Fisheries resources of the Black River

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Abstract. The N.C. Wildlife Resources Commission conducted a baseline survey of fish populations in the Black River in the summer of 1962. Subsequent surveys focused primarily on sport fish species. A systematic boat-mounted electrofishing survey was conducted in the Black River in 2015 and 2016 to elucidate the effect of hand-crank electrofishing on introduced catfish populations. The purpose of this report is to summarize data on all collected species and provide comparisons to the 1962 baseline survey. Overall, 1,867 fish representing 36 species were collected, including 22 Inland Game Fish and 7 nonnative species. Four Species of Greatest Conservation Need as identified in the N.C. Wildlife Action Plan were observed in 1962 but were not collected in 2015–2016. Fifteen species not observed in 1962 were collected in this survey. Bluegill, Redear Sunfish, Largemouth Bass, and Redbreast Sunfish were the most abundant Inland Game Fish, while Flathead Catfish, Blue Catfish, Channel Catfish, and Bowfin were the most abundant nongame fish. No native catfish were observed, despite their historical abundance and diversity. Introduced species, habitat and water quality degradation, and climate change threaten the Black River's fisheries resources and are the greatest challenge to restoring and managing native sport fish species.

The Black River's freshwater fisheries remained largely undescribed until the North Carolina Wildlife Resources Commission (NCWRC) surveyed it in the summer of 1962 as part of a systematic inventory of ichthyofauna in the state's river basins (Louder 1963). The Black River was described as one of the best fishing waters in the Cape River Basin, supporting excellent populations of Largemouth Bass *Micropterus salmoides*, Chain Pickerel *Esox niger*, and Redbreast Sunfish *Lepomis auritus* (Louder 1963). Fish (1968) later reported excellent fishing for Chain Pickerel, Largemouth Bass, catfish, Yellow Perch *Perca flavescens*, and sunfish. Following angler reports of declining sport fish catch in downstream portions of the Black River, investigations were conducted to evaluate the impact of gill nets (1977–1978; NCWRC unpublished data) and to characterize centrarchid abundance and size structure (Ashley and Rachels 1989). Ashley and Rachels (1998) documented a declining Redbreast Sunfish population during surveys conducted from 1994–1997. An index of biotic integrity survey using boat electrofishing was conducted annually from 1995–2005 (except 1999 due to Hurricane Floyd), and no trends in species diversity or abundance were apparent (NCWRC unpublished data).

In 2015 and 2016, NCWRC conducted a survey to assess the effects of hand-crank electrofishing on vital rates and abundance of fish populations in Southeastern North Carolina. The primary goal, assessing impacts of hand-crank electrofishing on nonnative catfish populations, was addressed by Fisk et al. (2019). The following report is a general summary of the fisheries resources in the Black River in 2015–2016. Comparisons are made to the catch composition reported by Louder (1963). Age structure, growth, and mortality are contrasted with other rivers assessed during the 2015–2016 hand-crank electrofishing project.

Methods

Study site. The Black River is a free-flowing coastal plain stream (Strahler Order = 5) that begins at the confluence of Six Runs and Great Coharie creeks near Garland, NC. It flows approximately 108 km to its confluence with the Cape Fear River near Navassa, NC. The only major tributary of the Black River is the South River, which joins the Black River near river kilometer (RKM) 58. The Black River watershed (U.S. Geological Survey hydrologic unit 03030006) drains 4,077 km^2 and is 33% agriculture, 23% forested, 22% wetland, 16% grassland/shrub, 5% developed, and 1% open water (USDA 2021). The watershed has 529 active permitted swine feeding operations and the highest density of permitted swine in North Carolina (612 swine/km^2; NCDWR 2021a). As of 2021, there are 1 major and 13 minor NPDES permitted discharges (NCDWR 2021b). Additionally, there are 14 public municipal stormwater systems rated in fair or poor condition that utilize no best management practices (NC One Map 2021). The Black River carries an Outstanding Resource Waters classification (ORW) for its entire length (NCDENR 2004).

A stratified-random survey design was employed to collect fish in May/June 2015 and May/June 2016. Two strata were of interest to the primary goal of the project: a stratum where hand-crank electrofishing is allowed (RKM 0–RKM 52) and a stratum where hand-crank electrofishing is prohibited (upstream of RKM 52). A 10-km buffer was maintained between the two strata to minimize the probability of sampling fish that utilize both strata. Five 0.5-km sites were randomly selected in each stratum (10 sites total) to target all fish species. Ten additional 1-km sites were randomly selected in each stratum (20 sites total) to target catfish. For the purpose of this report, strata sampling data were aggregated and were given no further consideration.

Field collection. In the 10 sites targeting all fish species, boat-mounted electrofishing (Smith-Root 7.5 GPP; 120 Hz; 4,000–8,000 W) was utilized along each shoreline (1-km sample). All fish were collected as encountered, and voucher specimens were preserved in buffered formalin if identification could not be ascertained in the field. Low-frequency boat-mounted electrofishing (Smith-Root 7.5 GPP; 15 Hz; 1,800–2,500 W) was used in the 20 sites targeting catfish. A chase boat was employed to increase catch rates; boats proceeded downstream through the 1-km sample site at 4–8 kph, and all ictalurids were collected as encountered.

For both sampling methods, all collected fish were measured for total length (TL; mm) and weight (g). Otoliths were removed from up to 10 fish per 2-cm size-class for the following species: Flathead Catfish *Pylodictis olivaris*, Blue Catfish *Ictalurus furcatus*, Channel Catfish *I. punctatus*, Bluegill *Lepomis macrochirus*, Largemouth Bass, Redbreast Sunfish, and Redear sunfish *L. microlophus*. Fish in young-of-year size-classes were assumed age 0 following Carlander (1969, 1977). Catfish otoliths were prepared according to Nash and Irwin (1999) and Buckmeier et al. (2002) and read by two independent readers. Centrarchid otoliths were prepared following Long and Grabowski (2017) and were also read by two independent readers. Age disagreements were resolved or individuals were removed from the age dataset following a concert read. Multinomial age-length keys (Ogle 2015) were constructed and individual ages were assigned following the method of Isermann and Knight (2005).

Data analyses. Catch of each species was compared to Louder (1963). Relative abundance was indexed as catch-per-unit-effort (fish/h). Density plots were used to summarize size structure for species with five or more collected individuals. Relative frequency plots were used to examine age-class composition.

Growth was modeled using a Bayesian methodology and the von Bertalanffy growth function (VBGF; Beverton and Holt 1957; Doll and Jacquemin 2019). The von Bertalanffy growth function is expressed as

$$L_T = L_\infty\left[1 - e^{-K(T-t_0)}\right],$$

Where L is length, L_∞ is the mean length of the oldest age class (asymptotic length), K describes how quickly mean length at age approaches L_∞, t_0 represents the age when mean fish length is zero, and T denotes age. Informative priors for L_∞ were derived using the NCWRC BIODE database. Specifically, each species had a prior for L_∞ that was Gaussian distributed with a mean and standard deviation calculated from the maximum total lengths of each BIODE project with total length data collected between 2000 and 2014. Projects that did not have sufficient information (i.e., catch of sufficiently large individuals for a given species) were excluded from developing the prior. Priors for the other model estimated parameters (K and t_0) were weakly informative and constant across species [$K \sim$ Cauchy(0.25, 0.25) with a lower bound of zero; $t_0 \sim$ Cauchy(0, 1)]. Growth models were implemented using Stan (Stan Development Team 2019) and interfaced through R package “brms”. All growth models used 4 concurrent Markov chain Monte Carlo (MCMC) chains, each with 4,000 total iterations, no thinning, and a 2,000 iteration burn-in period. Models were deemed to have reached approximate convergence if visual examination of trace plots indicated the chains were stationary and mixed, and the potential scale reduction factor ($\hat{R}$) of each estimated parameter was less than 1.1 (Gelman and Shirley 2011; Doll and Jacquemin 2019). The fit of each model was assessed by conducting a posterior predictive check (Doll and Jacquemin 2019).

Poisson log-linear models were used to estimate instantaneous total mortality (Z; Millar 2015). Poisson regression is the most robust catch-curve method to assumption violations, which include: recruitment is constant through time, mortality is constant through time and across ages, all fish are equally vulnerable to the sampling gear, and the age composition is estimated without error (Nelson 2019). Age at recruitment to the catch-curve was considered the modal age plus one year (*i.e.*, Peak +1; Smith et al. 2012; Nelson 2019). All data analyses were conducted using R 4.0.

Results

Catch. A total of 1,867 individuals representing 36 species were collected (Table 1). Bluegill, Bowfin *Amia calva*, Flathead Catfish, Largemouth Bass, Redbreast Sunfish, Redear Sunfish, and Spotted Sunfish *Lepomis punctatus* were all collected in 100% of the sample sites in which they were targeted. Bluegill, Redear Sunfish, Largemouth Bass, and Redbreast Sunfish were the most abundant Inland Game Fish, while Flathead Catfish, Blue Catfish, Channel Catfish, and Bowfin were the most abundant nongame fish. Relative abundance of Bluegill and Redbreast Sunfish was greatest in upstream samples, while Largemouth Bass and Redear Sunfish did not exhibit strong spatial gradients (Figure 2). Channel Catfish were most abundant in upstream samples, while Blue Catfish were most abundant near the confluence with the Cape Fear River and were completely absent in samples upstream of RKM 36 (Figure 3). Bowfin and Flathead Catfish did not exhibit strong spatial gradients.

The high frequency electrofishing site with the greatest species diversity was RKM 88 with 24 species collected, while RKM 17 had the fewest collected species (14; Table 2). Diversity in low frequency electrofishing sites was patchy, with RKM 6–18 yielding all three nonnative ictalurids and many upstream sample sites with only Flathead Catfish collections (Table 3).

Fifteen species were collected that were not present in the 1962 survey by Louder (1963). Among those are seven nonnative species, four of which were likely introduced after the 1962 survey (Blue Catfish, Flathead Catfish, Grass Carp *Ctenopharyngodon idella*, and “Spotted Bass” *Micropterus* sp.; see Table 1). The following species were observed in the 1962 survey but were not observed in 2015–2016: American Shad *Alosa sapidissima*, Banded Pygmy Sunfish *Elassoma zonatum*, Banded Sunfish *Enneacanthus obesus*, Blackbanded Sunfish *Enneacanthus chaetodon*, Broadtail Madtom *Noturus n.* sp., Eastern Mudminnow *Umbra pygmaea*, Flat Bullhead *Ameiurus platycephalus*, Margined Madtom *Noturus insignis*, Sandbar Shiner *Notropis scepticus*, Sawcheek Darter *Etheostoma serrifer*, Swamp Darter *Etheostoma fusiforme*, Tadpole Madtom *Noturus gyrinus*, Tessellated Darter *Etheostoma olmstedi*, and White Catfish *Ameiurus catus* (Table 1). Many of these species are difficult to sample using boat-mounted electrofishing due to their small size, physiology, or habitat preference. However, four native ictalurid species were collected by Ashley and Rachels (1989) using boat electrofishing methodologies similar to the current study in the main stem Black River. The four Species of Greatest Conservation Need (SGCN) as identified in the N.C. Wildlife Action Plan (NCWRC 2015) observed in 1962 were absent in 2015–2016 (Table 1).

Size structure. Twelve Inland Game Fish and 17 nongame species had at least 5 collected individuals and were described using density plots. Chain Pickerel were the largest Inland Game Fish, followed by Largemouth Bass, Black Crappie *Pomoxis nigromaculatus*, and Yellow Perch (Figure 4). Redear Sunfish were the largest lepomid, followed by Bluegill, Warmouth *L. gulosus*, Redbreast Sunfish, Spotted Sunfish, Pumpkinseed *L. gibbosus*, and Dollar Sunfish *Lepomis marginatus* (Figure 4). Flathead Catfish were the largest nongame fish, followed by Longnose Gar *Lepisosteus osseus*, Common Carp *Cyprinus carpio*, and Bowfin (Figure 5).

Age structure. Bluegill ranged from age 0 to age 5, with age-0 to age-2 fish comprising 71% of the population (Figure 6). Blue Catfish ranged from age 0 to age 11, with age-4 and younger fish comprising 96% of the population (Figure 6). Channel Catfish ranged from age 1 to age 12, with 83% of the population age 4 and younger (Figure 6). Flathead Catfish ranged from age 0 to age 19 with 80% being age 4 and younger (Figure 6). Largemouth Bass ranged from age 0 to age 8, with 81% of the population age 3 or younger (Figure 6). Redbreast Sunfish ranged from age 0 to age 5, but 88% were age 2 or younger (Figure 6). Redear Sunfish ranged from age 0 to age 9, with 83% age 3 or younger (Figure 6).

The oldest Blue Catfish in this study (11) is significantly less than the maximum age reported from the Cape Fear River (21; Rachels and Fisk 2021a). Channel Catfish age structure and maximum age was similar to the Lumber River (Rachels and Fisk 2021b), and the maximum age approaches the maximum age reported from South Carolina (age 14; Stevens 1959). Flathead Catfish age structure was similar to the Waccamaw River (Rachels and Fisk 2021c), with relatively few older (>age 10) individuals. The maximum age and age structure of Largemouth Bass was similar to other coastal NC populations (Potoka and McCargo 2016; Smith and Potoka 2017, 2020; Rachels and Fisk 2021a, 2021b, 2021c). The Bluegill maximum age (5) was less than the maximum age reported in North Carolina (age 7 in Richardson and Ratledge 1961 and Rachels and Fisk 2021a) but identical to the Lumber and Waccamaw rivers (Rachels and Fisk 2021b, 2021c). The Redear Sunfish maximum age in this study (9) is the oldest reported age for the species in North Carolina, although Redear Sunfish have been reported to age 12 in its native range (Sammons et al. 2006). Redbreast Sunfish maximum age was similar to historical reports from the Black River watershed (max age = 6; Davis 1971) but was truncated relative to the Lumber River (max age = 8; Rachels and Fisk 2021b).

Growth. Approximate convergence was achieved for all von Bertalanffy growth models, and graphical posterior predictive checks indicated the models adequately replicated the observed data. The Bluegill VBGF was very precise throughout the age range (Figure 7). The Blue Catfish VBGF was very precise through age 4; however, the L_∞ was 471 mm greater than the largest observed Blue Catfish (Table 4; Figure 7). Channel Catfish length-at-age was highly variable and resulted in an imprecise VBGF after age 5 (Figure 7). The Flathead Catfish VBGF model fit was very precise for younger ages with increased uncertainty after age 11 (Figure 7). The combination of L_∞ and K (Table 4) suggests the Black River Flathead Catfish population has faster growth than other southeastern NC rivers (Rachels and Fisk 2021b, 2021c), with substantially faster growth than the adjoining Cape Fear River population (Rachels and Fisk 2021a). The Largemouth Bass VBGF was reasonably precise with increasing variability at older ages (Figure 7). The Redbreast Sunfish VBGF was imprecise (Figure 7) and may have been heavily influenced by the prior probability distributions (e.g., Figure 8). The Redear Sunfish VBGF was very precise through age 5 (Figure 7).

Mortality. Bluegill total instantaneous mortality was relatively high and approximately the same as mortality in the adjacent Cape Fear River population (Table 5; Rachels and Fisk 2021a). Mortality rates for Blue Catfish and Flathead Catfish were almost twice that of the Cape Fear River populations (Table 5; Rachels and Fisk 2021a). Channel Catfish total instantaneous mortality was comparable to the Lumber River and less than the Waccamaw and Cape Fear rivers (Rachels and Fisk 2021b, 2021c). Largemouth Bass total instantaneous mortality was greater than other southeastern NC rivers (Rachels and Fisk 2021a, 2021b, 2021c). Redbreast Sunfish experienced the highest level of mortality compared to other species in the Black River and was almost twice as high as Lumber River Redbreast Sunfish (Table 5; Rachels and Fisk 2021b). Redear Sunfish mortality estimates were comparable to the Lumber River population (Table 5; Rachels and Fisk 2021b).

Discussion

The aquatic community has undergone significant change as only 21 species were collected in both the 1962 baseline survey and the 2015–2016 survey. Most notably, no native catfish were collected. Native catfish species are vulnerable to Flathead Catfish predation (Guier et al. 1984; Thomas 1993), and Flathead Catfish appear to have extirpated White Catfish from the lower Cape Fear River Basin (Rachels 2021).

Comparisons are made between the sample composition in this survey and the 1962 survey by Louder (1963). These comparisons are somewhat tenuous given the different sampling gears utilized by the surveys. Nonetheless, the current survey suggests a significant decline in native ictalurids since the Louder (1963) survey. Additional surveys using a broad range of sampling gears, coupled with alternative analytical techniques (e.g., occupancy modeling), may aid in elucidating the current status of native ictalurids and other SGCN in the Black River.

Many issues threaten the Black River's fisheries resources; however, introduced species have likely had the greatest negative impact in recent history. Flathead Catfish have well-documented negative impacts on native sunfish and catfish (NCWRC 2019). Flathead Catfish were first introduced into the Black River sometime following stocking in the Cape Fear River Basin in 1965 (NCWRC 2019). Fourteen years after their introduction, Guier et al. (1984) found that native ictalurid populations had significantly declined in the adjacent Cape Fear River and were the most prevalent prey item in Flathead Catfish stomachs. Rachels (2021) examined the long-term changes in the Cape Fear River Basin's (including the Black River watershed) ictalurid assemblage and speculated that White Catfish may be extirpated from the entire river basin downstream of Jordan Lake. Other native ictalurids have been collected in some tributaries in the lower Cape Fear River basin that are devoid of Flathead Catfish (Rachels 2021; NCWRC unpublished data); preventing Flathead Catfish expansion should be a priority for native sport fish conservation. Similarly, Blue Catfish were stocked in the Cape Fear River in 1966 (and migrated to the Black River sometime thereafter) but occupy a lower trophic position and are not believed to have affected native sport fish species as significantly as Flathead Catfish (Scharf and Belkoski 2020). Nonetheless, negative impacts from Blue Catfish have been documented in other Atlantic Slope river systems (Orth et al. 2017); continued monitoring of the Black River Blue Catfish population is necessary to document potential sport fish assemblage changes.

Another nonnative species, referred to as “Spotted Bass” in this report, was first stocked into the Cape Fear River in 1978 from Coosa River, AL, source broodfish (Marshall Ray; personal communication; Nichols and Buff 1984) which precludes *Micropterus punctulatus*. It is likely that the Spotted Bass of the Black River originated from Cape Fear River stocking events. The introduction of congeners has caused significant impacts to Largemouth Bass in other waterbodies in North Carolina (e.g., Dorsey and Abney 2016). Although the Spotted Bass population appears to be limited in the Black River, additional study is needed in upstream portions of the river to elucidate the current status of *Micropterus* populations and the impacts of introduced black bass species.

Habitat and water quality degradation also threaten the Black River’s fisheries resources. Clearing and snagging activity is occasionally initiated in the Black River and its tributaries for flood-control purposes but has no long-term utility, increases sedimentation, and greatly diminishes fish habitat (Cobb and Kaufman 1993). Removal of large woody debris (LWD) in the river through clearing and snagging is especially harmful to Redbreast Sunfish, which prefer LWD habitat for spawning (Davis 1971; Bass and Hitt 1974; Sandow et al. 1974). Also, timber harvest and land-use changes in areas adjacent to both the river and its tributaries can increase sedimentation and negatively impact the temperature, streamflow, and dissolved oxygen regimes in the river (Filipek 1993). Specific to land use changes, the Black River watershed has the highest density of swine in concentrated animal feeding operations (CAFOs) in North Carolina (Martin et al. 2018; NCDWR 2021a). Standard practices utilized by these operations transport significant quantities of nutrients into groundwater (Burkholder et al. 2007). Additionally, volatilization of nutrients from spray fields increases atmospheric deposition of nitrogen (Mallin and Cahoon 2003; Burkholder et al. 2007); the counties adjacent to the Black River watershed are among the highest agricultural emitters of ammonia in the United States and have among the highest concentrations of ammonium in rainfall in the United States (Konarik 2006). Lastly, direct runoff from waste effluent spills have been documented to substantially increase bacteria and biological oxygen demand, leading directly to acute fish kill events (Mallin et al. 1997; Burkholder et al. 2007). Assessing the impacts of these operations has typically been confined to fish kill investigations; long-term analysis of fish community trends is likely confounded with nonnative species introductions.

Finally, climate models project an increase in the frequency of extreme precipitation events in North Carolina, as well as more intense hurricanes (Kunkel et al. 2020), thereby increasing the likelihood of high streamflow events. These events can have significant negative impacts on water quality (Mallin and Corbett 2006; NCDEQ 2019) and lead to widespread fish kills. Additionally, sea level rise may increase salinity in downstream sections of the Black River, thereby converting current freshwater habitats into estuarine habitats (NC Climate Risk Assessment and Resilience Plan 2020) and shifting the fish community towards estuarine species. Fish sampling conducted in areas that are projected to experience habitat regime shifts should be linked with larger monitoring programs and goals to study the effects of climate change on sport fish populations. Additionally, fisheries hurricane response plans should be formalized and broadened to encompass goals that promote long-term resilience and management strategies that proactively reduce the risk of chronic stressors and acute fish kill events.

Management Recommendations

1. Reduce populations of Blue and Flathead catfish by reducing barriers to harvest and investigating novel control techniques.
2. Investigate occupancy of native catfish.
3. Initiate management actions to restore native catfish populations. Reduced creel limits, hatchery supplementation, and reducing predatory stressors may be required.
4. Within 5 years, conduct a creel survey to assess current harvest rates and angling practices.
5. Within 10 years, conduct basin-wide survey of Black River fish communities.
6. Investigate effects of agricultural land use on sport fish population dynamics.
7. Identify, plan, fund, and support projects throughout the river basin that improve fish habitat and water quality.

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TABLE 1. Species collected in hand-crank electrofishing survey (2015–2016) and the NCWRC baseline survey (conducted in 1962; Louder 1963; Starnes and Hogue 2011). **Bold** denotes Inland Game Fish, *italics* denote Species of Greatest Conservation Need, and (◊) denotes nonnative species.

Common name	Scientific name	Catch 1962	Catch 2015–2016	Sites with catch 1962[a]	Sites with catch 2015–2016[b]
American Eel	*Anguilla rostrata*	74	47	100%	90%
American Shad	*Alosa sapidissima*	1	0	25%	0%
Banded Pygmy Sunfish	*Elassoma zonatum*	9	0	50%	0%
Banded Sunfish	*Enneacanthus obesus*	8	0	25%	0%
Blackbanded Sunfish	*Enneacanthus chaetodon*	3	0	25%	0%
Black Crappie	*Pomoxis nigromaculatus*	22	20	50%	80%
◊ Blue Catfish	*Ictalurus furcatus*	0	178	0%	23%
Bluegill	*Lepomis macrochirus*	56	254	100%	100%
Bluespotted Sunfish	*Enneacanthus gloriosus*	6	2	50%	10%
Bowfin	*Amia calva*	1	94	25%	100%
Broadtail Madtom	*Noturus n. sp.*	2	0	25%	0%
Chain Pickerel	*Esox niger*	22	8	100%	50%
◊ Channel Catfish	*Ictalurus punctatus*	0	103	0%	53%
Coastal Shiner	*Notropis petersoni*	40	53	100%	60%
Comely Shiner	*Notropis amoenus*	0	3	0%	10%
◊ Common Carp	*Cyprinus carpio*	0	9	0%	50%
Creek Chubsucker	*Erimyzon oblongus*	29	14	50%	50%
Dollar Sunfish	*Lepomis marginatus*	3	11	25%	50%
Eastern Mosquitofish	*Gambusia holbrooki*	4	4	50%	20%
Eastern Mudminnow	*Umbra pygmaea*	2	0	50%	0%
Eastern Silvery Minnow	*Hybognathus regius*	0	24	0%	20%
Flat Bullhead	*Ameiurus platycephalus*	3	0	25%	0%
◊ Flathead Catfish	*Pylodictis olivaris*	0	238	0%	73%
Flier	*Centrarchus macropterus*	3	1	25%	10%
Golden Shiner	*Notemigonus crysoleucas*	100	12	100%	60%
◊ Grass Carp	*Ctenopharyngodon idella*	0	1	0%	10%
Hogchoker	*Trinectes maculatus*	0	17	0%	60%
Largemouth Bass	*Micropterus salmoides*	8	101	100%	100%
Longnose Gar	*Lepisosteus osseus*	2	75	50%	90%
Margined Madtom	*Noturus insignis*	1	0	25%	0%
Pirate Perch	*Aphredoderus sayanus*	123	6	100%	40%
Pumpkinseed	*Lepomis gibbosus*	5	26	50%	60%
Redbreast Sunfish	*Lepomis auritus*	11	87	100%	100%
◊ Redear Sunfish	*Lepomis microlophus*	0	199	0%	100%
Redfin Pickerel	*Esox americanus*	1	12	25%	50%

TABLE 1. Continued…

Common name	Scientific name	Catch 1962	Catch 2015–2016	Sites with catch 1962[a]	Sites with catch 2015–2016[b]
Sandbar Shiner	*Notropis scepticus*	2	0	25%	0%
Satinfin Shiner	*Cyprinella analostana*	0	6	0%	30%
Sawcheek Darter	*Etheostoma serrifer*	12	0	75%	0%
Southern Flounder	*Paralichthys lethostigma*	0	1	0%	10%
Spottail Shiner	*Notropis hudsonius*	0	7	0%	30%
◊ Spotted Bass [c]	*Micropterus* sp.	0	1	0%	10%
Spotted Sucker	*Minytrema melanops*	109	65	100%	90%
Spotted Sunfish	*Lepomis punctatus*	0	80	0%	100%
Swamp Darter	*Etheostoma fusiforme*	3	0	50%	0%
Tadpole Madtom	*Noturus gyrinus*	34	0	100%	0%
Tessellated Darter	*Etheostoma olmstedi*	71	0	100%	0%
Warmouth	*Lepomis gulosus*	26	45	100%	80%
White Catfish	*Ameiurus catus*	14	0	25%	0%
Whitefin Shiner	*Cyprinella nivea*	0	10	0%	20%
Yellow Perch	*Perca flavescens*	19	53	100%	60%

[a] Sites 11J-4, 12I-1, 12I-5, and 12I-6 in Louder (1963) as amended by Starnes and Hogue (2011).

[b] Percentages calculated with catfish targeted in all sites (n = 30); other species targeted in high-frequency sites only (n = 10).

[c] This species has historically been considered *M. punctulatus* but is of Coosa River, AL origin.

TABLE 2. Aggregated catch (2015 and 2016) by high frequency (120 PPS) electrofishing site. The final row gives the number of species captured within each site.

Species	River kilometer									
	17	22	24	33	35	84	85	88	93	95
American Eel	1	2	0	4	3	10	9	7	4	7
Black Crappie	0	2	1	0	1	2	3	8	2	1
Blue Catfish	0	0	0	1	0	0	0	0	0	0
Bluegill	14	10	17	18	5	31	43	51	48	17
Bluespotted Sunfish	0	0	2	0	0	0	0	0	0	0
Bowfin	10	10	14	2	6	16	17	12	4	3
Chain Pickerel	0	1	2	0	3	0	1	0	1	0
Channel Catfish	0	1	2	7	3	4	3	12	9	8
Coastal Shiner	0	0	1	3	5	0	0	19	15	10
Comely Shiner	0	0	0	0	0	0	0	0	0	3
Common Carp	0	0	0	1	1	0	0	4	2	1
Creek Chubsucker	2	2	3	0	2	0	0	0	5	0
Dollar Sunfish	0	0	0	0	0	3	3	1	2	2
Eastern Mosquitofish	0	0	0	0	0	2	0	0	0	2
Eastern Silvery Minnow	0	0	0	0	0	2	0	22	0	0
Flathead Catfish	0	1	0	3	1	0	0	2	1	0
Flier	0	1	0	0	0	0	0	0	0	0
Golden Shiner	0	4	0	0	2	2	1	1	0	2
Grass Carp	1	0	0	0	0	0	0	0	0	0
Hogchoker	0	0	1	0	0	4	3	4	4	1
Largemouth Bass	5	13	8	8	14	1	18	16	13	5
Longnose Gar	3	5	0	2	9	22	10	10	9	5
Pirate Perch	0	0	3	0	0	1	0	0	1	1
Pumpkinseed	4	15	2	0	0	1	0	2	2	0
Redbreast Sunfish	5	4	10	3	4	12	16	11	14	8
Redear Sunfish	25	33	38	18	20	1	15	11	28	10
Redfin Pickerel	0	0	1	0	0	1	2	1	7	0

TABLE 2. Continued…

Species	River kilometer									
	17	22	24	33	35	84	85	88	93	95
Satinfin Shiner	0	0	0	1	0	0	0	2	0	3
Southern Flounder	1	0	0	0	0	0	0	0	0	0
Spottail Shiner	0	0	2	0	0	3	0	0	0	2
Spotted Bass	0	1	0	0	0	0	0	0	0	0
Spotted Sucker	0	7	2	5	7	6	10	10	13	5
Spotted Sunfish	1	2	5	4	8	24	9	13	10	4
Warmouth	7	11	13	3	5	0	1	2	3	0
Whitefin Shiner	0	0	0	0	0	5	0	5	0	0
Yellow Perch	5	24	9	2	11	0	0	2	0	0
Total species	14	20	20	17	19	21	17	24	22	21

TABLE 3. Aggregated catch (2015 and 2015) by low frequency (15 PPS) electrofishing site. The final row gives the number of species captured within each site.

	River kilometer																			
Species	6	8	14	16	18	24	27	30	33	36	83	84	85	87	88	89	91	93	94	95
Blue Catfish	55	70	13	24	14	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Channel Catfish	10	6	4	16	13	0	0	0	0	2	1	1	0	0	0	0	0	0	0	1
Flathead Catfish	13	8	8	12	20	4	9	12	4	26	9	11	16	8	18	8	3	17	9	15
Total species	3	3	3	3	3	1	1	1	1	3	2	2	1	1	1	1	1	1	1	2

TABLE 4. Estimated von Bertalanffy growth parameters. Quantiles represent the median (0.50; most credible estimate) and lower (0.05) and upper (0.95) 90% credible intervals of the joint posterior distribution.

Parameter	Quantiles		
	0.05	0.50	0.95
Bluegill			
L_∞	264	288	313
K	0.22	0.26	0.31
t_0	-1.03	-0.87	-0.72
Blue Catfish			
L_∞	1,010	1,139	1,288
K	0.08	0.09	0.11
t_0	-0.64	-0.53	-0.43
Channel Catfish			
L_∞	565	636	720
K	0.21	0.29	0.37
t_0	0.04	0.31	0.54
Flathead Catfish			
L_∞	1,203	1,332	1,475
K	0.08	0.09	0.11
t_0	-0.37	-0.20	-0.03
Largemouth Bass			
L_∞	495	544	597
K	0.23	0.29	0.37
t_0	-0.53	-0.27	-0.03
Redbreast Sunfish			
L_∞	223	256	292
K	0.24	0.33	0.42
t_0	-0.64	-0.41	-0.21
Redear Sunfish			
L_∞	307	335	366
K	0.22	0.27	0.33
t_0	-0.90	-0.65	-0.43

TABLE 5. Poisson log-linear modeled instantaneous total mortality (*Z*) and discrete annual mortality (*A*). Confidence interval for instantaneous total mortality was modeled using gamma distribution.

Species	Aged otoliths	Max age	*Z* (SE)	*Z* 90% CI	*A*
Bluegill	172	5	1.03 (0.29)	0.60–1.54	64%
Blue Catfish	71	11	0.58 (0.08)	0.45–0.72	44%
Channel Catfish	70	12	0.40 (0.05)	0.32–0.48	33%
Flathead Catfish	156	19	0.46 (0.08)	0.34–0.60	37%
Largemouth Bass	78	8	0.69 (0.16)	0.45–0.97	50%
Redbreast Sunfish	62	5	1.07 (0.34)	0.58–1.69	66%
Redear Sunfish	142	9	0.64 (0.23)	0.31–1.08	47%

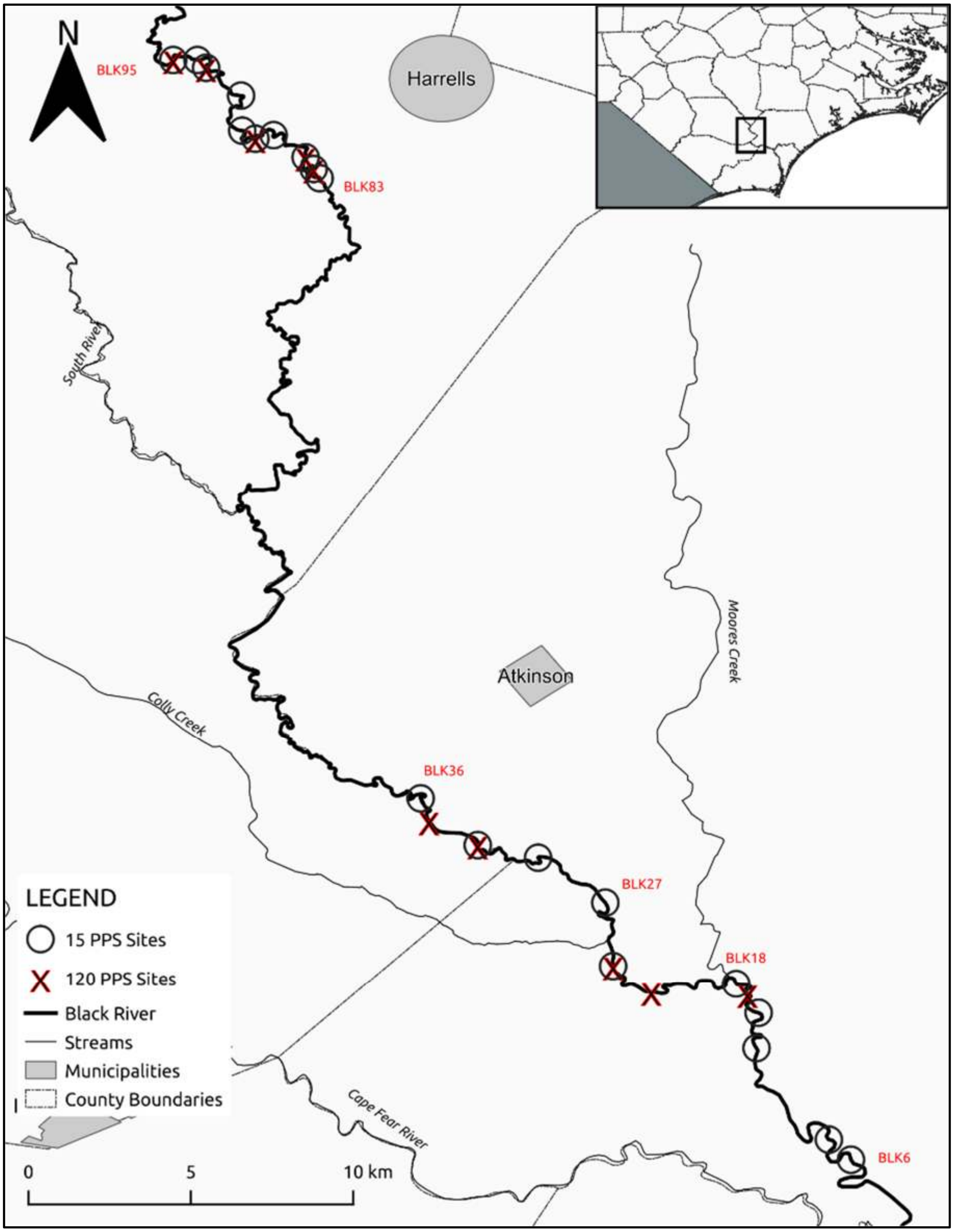

FIGURE 1. Black River boat electrofishing sites surveyed in North Carolina in 2015 and 2016. Several sites are labeled (red) with their river kilometer.

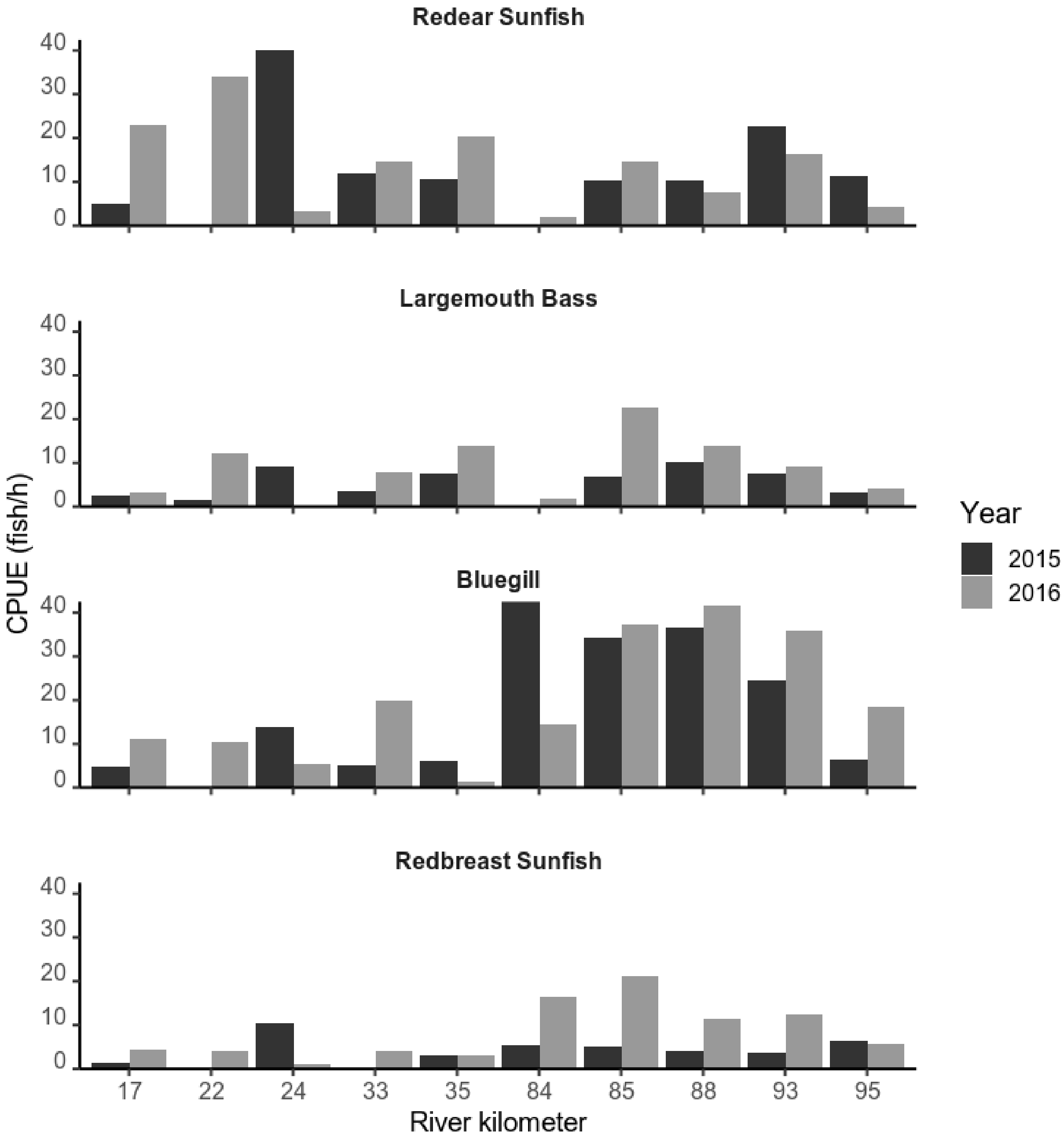

FIGURE 2. Catch per unit effort by site (river kilometer) and year for the four Inland Game Fish with the greatest catch in the high frequency (120 PPS) electrofishing sites. The x-axis is ordered left to right, downstream to upstream.

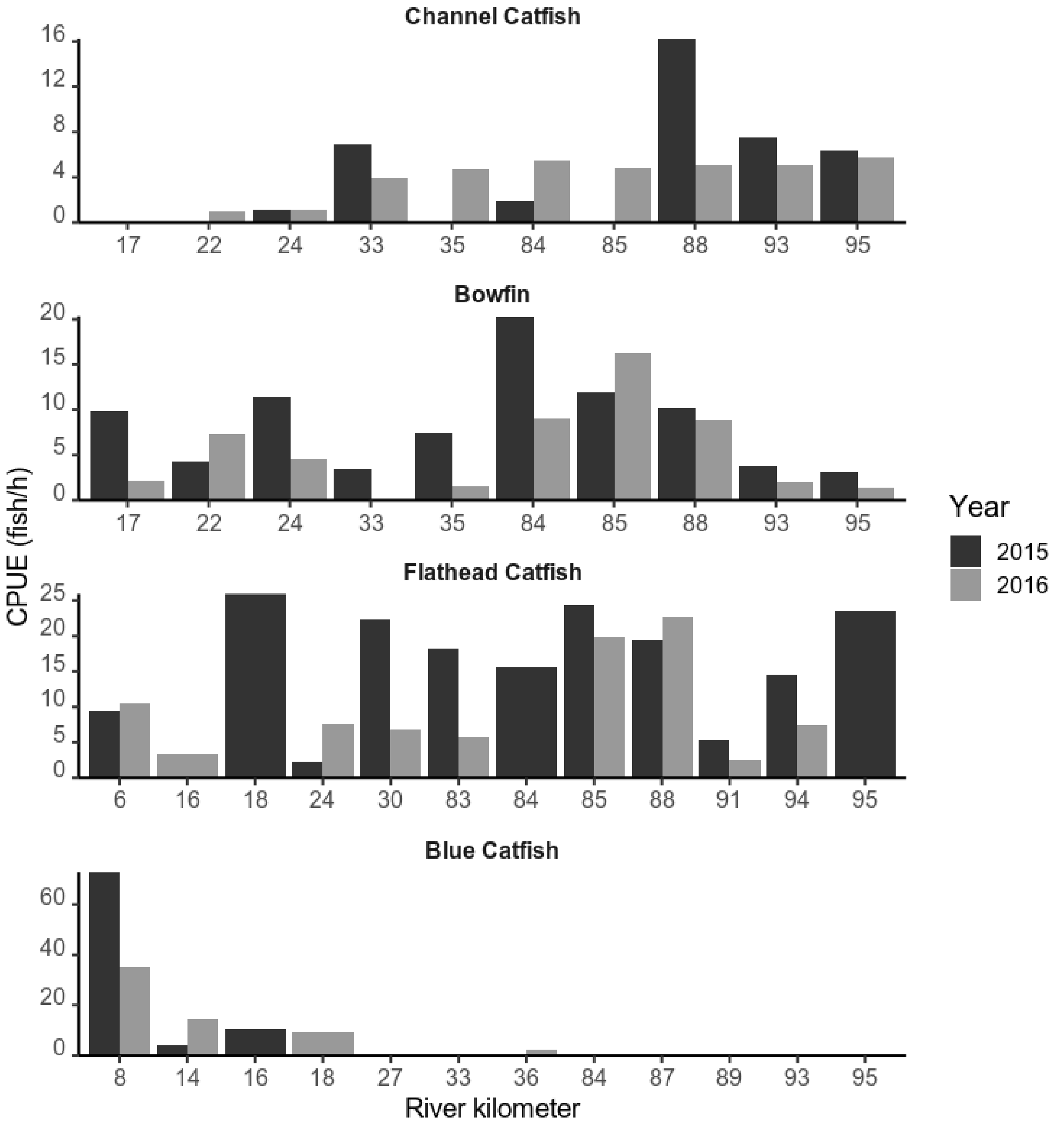

FIGURE 3. Catch per unit effort by site (river kilometer) and year for the four nongame fish with the greatest catch. Blue Catfish and Flathead Catfish sites and effort are from low frequency (15 PPS) electrofishing; other species depict effort from high frequency (120 PPS) electrofishing sites.

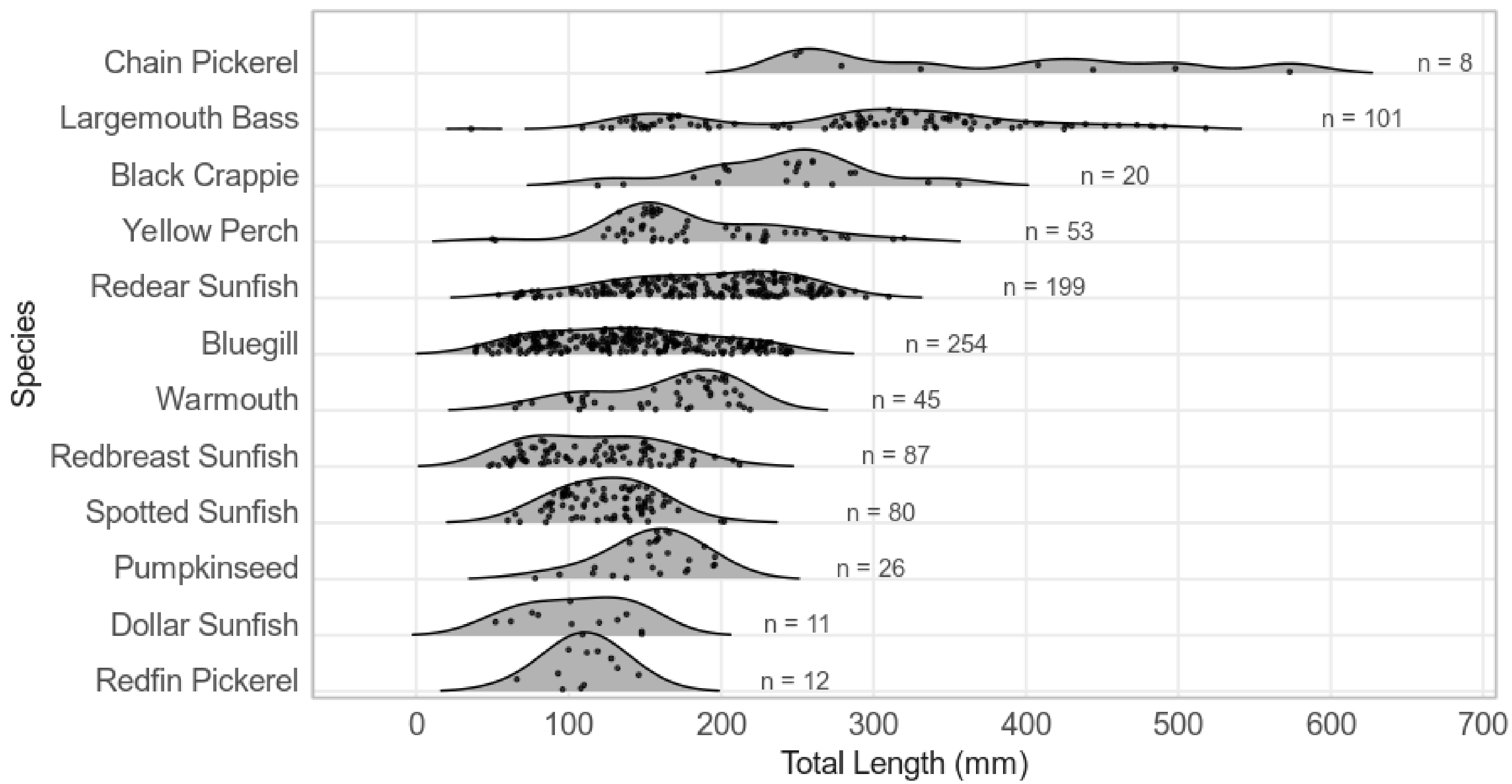

FIGURE 4. Density plots of Inland Game Fish with five or more collected individuals in descending order by maximum size of the largest individual. The sample size is denoted to the right of each size distribution.

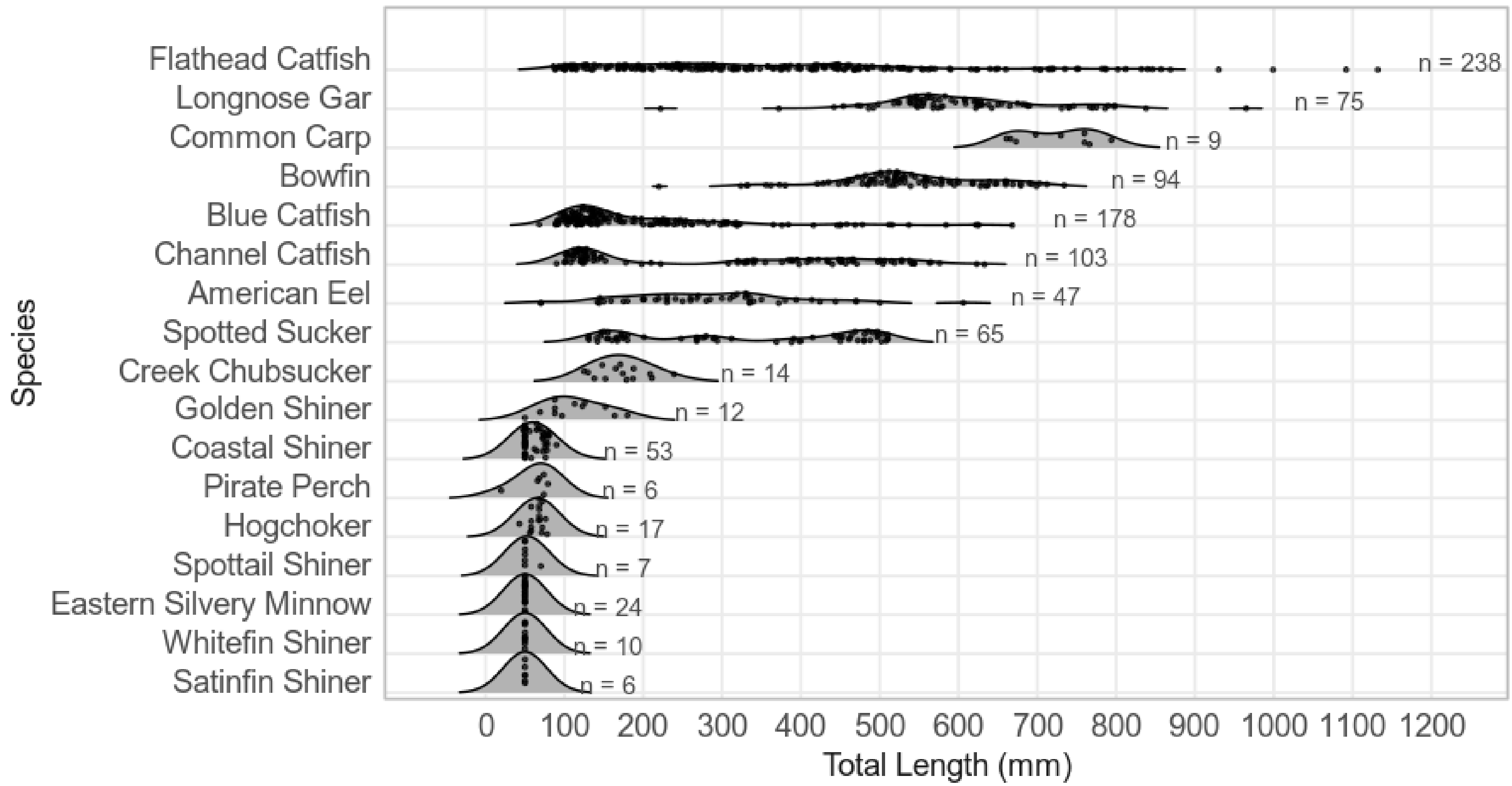

FIGURE 5. Density plots of nongame fish with five or more collected individuals in descending order by maximum size of the largest individual. The sample size is denoted to the right of each size distribution.

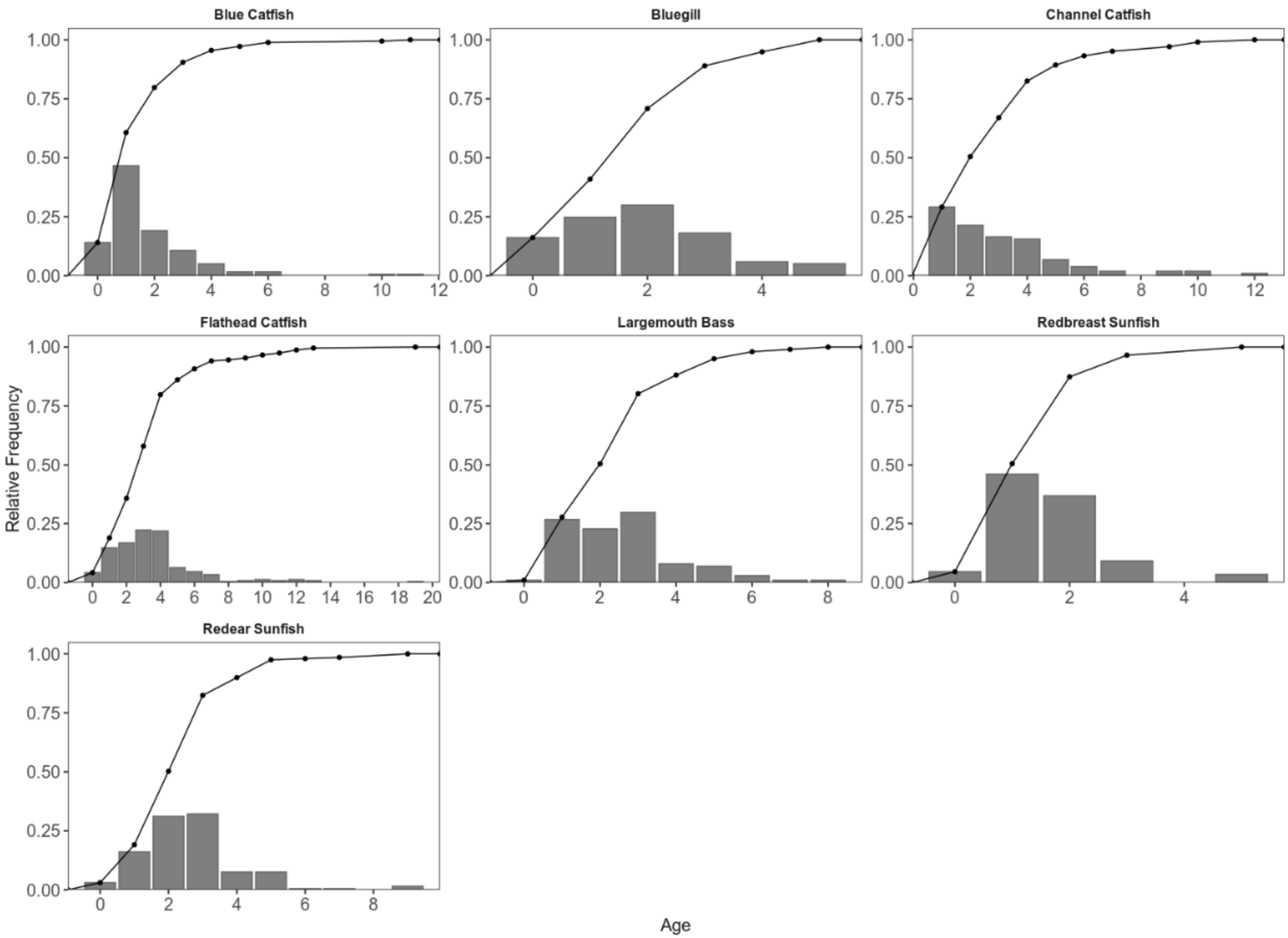

FIGURE 6. Age class relative frequency by species (bars). Line denotes cumulative age frequency.

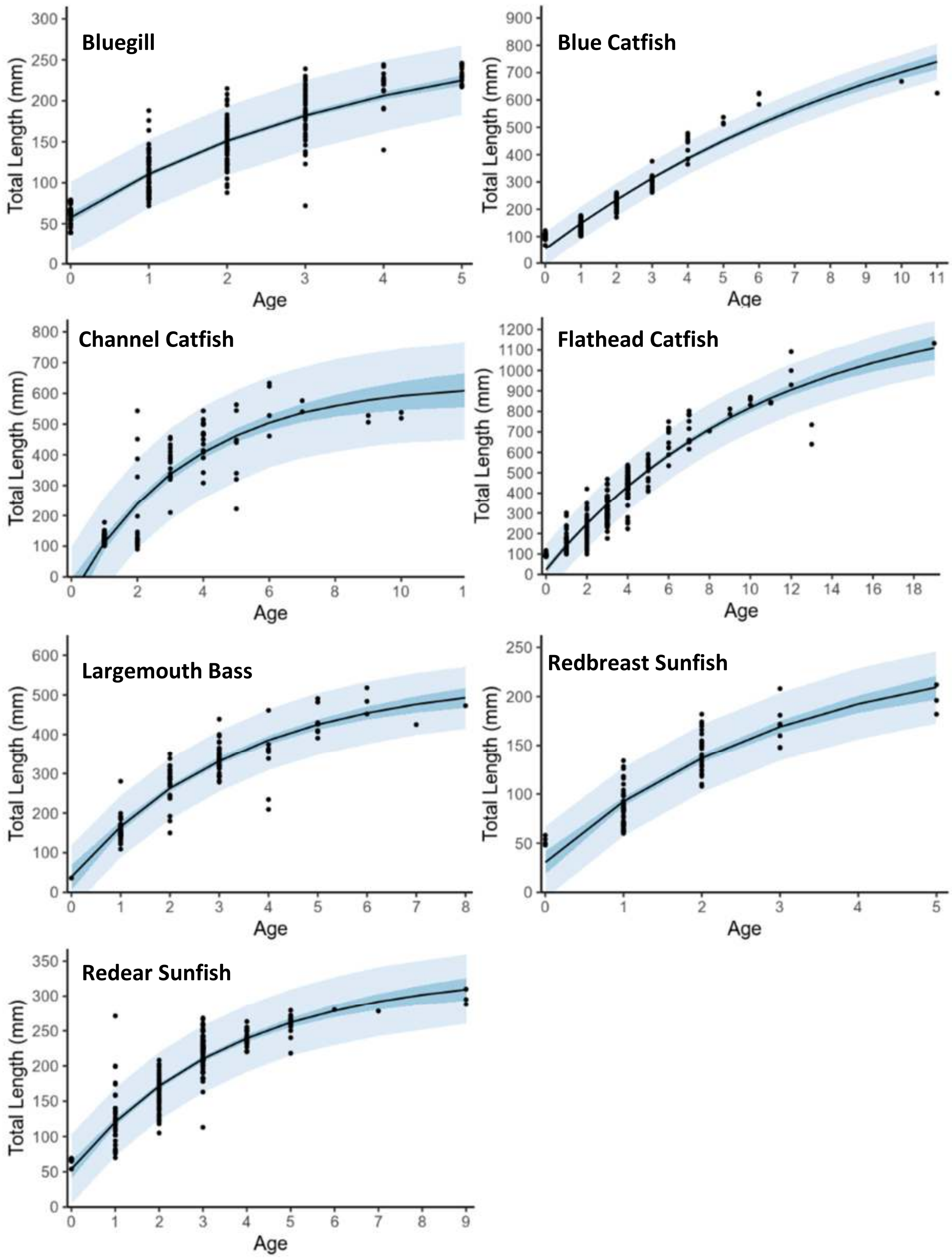

FIGURE 7. Posterior predicted median length-at-age from von Bertalanffy growth models (black line) and observed individuals (point markers). The dark shaded area denotes the 90% credible interval of the model, while the light shaded area denotes the 90% credible interval of the posterior predictive distribution.

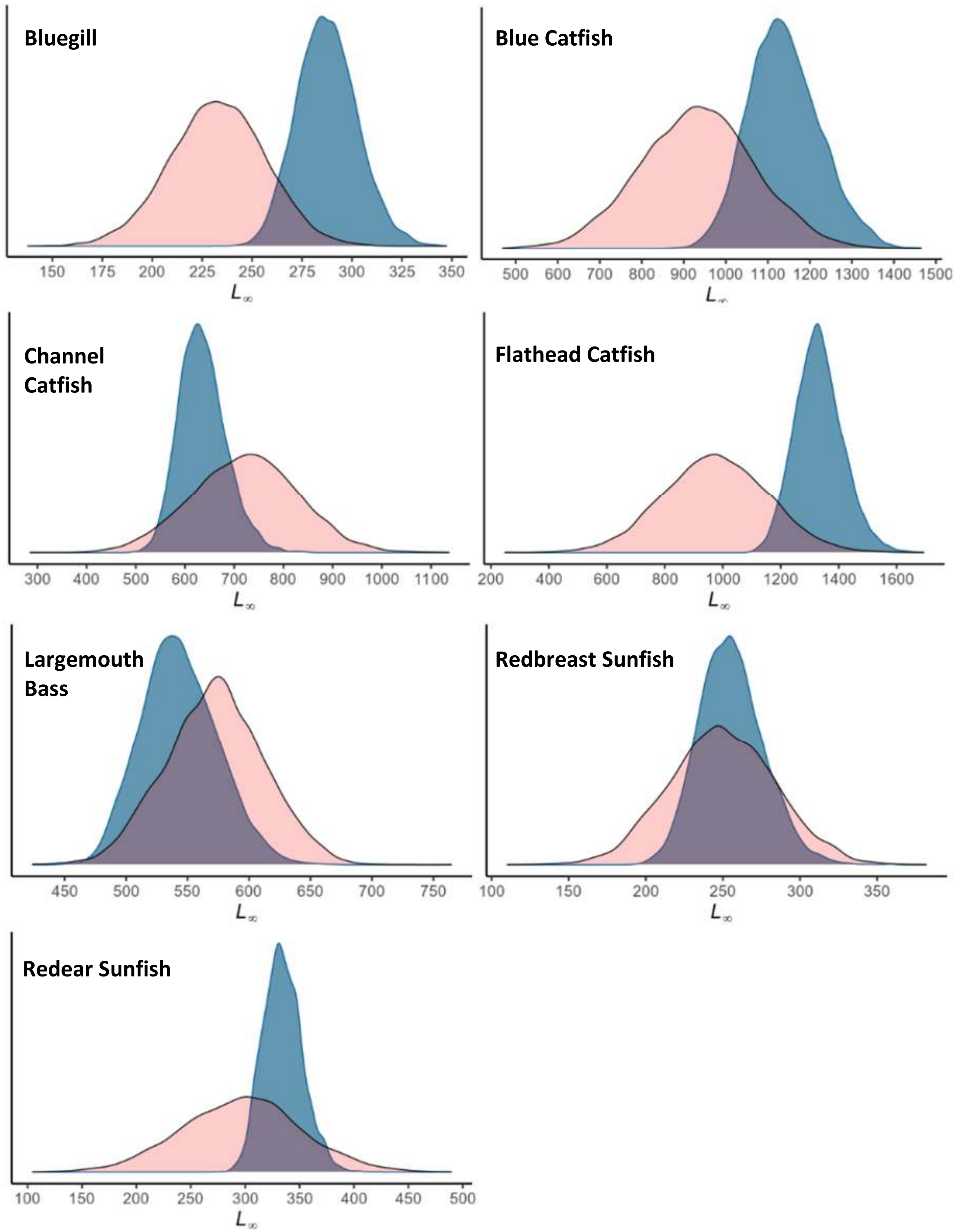

FIGURE 8. Prior (red) and estimated joint posterior (blue) probability distributions for L_∞. All values within the joint posterior distribution are considered credible, while the most credible estimate of L_∞ occurs at the peak of the curve.