources areas they own and improve environmental stewardship of these areas.

The mission of the Partnership is to organize and provide resources to identify ecologically valuable, publicly owned open spaces within Wake County, and to build capacity for appropriate management and long-term stewardship of those areas. WakeNature encourages a coordinated approach to classifying and managing the most ecologically valuable natural areas in Wake County, as well as better public education about our local natural heritage. More information is available from its website https://wakenature.wordpress.com.

Chapter 7
Monitoring

7

Chapter 7. Monitoring

***Required Element 5**: Proposed plans for monitoring species (as identified in Required Element 1) and their habitats (as described in Required Element 2), for monitoring the effectiveness of the conservation actions proposed in Required Element 4, and for adapting these conservation actions to respond appropriately to new information or changing conditions.*

7.1 Introduction

Monitoring and evaluation are tools that scientists can use to measure change over time in species populations, habitat status, or the effects of activities. These tools also provide information for the interpretation of those measured changes. Monitoring and evaluation are especially important to examining whether there has been a response to applied conservation actions, and are necessarily linked to conservation and management objectives. Monitoring conducted at multiple levels (e.g., species, guilds, or natural communities) and across multiple scales (e.g., local, statewide, and regional) is required to assess changes that occur in populations and habitats over time:

- Species-specific monitoring is an important component of any conservation program and allows an agency or organization to assess topics such as wildlife population trends, estimated population size, relative abundance, or shifts in distribution or range. Monitoring of individual species, when coordinated at the appropriate level, contributes to the conservation of species beyond local populations and at scales far beyond individual state boundaries.

- Guild-level monitoring (e.g., ephemeral pond amphibians, colonial waterbirds) is essential for tracking and assessing habitat-level impacts over time. It allows us to assess habitat availability, use, and condition over time, and can be used to measure the effectiveness of habitat-based management activities. Habitat and natural community monitoring is necessary to track landscape-level trends and to anticipate future needs as threats change.

- Implementation monitoring is needed to measure project success and advancement toward achieving project goals. It allows us to adapt conservation actions to respond appropriately to new information or to changing conditions.

Monitoring needs for particular species or guilds are detailed in other sections of this Plan: Chapters 3 (NC Species), Chapter 4 (Habitats),and Chapter 5 (Threats) .This chapter provides information about monitoring activities conducted by NC Wildlife Resources Commission

(NCWRC) and conservation partners. These activities implement the recommendations made in previous chapters and are accomplished through the planning process and collaboration and cooperation among the agencies, organizations, and initiatives discussed in Chapter 6.

Section 7.2 provides information about species-specific and guild-level monitoring activities, while Section 7.3 addresses habitat and natural community monitoring. A list of Species of Greatest Conservation Need (SGCN) can be found in Appendix 3 and their habitat associations are provided in Appendix 3-17 and 3-18. Lists of monitoring activities and programs conducted by NCWRC and partners is available in Appendix 7.

7.1.1 Monitoring on Public Lands

In North Carolina, the largest acreages of publicly owned land are managed by state and federal agencies, and there are many smaller tracts owned by local municipalities and conservation organizations. Species and habitat monitoring is part of routine monitoring conducted on state and federal public lands. NCWRC coordinates with other agencies and organizations to identify shared priorities and to facilitate efficient monitoring and data synthesis. Table 7-1 provides examples of large tracts of public lands monitored by federal and state agencies. More information about the management programs on these lands can be found in Chapter 6.

Table 7-1 Examples of large public land tracts with monitoring programs.

Agency	Land Tracts with Monitoring Programs
Department of Defense (DOD) Integrated Natural Resource Management Plans stipulate monitoring needs for each installation	**ARMY** https://www.denix.osd.mil/army-nr/army-integrated-natural-resources-management-plan-inrmp **Marine Corp** https://www.lejeune.marines.mil/Offices-Staff/Environmental-Mgmt/ •
US Forest Service (USFS) Land and Resource Management Plans identify monitoring needs related to each forest's Management Indicator Species and communities.	https://www.fs.usda.gov/r08/northcarolina/planning

Table 7-1 Examples of large public land tracts with monitoring programs.

Agency	Land Tracts with Monitoring Programs
US Fish and Wildlife Service (USFWS) Comprehensive Conservation Plans outline the programs and corresponding resource needs for managing each wildlife refuge over a 15-year period.	https://www.fws.gov/library/collections/comprehensive-conservation-plans
NC Wildlife Resources Commission (NCWRC) Game Land Management Plans (GLMPs) outline science-based land management goals and describe measures needed to support sustainable natural resources through implementation of comprehensive conservation programs.	https://www.ncwildlife.gov/hunting/where-hunt-shoot/game-land-management-plans
NC Division of Parks & Recreation (NCDPR) General management plans (GMPs) for individual parks provide a comprehensive evaluation of park resources, outline management actions to conserve important ecosystem functions, and are combined and used with the Statewide Comprehensive Outdoor Recreation Plan.	https://www.ncparks.gov/document-collection/general-management-plans

7.1.2 Monitoring Coordination and Data Sharing

Coordinated monitoring efforts are critical to achieving efficient and effective conservation. Local efforts help to sustain and strengthen monitoring programs that benefit sea turtles, Bog Turtles, and colonial nesting waterbirds in North Carolina. Initiatives such as the South American Migratory Bird Initiative (SAMBI), Partners In Flight (PIF), and the Robust Redhorse Conservation Committee (RRCC), and cooperative agreements such as the NC Colonial Waterbird Cooperative Agreement (with 12 state and federal agency and nonprofit signatories) implement efforts at regional levels. The North American Breeding Bird Survey (NABBS) is an example of a long-term, large-scale, international monitoring program that tracks bird populations and provides an index of avian status and trends at various geographic scales. The conservation achieved through these programs and others demonstrates the success and importance of such collaborations.

The US Forest Service (USFS) provides technical guidance on how to monitor populations and habitats in one integrated design for multiple species (USFS 2006). The efforts of the various North American Bird Conservation Initiative (NABCI) programs provide models on which to build coordinated monitoring efforts for other taxa, and recommendations from NABCI plans have been incorporated into NCWRC monitoring programs. Monitoring infrastructures developed by various programs (see Table 7-2) support specific monitoring goals for birds in North Carolina and contributes to regional, national, and even international bird conservation efforts.

Table 7-2 Examples of cooperative monitoring efforts.

Initiative	Plan Year and Name
Atlantic Coast Joint Venture (ACJV)	• 2025 Rapid Assessment Monitoring for Tidal Marsh Sparrows on Salt Marsh Restoration Projects (version 2) https://acjv.org/documents/monitoring_guidance_SALS.pdf • 2022 American Black Duck Conservation Plan https://www.acjv.org/documents/ACJV-American-Black-Duck-Conservation-Plan.pdf • 2014 The Piedmont Bird Conservation Region (BCR 29) Implementation Plan https://acjv.org/documents/piedmont-2014.pdf
North American Waterfowl Management Plan	• 2023 Revision. North American Waterfowl Management Plan https://nawmp.org/sites/default/files/2024-07/2023.01_north-american-waterfowl-management-plan-species-prioritizations-2023-revision.pdf

Table 7-2 Examples of cooperative monitoring efforts.

Initiative	Plan Year and Name
	• 2018 North American Waterfowl Management Plan Update https://nawmp.org/sites/default/files/2018-12/6056%202018%20NAWMP%20Update_EN16.pdf
South Atlantic Migratory Bird Initiative (SAMBI) and Implementation Plan	• 2008 South Atlantic Migratory Bird Initiative Implementation Plan https://www.acjv.org/documents/SAMBIImplementation_Plan_12_08.pdf • 2005 Implementing a Regional Shorebird and Waterfowl Survey and Monitoring Database https://seafwa.org/sites/default/files/journal-articles/stanton-389-393.pdf
U.S. Shorebird Conservation Plan	• 2002 Southeastern Coastal Plains-Caribbean Regional Shorebird Plan Partnership(Hunter et al. 2002) https://www.shorebirdplan.org/wp-content/uploads/2013/01/SECPCRRev02.pdf
North American Waterbird Conservation Plan	• 2002 Waterbird Conservation for the Americas: The North American Waterbird Conservation Plan, Version 1 https://www.fws.gov/sites/default/files/documents/north-america-waterbird-conservation-plan.pdf
PIF North American Landbird Conservation Plan https://partnersinflight.org/resources/the-plan/	• 2012 A Field Guide to Southeast Bird Monitoring Protocols and Programs https://www.partnersinflight.org/wp-content/uploads/2017/02/SEPIF_SEMonitoringGuide.pdf
Department of Defense (DOD) https://www.denix.osd.mil/dodpif/groups/research-and-monitoring/products	• 2010 Coordinated Bird Monitoring: Technical Recommendations for Military Lands https://www.denix.osd.mil/dodpif/denix-files/sites/37/2018/03/DoDCBM_Plan-1.pdf • 2017 Recommendations for Monitoring and Managing Source Populations of Species of Concern on Military Installations https://www.denix.osd.mil/dodpif/denix-files/sites/37/2020/05/RC-2121-Users-Guide_508.pdf

There is an ongoing need for collaborative monitoring efforts for all SGCN and for wide-ranging species (e.g., pelagic seabirds, neotropical migratory birds). Strong data standards and a centralized system for housing and managing data and analyzing results are critical to the success of monitoring programs. Standardized protocols are needed to ensure that data collected are compatible with similar programs and can be integrated with regional, national, or international data sets. Population units relevant to conservation planning and research must be defined and standards or protocols developed where none presently exist. Reliable and reproducible techniques should be used and new population-monitoring techniques should be evaluated as needed.

Emerging technologies, research methods, and wildlife issues will require more genetics research and DNA analysis in order to better understand disease, conduct forensic analysis, and improve taxonomic identification and classification. These new opportunities for generating datasets need protocols and methods that will minimize problems with sharing data (Taberlet and Luikart 1999; Bonin et al. 2004; Waits and Paetkau 2005; Lukacs and Burnham 2005; Schwartz et al. 2007). Participation in a clearinghouse could facilitate sharing data among partners.

Regional and national coordination is needed to evaluate the capacity of existing state programs to combine and monitor populations across their range. One effort is the US Geological Survey's (USGS) Species Management Research Program which supports and provides collection and analysis of biological data for local, regional, and national assessment of biological resources and the ecosystems that support them (https://www.usgs.gov/programs/species-management-research-program).

7.1.3 Indicators and Targets

The Southeast Conservation Adaptation Strategy (SECAS) worked collaboratively with numerous agencies and organizations to develop 60 natural resource and cultural resource indicators that represent terrestrial, freshwater, and coastal/marine ecosystems (SECAS 2025).
A list of indicators is available online
https://secassoutheast.org/pdf/IndicatorCheatSheet_2024.pdf
The number of agencies and organizations tracking trends associated with particular habitat types or regions of the state can make coordination and statewide assessments difficult. There is variability in terms of what is actually monitored, the indicators and criteria that are measured, and methods used to measure those indicators. A key improvement should be the establishment of a statewide clearinghouse of information for assessing habitat status and environmental trends information across North Carolina.

7.2 Monitoring Protocols

In addition to the species and habitat monitoring protocols recommended in this Plan, scientific literature is another resource for methodologies appropriate for monitoring various wildlife species. A brief list of examples includes the following resources:

7.2.1 Amphibians and Reptiles

- A comparison of herpetofaunal sampling effectiveness of pitfall, single-ended, and double-ended funnel traps used with drift fences. CH Greenberg, DG Neary, LD Harris, 1994. Journal of Herpetology 28(3):319-324. An assessment of relative effectiveness of pitfalls, single-ended, and double-ended funnel traps at 12 replicate sites in sand pine scrub using drift fence arrays. All three trap types yielded similar estimates of relative abundance of lizards and frogs but not snakes.

- Using egg-mass counts to monitor wood frog populations. WB Crouch, WC Paton, 2000. Wildlife Society Bulletin 28(4):895-901. Assessment of the efficacy of using egg-mass counts to monitor wood frog population because they may not be detectable using calling surveys at breeding ponds.

- A case for using plethodontid salamanders for monitoring biodiversity and ecosystem integrity of North American forests. HH Welsh Jr., S Droege, 2001. Conservation Biology 15(3):558-569. Considers variability associated with sampling for plethodontid salamanders as indicators of biodiversity and ecosystem integrity in forested habitats. by estimating the coefficient of variation from available time-series data in comparison and comparison results with lepidoptera, passerine birds, small mammals, and other amphibians.

- Using automated digital recording systems as effective tools for the monitoring of birds and amphibians. MA Acevedo, LJ Villanueva-Rivera, 2006. Wildlife Society Bulletin 34(1):211-214. A comparison of an automated digital recording system (ADRS) with traditional methods (point-counts and transects) for the assessment of birds and amphibians.

- Reptile biodiversity, standard methods for inventory and monitoring. RW McDiarmid, MS Foster, C Guyer, JW Gibbons, N Chernoff (eds.), 2011. University of California Press, Berkeley and Los Angeles (CA). 424 p. A comprehensive guide to the best methods for carrying out standardized quantitative and qualitative surveys of reptiles, while maximizing comparability of data between sites, across habitats and taxa, and over time. The contributors discuss each method, provide detailed protocols for its implementation, and suggest ways to analyze the data,

- Identifying monitoring gaps for amphibian populations in a North American biodiversity hotspot, the southeastern USA. SC Walls, 2014. Biodiversity Conservation 23:3341-3357.

A review of primary literature to ascertain the status of amphibian monitoring efforts in the southeastern USA,

7.2.2 Aquatic Species

- Sampling rare or elusive species : concepts , designs , and techniques for estimating population parameters. WL Thompson (ed.), 2004. Island Press, Washington (DC). 428 p. Descriptions of sampling designs and counting (estimation) techniques for reliably estimating occupancy , abundance , and other population parameters of rare or elusive plants and animals .

- Predictive species and habitat modeling in landscape ecology, concepts and applications. CA Drew, YF Wiersma, F Huettmann (eds.), 2011. The ecological theory and an assessment of the relevant assumptions that underlie predictive landscape-scale species and habitat modeling.

- Development and evaluation of a boat-mounted RFID antenna for monitoring freshwater mussels. JR Fischer, TE Neebling, MC Quist, 2012. Freshwater Science 31(1):148-153. Design, construction, and evaluation of a boat-mounted RFID antenna to detect individually PIT-tagged benthic aquatic organisms (mussels) and evaluation of the effects of tag orientation on detection distances in water with a 32-mm half-duplex PIT tag.

- Characterizing lentic freshwater fish assemblages using multiple sampling methods. JR Fischer, MC Quist, 2014. Environmental Monitoring and Assessment 186(7):4461-4474. six lakes and impoundments (48–1,557 ha surface area) were sampled seasonally with seven gear types to evaluate the combined influence of sampling methods and timing on the number of species and individuals sampled.

- Utility of environmental DNA for monitoring rare and indicator macroinvertebrate species. E Machler, K Deiner, P Steinmann, F Altermatt, 2014. Freshwater Science 33(4):1174-1183. eDNA techniques were used for a broad taxonomic array of macroinvertebrate species in river and lake systems in parallel to the conventional kicknet-sampling method commonly applied in aquatic habitats. The eDNA method showed medium to very high consistency with the data from kicknet-sampling and was able to detect both indicator and nonnative macroinvertebrates.

7.2.3 Birds

- Coordinated Bird Monitoring: Technical Recommendations for Military Lands. 2010. J Bart and A Manning, USGS; L Dunn, Great Basin Bird Observatory; R Fischer and C Eberly, Department of Defense Partners in Flight. A Report Prepared for the Department of Defense Legacy Resource Management Program Legacy Project # 05-246, 06-246, 07-246. Online https://pubs.usgs.gov/of/2010/1078/pdf/ofr20101078.pdf

- Statistical guide to data analysis of avian monitoring programs. N Nur, SL Jones, GR Geupel. 1999. USFWS,Biological Technical Publication BTP-R6001-1999, Washington (DC). A guide for designing monitoring programs for landbirds and analyzing data collected on terrestrial bird populations.

- Handbook of field methods for monitoring landbirds. DJ Ralph, GR Geupel, P Pyle, TE Martin, DF DeSante. 1993. USDA Forest Service Pacific Southwest Research Station, Albany (CA). A compilation of methods for determining population size, demographics, and status of various birds and habitats. Methods include censuses, mist-netting, nest searches, and general observations. (see http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1104&context=usdafsfacpub.).

- Nest-monitoring plots: methods for locating nests and monitoring success. TE Martin, GR Geupel, 1993. Journal of Field Ornithology 64(4):507-519. Standardized methods and cues are described that aid in locating and monitoring nests of neotropical migratory birds to allow comparisons across studies in space and time.

- Managing and monitoring birds using point counts: standards and applications. CJ Ralph, S Droege, JR Sauer, 1995. USDA Forest Service General Technical Report PSW-GTR-149. Arcata (CA). A summary of suggested standards for consistency between studies using point counts during the breeding season to track population trends or determine associations between birds and their habitats. (http://www.fs.fed.us/psw/publications/documents/psw_gtr149/psw_gtr149_pg161_168.pdf?)

- Monitoring Bird Populations by Point Counts. CJ Ralph, JR Sauer, S Droege (eds.), 1997. General Technical Report PSW-GTR-149 USDA Forest Service Pacific Southwest Research Station, Albany (CA). contains in part papers presented at the Symposium on Monitoring Bird Population Trends by Point Counts, which was held November 6-7, 1991, in Beltsville, Md., in response to the need for standardization of methods to monitor bird populations by point counts.

7.2.4 Mammals

- Indices for assessment and monitoring of large mammals within an adaptive management framework. J Boddicker, JJ Rodriguez, J Amanzo, 2002. Environmental Monitoring and Assessment 76:105-123. The design, applicability and effectiveness of two indices applied within a framework of adaptive management. An occurrence index assesses the composition and distribution of large mammals at a site, and an abundance index monitors the abundance of large mammals over time in relation to development. Online https://museohn.unmsm.edu.pe/docs/pub_masto/Boddicker_et_al_2002_Indices_for_assessment_and_monitoring_large_mammals.pdf

- Field methods for studying nutria. J Meyer, 2006. Wildlife Society Bulletin 34(3):850-852. Methods used for live-trapping, handling, and marking of animals strongly depend on the species considered and the circumstances at particular study sites. This paper provides a short overview on methods used for capturing and marking nutrias, which may be appropriate for other aquatic mammals, and relates field experiences of the author.

- Integration of automated detection methods into NOAA Southwest Fisheries Science Center (SWFSC) acoustic marine mammal monitoring protocol. TM Yack, J Barlow, S Rankin, D Gillespie, 2009. Journal of the Acoustical Society of America 125(4):2588-2588. PAMGUARD 1.0 CORE software was evaluated for use in automated detection of cetacean acoustic signals. Three different detector configurations of PAMGUARD were evaluated.

- Protocol for large-scale monitoring of riparian mammals. DB Lesmeister, CK Nielsen, 2011. Wildlife Biology in Practice 7(2):55-70. A a large-scale monitoring protocol for populations of Beaver, American Mink, Muskrat, and North American River Otter. (see http://socpvs.org/journals/index.php/wbp/article/view/10.2461-wbp.2011.7.15/257).

- Optimizing camera traps for monitoring small mammals. AS Glen, S Cockburn, M Nichols, J Ekanayake, B Warburton, 2013. PLoS ONE 8(6):e67940. doi:10.1371/journal.pone.0067940. Optimal specifications for a low-cost camera trap for small mammals. The factors tested were 1) trigger speed, 2) passive infrared vs. microwave sensor, 3) white vs. infrared flash, and 4) still photographs vs. video. A new approach was tested to standardize each camera’s field of view success rates were compared of four camera trap designs in detecting and taking recognizable photographs.

7.3 Species Monitoring

Some populations are naturally dynamic because of life history strategies (*r*- versus *k*-reproductive strategies) while others may fluctuate on a generational, seasonal, or periodic basis depending on various environmental or biodiversity factors. Multiple investigation strategies may be needed to understand the dynamics of a species' population size. Surveys, monitoring, and research to facilitate appropriate conservation actions must be conducted to determine vulnerability of priority species to specific threats and studies should provide recommendations for mitigation and restoration. In North Carolina, birds and sea turtles are the only vertebrate groups for which there are historically established, standardized, long-term monitoring efforts. Recent efforts have incorporated national protocols for acoustic bat monitoring at a regional landscape level. It is important to continue implementing established monitoring programs to further strengthen trend and population estimates, and, as baseline inventory and survey data allow, to establish new monitoring efforts across all other taxa groups.

In addition to the work conducted by NCWRC, the Commission coordinates a great deal of species status and population monitoring conducted by others and manages a collection permit system to regulate the collection of nongame fauna. The data from annual collection permit reports submitted by permit holders is reviewed by NCWRC and added to a statewide database. Voucher specimens collected during priority aquatic species surveys and monitoring efforts are archived at the NC Museum of Natural Sciences (NCMNS) to identify and document where species occur; this information is included in datasets managed by the Museum. All of the data collected by NCWRC becomes part of a database managed by the North Carolina Natural Heritage Program (NCNHP) and available for public use through the NC Natural Heritage Data Explorer (https://ncnhde.natureserve.org).

Monitoring is also a standard component of many other agency planning efforts, such as the NCDEQ's Fish Community Assessment Data (https://www.deq.nc.gov/about/divisions/water-resources/water-sciences/biological-assessment-branch/fish-community-assessment-data), the USFS Land and Resource Management Plans, and DOD Integrated Natural Resource Management Plans (see Section 7.2.1). The NCDEQ data collected for the stream fish community assessment program is shared with NCWRC, NCMNS, and NCNHP and any nonnative species records collected by the program are shared with the USGS Nonindigenous Aquatic Species Program (https://nas.er.usgs.gov). Future monitoring efforts need to build on and utilize these existing systems. There are other monitoring efforts conducted in the state on smaller scales or at levels focused on specific wildlife needs and as part of research by universities or private organizations such as special interest groups (especially for birds) (NCDPR 2000; Mitchell 2002; Smyth et al. 2010).

As bird monitoring efforts are by far the most advanced and established of any species group, the establishment of protocol for other species groups (e.g., small mammals, amphibians, reptiles) should be developed with strong consideration of the lessons learned through the various monitoring efforts of NABCI. Assessments must be conducted to document status trends following completion of baseline survey work.

As stipulated in recovery plans for federally listed endangered and threatened species, regular monitoring is coordinated through efforts among state and federal agencies (e.g., NCWRC, NCDENR, USFWS, NCDMF, and NOAA Fisheries). Many of these recovery plans are available for download from the internet (https://www.fws.gov/program/recovery/recovery-plans).

The following sections outline monitoring needs for taxa groups and provide information about protocols that can be used. A summary of activities conducted in the state that are representative of collaborative efforts implementing local, regional, and state-wide monitoring activities is available in Appendix 7. In some cases, there may be multiple lead agencies involved in a given effort depending on location (e.g., Red-cockaded Woodpeckers on state- and federally owned public lands), but for simplicity, all agencies and organizations involved with the monitoring effort are listed.

7.3.1 Amphibians and Reptiles

Monitoring protocols for amphibians (especially wetland breeding anurans and salamanders) and reptiles (especially secretive snakes, priority turtles, and terrapins) developed by Partners in Amphibian and Reptile Conservation (PARC) need to be applied statewide. The North Carolina Partners in Amphibian and Reptile Conservation (NC PARC) can serve as the umbrella program in North Carolina for monitoring activities and data sharing. Coordinated nesting and stranding monitoring of sea turtles is critical and collaboration with partners (NOAA-Fisheries, USFWS) must be continued. (https://parcplace.org/reports/inventory-and-monitoring)

Habitats that should be included in amphibian and reptile monitoring efforts are rock outcrops, early successional habitats, Longleaf Pine forests, dry coniferous woodlands, pocosins, wet pine savannas, floodplain forests, all wetlands (including isolated wetlands, riparian corridors, and bogs), maritime forests, and estuarine systems (Mitchell 2002).

7.3.2 Aquatic Species

Many aquatic species in North Carolina (especially crayfishes and snail species) lack distribution, survey, and inventory data on which to build long-term monitoring efforts. For these groups, established monitoring priorities may not be attainable in the near term. For those taxa and species with adequate baseline data, there is strong need to improve long-term monitoring across species groups, habitats, and management actions. Important partners (statewide) to engage in aquatic species and habitat monitoring include the NC Division of Water Resources (NCDWR), NCMNS, and USFWS.

Three fundamental monitoring needs include:

- Long-term monitoring to identify population trends of SGCN and other priority species.
- Working with partners to establish appropriate protocols, schedules, and sites for long-term population monitoring.
- Monitoring for selected fishes and mussel species in western region river basins.

Special-purpose monitoring is needed to assess the performance of specific conservation actions, including stream restoration projects, hydropower remediation, and species enhancement and restoration projects. Nonnative species impacts need to be monitored, especially impacts by populations of potentially injurious nonnative species, and impacts to SGCN when specific nonnative species are identified within river basins.

7.3.3 Birds

It is important to continue ongoing monitoring coordination and adhere to recommendations developed by national and regional entities of NABCI, which includes PIF regional and state plans, Southeastern Migratory Bird Conservation Initiative, the North American Waterbird Conservation Plan, and Audubon NC. Coordination with the Continental Bird Monitoring Workgroup of the International Association of Fish and Wildlife Agencies (IAFWA) to strengthen the coordination of bird monitoring efforts is another priority.

Other strategies include:

- Continuing to participate in ongoing monitoring research the USGS Patuxent Wildlife Research Center is conducting to evaluate monitoring protocols for migratory birds (Erwin and Blohm 2016) (https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1142&context=usgspubs)

- Expanding current bird monitoring across the state, especially Monitoring Avian Productivity and Survivorship (MAPS) and migration banding stations, as training opportunities and technical assistance allow, in order to improve population status information for birds not adequately sampled under existing protocol (e.g., Breeding Bird Survey).

- Establishing 'surrogate' species where possible—species that may be representative of the habitat needs of a particular guild of species and are widespread enough to allow for population-level monitoring.

- Continuing established shorebird and waterbird monitoring efforts along all coastal and estuarine habitats, and expanding monitoring efforts for secretive marshbirds along estuarine, lake, and tidal swamp habitats using established protocol (Conway 2004).

- Continuing to monitor recovering species such as Bald Eagles and Peregrine Falcons in their key habitats.

Key species (or species groups) include Swainson's Warbler, Cerulean Warbler, Henslow's Sparrow, Bachman's Sparrow, other grassland specialists, Wayne's Black-throated Green Warbler, Painted Bunting, hawks, ground-nesters, cavity-nesters, and owls.

Key habitats include Longleaf Pine forests, floodplain forests, early successional habitats, high-elevation forests, pocosins, nonalluvial wetlands, and maritime forests. Ideally, monitoring should continue expanding across all habitats in order to strengthen trend data for all species.

7.3.4 Mammals

Standards and protocols for surveys and monitoring exist for some mammals and should be use to improve data matching with regional datasets. Establish and monitor bat numbers and species composition using reliable, reproducible techniques (Keeley et al. 2003). Conservation recommendations for monitoring Rafinesque's Big-eared Bat and Southeastern Bat include protocols for short- and long-term monitoring (BCI and SBDN 2013).

The North American Bat Monitoring Program (NABat) is an international, multiagency program to monitor bats at local to range-wide scales that will provide reliable data to promote effective conservation decision making and the long-term viability of bat populations (Loeb et al. 2015). Bat monitoring efforts in North Carolina (and throughout the southeast) need to be coordinated and data shared through a unifying body (e.g., SBDN, USFS, or USGS).

There is also a need for long-term survey and monitoring programs for all small mammals in North Carolina. Key habitats to focus monitoring efforts for small mammals are early successional habitats, dry coniferous woodlands, floodplain forests, and mesic and oak forests. For bats, key habitats for monitoring are caves, floodplain forests, mesic forests, and dry coniferous woodlands.

7.4 Habitat Monitoring

Given the varied habitat monitoring efforts ongoing across North Carolina, it is impossible to use a single trend to make a gross assessment of changes in habitat quality and quantity. A variety of indicators used in combination, however, could provide an indication of habitat and ecosystem conditions, such as forest conversion rates, land development rates, wetland losses, percent of impervious surface changes by watershed or river basin, and/or Impaired Waters listings. Monitoring needs for particular habitats are detailed throughout the natural community descriptions in Chapter 4 (Habitats).

Ongoing habitat monitoring conducted by NCWRC is largely associated with habitat restoration activities in order to gauge success in pre- vs. post-restoration treatments. Other efforts coincide with regular species monitoring (e.g., habitat monitoring is a component of biennial colonial waterbird monitoring). Habitat monitoring is a critical component of NCWRC projects such as:

- Game lands management activities
- Watershed enhancement program activities
- Waterfowl management areas/impoundments
- Hydropower remediation/Federal Energy Regulatory Commission (FERC) relicensing efforts

The North Carolina Division of Parks and Recreation (NCDPR) conducts natural resource inventory and monitoring in state parks and provides access to data for each park online https://auth1.dpr.ncparks.gov/nrid/public.php (NCDPR 2025). The guidelines have been used for baseline inventories of park resources, long-term monitoring studies, and cooperative research agreements with the agency.

Land in North Carolina is primarily in private ownership, which emphasizes the importance of refining and strengthening remote sensing techniques when direct access to lands may not be feasible. Satellite imagery Light Detection and Ranging (LIDAR) and digital elevation models, and geo-spatial data analysis tools have become more accessible and digital resources for statewide, regional, and national coverage are generally available through numerous sources. High-quality GIS data sets and imagery are available online from the NCDOT Business Partner Resources, Enterprise GIS data https://connect.ncdot.gov/resources/gis/Pages/default.aspx.

7.4.1 Terrestrial Habitat Monitoring Programs

NCNHP Natural Heritage Program Natural Areas (NHPNA) identifies terrestrial and aquatic sites that are of special biodiversity significance. A survey-based approach and indicator species are used to determine what habitat units constitute core areas and what priority rank they should receive. Indicator species are selected based on their sensitivity to the integrity and fragmentation of specific types of habitat. Landscape/Habitat Indicator Guilds are used for analysis and to monitor, as well as compare, the relative quality of these high-quality habitats and natural communities through time. Comprehensive natural areas surveys have been conducted for 92 counties in the state. Landscape Habitat Guild and county Natural Areas Inventory reports are available online from the NCNHP web page https://www.ncnhp.org/publications/natural-heritage-program-publications.

Coastal wetlands inventories and functional assessments as well as beach erosion rates are conducted by the NC Division of Coastal Management (NCDCM). Annual wetland and stream buffer losses and gains are tracked by NCDWR. Wetlands mitigation site monitoring is conducted by the NC Ecosystem Enhancement Program (NCEEP; a joint effort between the

NCDOT, the US Army Corps of Engineers [USACE], and the NC Department of Environment and Natural Resources [NCDENR]).

The USFS Southern Research Station's Southern Region Inventory, Monitoring, and Analysis group conducts periodic forest surveys in North Carolina (and nationwide) to provide statistics for measuring changes and trends in the extent and condition of forest land, associated timber volumes, and rates of timber growth, mortality, and removals. Forest Inventory and Analysis (FIA) data and tools are available online https://research.fs.usda.gov/srs/inventory. An overview of forest resources in North Carolina based on USFS inventory FIA program was published in 2014 and is available online https://www.srs.fs.usda.gov/pubs/ru/ru_srs101.pdf.

The Natural Resources Conservation Service's (NRCS) National Resources Inventory (NRI, https://www.nrcs.usda.gov/nri) program collects and disseminates information on a state, regional, and national level about the status, condition, and trends of soil, water, and related resources in the United States, including land use, erosion, nonfederal and federal lands inventory, cropland use, prime farmland, and wetlands and deepwater habitats. The 2017 NRI Summary Report is available online https://www.nrcs.usda.gov/sites/default/files/2022-10/2017NRISummary_Final.pdf.

Regional and statewide Gap Analysis Project (GAP) land cover data provides a potential source with which to assess land cover trends over time. Regional GAP efforts across the southeast (http://www.basic.ncsu.edu/segap/) do present potential opportunities for land cover change detection analyses in the future.

NatureServe provides a national assessment of ecological landscape conditions to model the effects of landscape fragmentation on biodiversity. The NatureServe Modeling Landscape Condition tool produces a remote assessment index of ecological conditions using available spatial data and user applied knowledge and assumptions about stressors and relative ecological condition for sites of interest. https://www.natureserve.org/products/modeling-landscape-condition.

Data Basin (https://databasin.org) is a science-based mapping and analysis platform that provides collaborative information for sharing and analyzing data and information. An example for North Carolina is the Southeast Aquatic Resources Partnership (SARP) Riparian Assessment (2011, https://southeastaquatics.net/resources/pdfs/Riparian%20Assessment%20White%20Paper%20-%20final.pdf/at_download/file) data set that assesses the current condition of riparian habitat within a 30-meter buffer along streams and rivers throughout the SARP region and provides a baseline against which to measure future progress toward achieving riparian habitat conservation and restoration goals. Another example is the series of Sea Level Affecting Marshes Model datasets that illustrate potential changes in marsh and coastal environments due to long-term sea level rise (SLR)(https://coast.noaa.gov/digitalcoast/tools/slamm.html). Data Basin is also a resource for indicator species models developed by SECAS.

LANDFIRE is a program that provides over 20 national geo-spatial data sets for vegetation type and cover, fuel loads, and land disturbance. Vegetation is mapped using predictive landscape models based on extensive field-referenced data, satellite imagery and biophysical gradient layers using classification and regression trees. LANDFIRE uses vegetation products (i.e., NatureServe's Ecological Systems classification) to create fuel and fire regimes data. The NatureServe Explorer provides descriptions for each ecological system including species, distribution and classification information. Available online https://www.landfire.gov.

7.4.2 Aquatic Habitats Monitoring

Strategies for monitoring various community types include expanding monitoring efforts on public lands, initiating monitoring protocols on key private lands (especially industrial forest land), and collaborating with key partners (e.g., USFS, DOD, USFWS) and private timber companies.

NCDWR conducts extensive Index of Biotic Integrity (IBI) monitoring for their basin-wide planning efforts, including lake assessments, phytoplankton monitoring, physical and chemical water quality monitoring, and aquatic toxicity monitoring (as well as fish and benthic macroinvertebrate monitoring). NCDWR also designates and maintains a list of impaired waters (305(b) and 303(d) Reports) and tracks percent impervious surfaces by basin.

Where dams regulate stream flow, long-term monitoring and research are needed to determine if existing minimum flow requirements are adequate to support aquatic communities and not just available habitat. The data generated from monitoring can be used to establish thresholds for flow requirements (i.e., ecological flows) necessary to sustain all riverine and riparian processes. This is especially important where there is a lack of biological and hydrological data and knowledge about synergistic influences such as water velocities, water quality, salinity, temperature, and DO.

NOAA Fisheries conducts submerged aquatic vegetation (SAV) mapping and monitoring in coordination with USEPA and NCDWR. According to the Coastal Habitat Protection Plan (CHPP) (Deaton et al. 2010), however, no quantified trends analysis is available for the state, as currently there is only one complete SAV mapping dataset (1983–91) (Street et al. 2004). CHPP (Deaton et al. 2010) includes a broad recommendation to coordinate and enhance water quality, physical habitat, and fisheries resource monitoring from headwaters to the nearshore ocean (key partners include NCDMF, NCDWR, NCDCM, NCWRC).

Recommendations in CHPP call for a site-specific, compound-specific monitoring program to assess potential impacts of endocrine-disrupting chemicals (EDCs) in North Carolina’s estuaries.

Estuarine monitoring of the concentration and prevalence of priority chemicals of concern, with a possible focus on the Neuse River system and research on the effects of EDCs on fishery species, particularly blue crab, oysters, and fish, should be a priority. Analysis and monitoring of long-term trends in estuarine salinity and temperature is needed to evaluate the impact of SLR and climate change on fishery resources in North Carolina. It is also important to quantify the episodic and chronic effects of trawling on nursery functions in different estuarine settings. CHPP also identifies a number of key monitoring needs across specific coastal fisheries habitats. These are:

Water column

- Conduct stream flow monitoring and research to assess the impact of freshwater withdrawals on water column habitat and fish populations in affected river basins.
- Continue coastal research and monitoring in order to improve our understanding of the processes of hypoxia and anoxia and the effect on fish populations.
- Implement more-detailed monitoring to assess the extent oceanfront septic systems are causing degradation to nearshore coastal waters.
- Identify basic water quality parameters (flow, temperature, pH, and DO) for wastewater permit applicants to monitor. If the data indicate the presence of pollutants in the discharge water, toxic chemical monitoring and toxicity testing should be required. Nutrients and ammonia should be monitored if a mass balance approach indicates excess nutrients. Biological monitoring of the macrobenthic community should be required in facilities discharging more than 0.5 million gallons per day.
- Monitor port waters for algal blooms and exotic species until treatment of ballast water is required and implemented in order to minimize risks of introduction elsewhere.

Submerged aquatic vegetation (SAV)

- Make certain portions of the Neuse and White Oak river basins high priorities for SAV and water clarity monitoring. Since some SAV is present in the shallow portions of the Neuse and portions of the White Oak river basins, and water quality data indicate some level of eutrophication exists, nutrient levels may be limiting survival or expansion of SAV in these areas.
- Monitor submerged grasses on a regular basis to assess the status of wasting disease and its association with human-induced stresses.
- Evaluate whether current sampling locations and methods are sufficient in estuarine waters to monitor the suitability of water quality conditions for SAV survival and growth.
- Verify recovery and determine if there is a spatial pattern of that recovery in areas where SAV restoration and enhancement projects have been implemented. If there is a pattern, special monitoring and protection should be afforded to those core areas from which SAV begins its recolonization.

Wetlands

- Implement additional monitoring to better assess impacts where extensive areas of wetlands were drained.
- Given a limited time to monitor for restoration success, criteria should focus on identifying trajectories of functional development that include wetland soil development.
- Conduct a study to quantify the cumulative impact of shoreline hardening on wetland vegetation and habitat-mediated predator–prey interactions in NC estuarine waters.

Soft bottom

- Gather more information to understand the consequences on the estuarine food web and to what extent anoxia is impacting the soft bottom community.
- Implement adequate monitoring of the effects of beach nourishment on the soft bottom community and associated surf fish populations as the number of beach nourishment projects increase. This should be required for all large-scale or long-term nourishment projects.
- Conduct long-term monitoring in combination with management actions that reduce discharge concentrations to determine effectiveness and future management needs.

Hard bottom

- Monitor hard bottom communities to assess the level of impact from trawling activity, particularly shrimp trawls in the southern portion of the coast.
- Initiate monitoring of hard bottom communities and coordinate with UNC-Wilmington or other ocean water quality monitoring programs to determine the effects of estuarine water quality, particularly nutrient and sediment loading, on hard bottom communities.

Chapter 8
Review, Coordination, Revision, and Next Steps

8

Chapter 8. Review, Coordination, Revision, and Next Steps

***Required Element 6**: Descriptions of procedures to review the WAP at intervals not to exceed 10 years.*

***Required Element 7**: Plans for coordinating the development, implementation, review, and revision of the WAP with federal, state, and local agencies and Indian tribes that manage significant land and water areas within the State or administer programs that significantly affect the conservation of identified species and habitats.*

***Required Element 8**: Congress has affirmed through the World Climate Research Program (WCRP) and State the Wildlife Grant, and other guidance to states and partners, that broad public participation is an essential element of developing and implementing these Plans, the projects that are carried out while these Plans are developed, and the Species of Greatest Conservation Need (SGCN) and Congress has indicated that such programs and projects are intended to emphasize.*

8.1 Introduction

The 2015 NC State Wildlife Action Plan (SWAP) outlined steps for implementation and monitoring of its priorities as well as recommendations and measures for review and revision of the document (see Chapters 6 and 8) (NCWRC 2015). Since publication of that Plan, new guidance has been provided by the US Fish and Wildlife Service (USFWS) and the Association of Fish and Wildlife Agencies (AFWA) concerning its review, coordination, revision, and content. The 2017 Administrative guidelines (USFWS 2006) and subsequent review and revision guidance (USFWS 2017) from USFWS outlined steps and requirements for a mandatory 10-year comprehensive review (and revision) but allowed for intermediate minor or major updates or revisions. Other guidance has been described in Chapter 1 of this document, including a recommendation to incorporate climate change during revision. This 2025 SWAP revision complies with the requirement to conduct a comprehensive review and revision at an interval not to exceed 10 years.

Using recommendations from various workshops, several committees, working groups, and teams were organized and tasked with guiding the revision process. The SWAP Steering Committee, Technical Team, Taxa Teams, *Ad Hoc* Stakeholder Advisory Committees, and other special topic workgroups are key components, and their membership reflects several agency and organization partners as well as private citizens (stakeholders). The 2025 SWAP revision was accomplished through the efforts of numerous individuals participating in virtual and in-person meetings held over a two and a half year period. A list of key members, participating agencies, and the structure of the committees and workgroups involved in the revision process and letters of support from partner groups are provided in Appendix 1.

8.2 Review and Revision Steps: 2025

North Carolina's comprehensive review and revision began in 2021, when a letter of notification was sent to the USFWS notifying the agency that the 10-year review and revision process was being initiated. The SWAP Steering Committee was convened by the Wildlife Action Plan Coordinator (NCWRC or Commission). The Steering Committee was composed of senior leadership from NCWRC and a conservation partner who is a member of the NCWRC's Nongame Wildlife Advisory Committee (NWAC). The Steering Committee provided policy and decision oversight, ensuring the SWAP followed USFWS guidance and requirements while also representing NCWRC's mission and the conservation priorities of partners, stakeholders, and interested citizens statewide.

8.2.1 Work Groups

Several work groups were convened throughout the process and tasked with considering specific topics and actions relevant to the SWAP revision. A work group was formed early in the review process to reevaluate the SGCN evaluation methodology and considered whether modifications were needed or whether the evaluation process should be replaced with another method. The final recommendation was to retain the current methodology and allow each taxa team to adjust the scoring parameters used to determine SGCN. This decision was made because the evaluation methodology is applied to each taxa group the same way whereas each taxa group has unique life histories. For example, the Bird Taxa Team members consider whether a species is in our state year-round, only during its breeding season, or only for winter habitat use. In contrast, amphibian populations have a completely different life history and are present year-round. However, amphibians have different breeding requirements and are less likely to move great distances in order to find suitable breeding habitat.

Another work group was convened to consider updating the methodology and process for determining Conservation Opportunity Areas (COAs) based on updated data and improved analysis capabilities. The COA process used for the 2015 SWAP was based on Southeast GAP data which addressed only terrestrial wildlife and did not cover all SGCN species. The work group recommended using the SECAS Blueprint data as a basis for analyzing opportunity areas and to consider where current or recent known populations of wildlife exist (element occurrences) as tracked by the NCNHP. NCWRC worked with SECAS staff to develop an analysis tool that uses data that is monitored and updated annually, allowing the COAs to be updated on a similar time scale.

8.2.2 Technical Team

A technical team of senior NCWRC biologists was convened and tasked with providing review and recommendations for content in the revised SWAP. The Technical Team functioned as a peer-review panel for the Wildlife Action Plan Coordinator by considering whether best practices were applied throughout the revision process.

8.2.3 Taxa Teams

The largest effort was made by the Taxa Teams comprised of taxonomic and species experts from numerous federal and state agencies and partner organizations. Eight teams were convened in 2022 and tasked with completing an evaluation of North Carolina fish and wildlife species to determine conservation concern, knowledge gaps, and management needs over the next 10 years.

The Taxa Teams used the evaluation methodology established for the 2015 SWAP and used for the 2020 SWAP Addendum 1. The results of the evaluation were used by the teams to update the SGCN lists for the eight taxonomic groups they evaluated. See Chapter 3 NC Species for additional information about each taxa group evaluated and the final SGCN recommendations.

Each Taxa Team held numerous onsite and virtual meetings in 2023 and 2024 that focused on collaborative evaluations and determination of SGCN and other priority species. Potential peer reviewers who are species experts were identified through recommendations from taxa team members and through review of university research staff familiar with North Carolina's species. Peer-reviewers were invited to review Taxa Team evaluation results and submit comments for incorporation into the SGCN selection process. Comments received were reviewed by the appropriate Taxa Team and incorporated as determined by the Team. The final evaluation results have been incorporated into Chapter 3 NC Species and the evaluation data is available in Appendix 3.

8.2.4 Technical Review and Revision

In 2024 the Wildlife Action Plan Coordinator worked with WRC biologists and staff from the NCNHP and the NCDACS Plant Conservation Program to review natural communities described in Chapter 4 Habitats. Revisions to this chapter included addition of a new community description for non-tidal freshwater marsh and community association updates to incorporate the newly published Classification of the Natural Communities of North Carolina, Fourth Approximation (Schafale 2024). The collaboration included review of updates to the NCNHP's climate vulnerability assessment reports (NCNHP 2010, 2024). The NCNHP vulnerability assessments describe how climate change and other impacts are expected to affect fish and wildlife species and compare and rank climate change against other categories of threats. Recommendations developed during the collaborative review identify needs for survey, monitoring, research, management, programs, and partnerships to address the impacts. These recommendations have been incorporated into natural community descriptions for aquatic, wetland, and terrestrial systems (see Chapter 4 of this Plan).

8.2.5 Public Outreach, Review and Comment

Outreach information was distributed statewide through the NCWRC's media and public communication network. Four flyers were published and sent to hundreds of thousands of constituents registered in the Commission's email distribution system. Each notice described components of the SWAP revision and asked for participation through public comments. Few comments were generated by the email campaign and only two constituents provided input on the revision process or SWAP content.

The draft revised SWAP was made available for public review in electronic format and comments were received from May 27 to June 30, 2025. The public review was intended to offer private citizens and those individuals from organizations not otherwise involved in the revision process an opportunity to review and provide comments and to offer new information for consideration. An announcement requesting the public's assistance was distributed statewide to news media outlets and was prominently featured on the NCWRC website. The draft document was available in PDF format, which could be viewed in a number of ways: online in a web browser using a variety of electronic devices (computer, mobile phone, tablet, e-reader); after downloading to a local storage device for offline viewing on an electronic device; or by downloading and then printing the pages. The electronic version of the announcement provided a hyperlink to the NCWRC public review website and the print version of the announcement provided a URL address to the website. Both versions included telephone and email contact information to request additional information, report problems or difficulties accessing the draft Plan, or ask questions. The website provided a link to an electronic form that automatically submitted comments to NCWRC. Each electronic submission received an automatic email response with a message thanking the individual for their participation and comments and providing them with a record of their comment(s).

Google Analytics was used to track the number of times the public review website was visited during the comment period. Software was used to compile a report of all electronic submissions made from the public review website.

All comments in their entirety and the actions taken to address the comments will be presented to the NCWRC Commissioners during a Committee of the Whole meeting in the summer of 2025. Afterward, Commissioners will be asked to approve a resolution to endorse the draft plan and submission of the document to the USFWS Regional Review Team to meet the required 10-year comprehensive review and revision.

8.3 Future Review and Revision

Review, revision and maintenance of the WAP will require the continuation of all the activities that went into development of the document (e.g., communication and coordination with partners, database updates), as well as the management of new activities (e.g., website updates, project implementation, evaluation, monitoring, adaptive management process).

Maintenance activities will be primarily coordinated by NCWRC but will require regular communication with partners and stakeholders. Considering the electronic format of the Plan, it is anticipated that future revision will be a straightforward and streamlined process.

Semi-annual reporting on projects and annual evaluation of project accomplishments by program supervisors are used to assess adaptive management needs on a project-by-project basis. Commission program supervisors and administration will assess individual project performance to determine if they are meeting program-level strategies on par with the conservation actions called for in the Plan. Program supervisors will work with staff and partners to review the results of individual projects and as needed, will use the adaptive management process to revise projects. Project descriptions and updates will be entered into the USFWS database for Tracking and Reporting on Actions for Conservation of Species (Wildlife TRACS) and shared with partners through news media releases, magazine articles, report summaries, or other methods to keep them abreast of project progression and highlights.

Biologists in the NCWRC's aquatic and wildlife diversity programs publish quarterly summaries on projects funded through the SWG program. These reports are available in PDF format for 2012-2025 on the web page https://www.ncwildlife.gov/wildlife-habitat/conservation-restoration-programs/wildlife-diversity-program/wildlife-diversity-reports. Annual reports for older 2007-2011 NCWRC projects funded through the SWG program are also available in PDF format on the web page.

When any type of SWAP revision is to occur, the SWAP Steering Committee and Technical Team will be convened and any other appropriate teams will be formed to complete the effort. Draft material developed for SWAP revisions will be peer reviewed for technical content, made available for public review and comment, and approved by the Commission's Committee of the Whole for incorporation into the Plan before submittal to USFWS for approval.

8.3.1 Short-term Revisions

There are any numbers of issues that can result in a need to revise the document in the short term and these are expected to be handled as either a minor or major revision to the WAP. Examples include

- updating the scientific name of a putative species when identification is confirmed and a species description has been published;
- changes to the federal or state listing status of a species;
- gaining new information through surveys, research, and monitoring that will influence management actions;
- reprioritization of activities following accomplished tasks;
- flaws in how the Plan serves to guide implementation activities that need to be eliminated; or

- correcting typographical errors in the text or editing images and graphics to correct errors.

A short-term revision of the SWAP may be needed in late 2025 after the Plan has been submitted to the USFWS Regional Review Team. NCWRC is currently working with internal GIS staff to add the new online analysis tool for COAs developed through collaboration with SECAS. This revision to the SWAP is in process and if completed before the final document is submitted it will be incorporated into the Plan. If the task is not completed in time to include with the SWAP submittal the work will be submitted to the USFWS Regional Review Team as a major revision.

8.3.2 Planned Interim and Comprehensive Revision

A comprehensive review and revision will occur within the required 10-year interval based on the publication date of the last comprehensive review and revision. There are many dynamics that will influence future needs and revision requirements; however, based on current USFWS requirements and the submittal of this SWAP revision, the next comprehensive revision will be due in 2035.

Interim review and revision of the WAP will occur as needed but is expected at no more than three- to five-year intervals. Interim revisions will depend on the completion and results of significant projects and as determined by the SWAP Steering Committee and Technical Team to be warranted. These types of revisions are expected to be submitted to USFWS as either minor or major revisions to the Plan. Other projects that may be included during an interim revision in order to integrate project results or critical information include (but are not limited to) the following:

- Research that incorporates North American Bat Conservation Partnership (NABCP) monitoring recommendations into regional bat monitoring efforts to accurately document populations of priority bat species so better estimates can be determined.
- New or improved approaches to internal supporting processes (e.g., species prioritization, threat assessment) that are worth the investment of revision before an unwieldy process becomes tradition.
- Expansion of the Plan to include species or groups (e.g., insects) that were secondarily addressed and revision will make a more truly comprehensive document.

Since it takes considerable time to assess changes related to implementation of conservation activities and to collect and analyze new information useful in making management decisions, reevaluation of SGCN and priority species is planned to be part of the interim review and revision process, based on recommendations from the SWAP Technical Team or the Taxa Teams. However, should immediate declines (e.g., White-nose Syndrome and bat population trends) become apparent for any species, taxonomic group, or species guild the SWAP Steering Committee can convene a Taxa Team to conduct an immediate reevaluation. Revision of any

SGCN and priority species list will be submitted to the USFWS as either a minor or major revision of the SWAP, depending on the methodology used.