2021 Sutton Lake Sport Fish Stock Assessment and Trend Analysis

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Abstract. Sutton Lake, built in 1972 as a cooling reservoir for L.V. Sutton Power Plant, is a popular angling destination. Largemouth Bass *Micropterus salmoides* and sunfish are frequently targeted, and their populations have fluctuated greatly over the years. Various methods, including implementing regulations to reduce harvest and Flathead Catfish *Pylodictis olivaris* removals, have been utilized to influence Largemouth Bass and sunfish abundance and age structure. Until 2019, a winter closure on Largemouth Bass harvest was in place. The fish populations of Sutton Lake were surveyed in October and November of 2021. A total of 1,333 fish were observed representing 16 species using boat electrofishing, experimental gill nets, and mini-fyke nets. Overall, 545 Largemouth Bass were captured. The oldest Largemouth Bass encountered was an age-8 individual. Estimated growth was relatively rapid for Largemouth Bass, with Largemouth Bass reaching 356mm by age 3. Relative abundance for stock size and larger (≥ 200 mm) individuals and harvestable (≥ 356 mm) individuals were relatively low in 2021 but were comparable to CPUE values for many years of sampling, though caution must be used when comparing CPUE values across years due to sampling being conducted in different seasons. Sutton Lake continues to be a dynamic system with considerable fluctuations in the Largemouth Bass population.

Sutton Lake is a 445-ha cooling reservoir constructed in 1972 for the L.V. Sutton Electric Plant and currently owned by Duke Energy Progress. The area around Sutton Lake includes a North Carolina Wildlife Resources Commission (NCWRC) public fishing area and boat ramp, along with game lands between the lake and the Cape Fear River. NCWRC electrofishing surveys of Sutton Lake began in 1988 (Nelson and Little 1990) and occurred annually at fixed sites through the spring of 2019. Duke Energy Progress also conducts environmental monitoring of Sutton Lake, including analysis of water quality, water chemistry, trace elements in water, sediments, and fish tissues, phytoplankton, fisheries, and aquatic vegetation (Duke Energy Progress 2017; Duke Energy Progress 2023). Duke Energy Progress fisheries monitoring occurs quarterly and is reported every 6 years in a detailed environmental monitoring report (Duke Energy Progress 2017; Duke Energy Progress 2023).

Various regulations have been enacted to manage Largemouth Bass *Micropterus salmoides*, including a 305-mm to 406-mm protective slot and four fish daily creel limit beginning in 1989, which was considered successful (Wynne et al. 1993). A creel survey in 1994 and 1995 indicated that 75% of Largemouth Bass harvest occurred from December 1 to March 31, 70% of Largemouth Bass harvested by anglers were larger than the protected slot size (>406mm), 82% of anglers targeted Largemouth Bass, and that over 70% of anglers rated their fishing trip as poor (Hammers and Little 1996). Following the creel survey, sampling was conducted to examine Largemouth Bass and sunfish populations before the implementation of a 457-mm minimum size limit for Largemouth Bass (Hammers and Little 1996) and a winter harvest closure for Largemouth Bass beginning in July of 1996 (Hammers and Herndon 1998). The Largemouth Bass population in Sutton Lake is dynamic. The Largemouth Bass population was at a low in 1997, increasing from 1998 to 2003, declined in 2004 (Hammers and Herndon 1998; Herndon et al. 2000; Rundle and Waters 2003; Rundle et al. 2005), and peaking in 2006, 2008, 2011, 2015, and 2017 (NCWRC 2010; Fisk and Dycus 2014; Rachels 2018). A 5-fish per day bag limit and 356-mm minimum length limit have been in effect since 2005 (Fisk and Dycus 2014; Rachels 2018). A creel survey was completed again in 2016, finding that 82% of anglers were targeting Largemouth Bass, less than 2% of caught Largemouth Bass were harvested, and only 10% of interviewed anglers were in favor of the winter closure of Largemouth Bass harvest (Morgeson and Fisk 2018; Rachels 2018). The winter closure was removed in 2019. Genetic analysis of fin clips from 50 Largemouth Bass collected in 2019 indicates the Largemouth Bass population contains a high percentage of Florida Bass genetics, with a mean Florida Bass *M. floridanus* allele frequency of 91% (greater than 95% is considered pure Florida Bass) (Taylor et al. 2019; NCWRC, unpublished data, 2020). Based on the 50 fin clips, 21 pure (>95%) Florida Bass and no pure Largemouth Bass were present in the sample; further, all Largemouth Bass analyzed had at least 82% Florida Bass alleles (NCWRC, unpublished data, 2020). Genetic analyses were conducted by Auburn University.

Largemouth Bass population fluctuations and missing age classes have been attributed to environmental conditions, lack of submerged vegetation, invasive species, and angler harvest (Hammers et al. 1995; Hammers and Little 1996; Hammers and Herndon 1998; Fisk and Dycus 2014). Sutton Lake has dikes meant to facilitate water circulation and cooling of heated water, water temperatures can exceed 32°C during summer months (NCWRC, unpublished data, 2012; Fisk and Dycus 2014; Morgeson and Fisk 2018). Warm water discharges can increase the length of the growing season for Largemouth Bass. However, high temperatures in the summer and high fishing pressure can lead to mortality, even though most Largemouth Bass are released (Fisk and Dycus 2014; Morgeson and Fisk 2018). Due to the usage of Sutton Lake as a cooling reservoir, aquatic vegetation has been managed through biological and chemical means since the lake was constructed. Aquatic vegetation, though great for fish, can negatively impact water intake and impede the use of Sutton Lake for cooling purposes. Redbelly Tilapia *Tilapia zilli*, aquatic herbicides, and Grass Carp *Ctenopharyngodon idella* have all been used to manage aquatic vegetation, and the use of Grass Carp rather than aquatic herbicides has been the method of aquatic vegetation control in recent years (Duke Energy Progress 2020; Duke Energy Progress 2023). Invasive Flathead Catfish *Pylodictis olivaris*, first discovered in Sutton Lake in 1993 (CP&L 1995), are thought to impact populations of other fish in Sutton Lake. During a 1999 survey of Flathead Catfish by NCWRC, 255 Flathead Catfish, 82% of which were greater than 600 mm in total length, were captured and removed (Herndon and Waters 2000). The stomach contents of the Flathead Catfish were analyzed, and Herndon and Waters (2000) found that 92% of the Flathead Catfish diet composed of fish, with 53% of the identified fish consisting of Largemouth Bass, sunfish, and other centrarchids. Efforts to remove Flathead Catfish appeared to be ineffective (Herndon and Waters 2000). Ashley et al. (2007) continued the Herndon and Waters (2000) study through 2006, collecting 491 additional Flathead Catfish and analyzing the condition of the 746 fish collected during both studies, 70% of which were larger than 600mm in total length. Ashley et al. (2007) documented low relative weights of Flathead Catfish and rapid growth rates. Harvest of Largemouth Bass has been addressed through various regulations over time, with the current regulation consisting of a 356-mm minimum size limit and a daily creel limit of five.

The fall 2021 survey is the first NCWRC survey since the season closure of Largemouth Bass harvest was removed. During October and November of 2021, we sampled Sutton Lake with multiple gears to monitor populations of Largemouth Bass and other species of fish.

Methods

Study site. Sutton Lake is adjacent to the Cape Fear River and located in New Hanover County (Figure 1). The lake has a mean depth of 1.9 m and 22-km of shoreline, and the surrounding land is mostly undeveloped and forested (Duke Energy Progress 2020). Water is pumped from the Cape Fear River into Sutton Lake when necessary to make up for water lost to evaporation (Duke Energy Progress 2023). Sutton Lake is classified as Swamp Waters, Class C by the North Carolina Division of Water Resources (Duke Energy Progress 2023).

Fish sampling. A generalized-random tessellation stratified (GRTS) survey design, created using package spsurvey (Kincaid et al. 2019) in R, was used to select 10 sample sites for boat electrofishing (Smith Root Apex; 120-Hz; 4,500–5,500 W), 12 sample sites for experimental gill nets (Miranda and Boxrucker 2009), and 6 sample sites for mini-fyke nets (Bonvechio et al. 2014) (Table 1). Sample sites were selected using non-uniform site selection probabilities for the boat electrofishing and uniform site selection probabilities for the gill net sites and mini-fyke net sites. Shoreline type was the primary site selection factor, ensuring that at least one site was on the sandy/vegetated shoreline on the eastern side of Sutton Lake, which was shallow and difficult to sample using boat electrofishing, with the rest of the sites being along levies and artificial shorelines.

Boat electrofishing was conducted during daylight hours for 10 minutes of electrofishing effort at each site with the boat oriented perpendicular to the shoreline. All fish were collected as they were encountered by one dip netter using 4-mm net mesh. Gill nets and mini-fyke nets were set perpendicular to shore no earlier than 3 hours before sunset and were retrieved the next day. Mini-fyke net leads were extended onto the shoreline where possible. A YSI Pro2020 meter measured dissolved oxygen concentration (mg/L) and saturation (%), conductivity (µS/cm), salinity (ppt), and temperature (°C).

Collected fish were enumerated and up to 100 individuals of each species (or more for abundant inland game fish) were measured for total length (TL; mm) and weighed (g) for each sampling gear. Otoliths were removed from Largemouth Bass for age determination.

Relative Abundance. Relative abundance was indexed as catch-per-unit effort (CPUE) for each sampling gear (boat electrofishing = fish/hour; gill net and mini-fyke net = fish/net night). Length frequency distributions were analyzed using density plots for species of interest with at least 15 length measurements. Previous sampling data was downloaded from the NCWRC BIODE database, cleaned using the NCIFD cleanBIODE function, and used to calculate CPUE using the cpueBIODE function of NCIFD (Wheeler and Rachels 2023). CPUE values were checked for accuracy against all previous NCWRC reports on Sutton Lake and data edited and reuploaded when necessary to fix errors and ensure accuracy. Data analyses were conducted using R 4.0.3 (R Core Team 2020), RStudio (version 1.2.5033; Rstudio Team 2020), and Microsoft Excel (Version 2206 Build 16.0.15330.20246).

Largemouth Bass Age and Growth. Largemouth Bass otoliths were aged independently by two experienced readers using a stereomicroscope. Disagreements were resolved using a concert read. An age-length key was developed using aged fish and a multinomial regression model to assign ages to unaged individuals (Venables and Ripley 2002; Isermann and Knight 2005; Gerritsen et al. 2006; Ogle 2015; Ogle et al. 2020).

Largemouth Bass growth was modeled using a Bayesian methodology and the von Bertalanffy growth function (VBGF; Beverton and Holt 1957; Doll and Jacquemin 2019; Rachels and Fisk 2021). The von Bertalanffy growth function is expressed as:

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

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, Largemouth Bass had a prior for L_∞ that was normally distributed with a mean (533) and standard error (22) calculated from the total lengths of the largest 1% of Largemouth Bass observed at Sutton Lake since 1989. Priors for the other model estimated parameters (K and t_0) were weakly informative. Growth models were implemented using Stan (Stan Development Team 2019) as interfaced through R package “brms”. The growth model used four concurrent Markov chain Monte Carlo chains, each with 4,000 total iterations, no thinning, a 2,000-iteration warmup period, for a total of 8,000 post-warmup draws. The model was 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 and the fit of each model was assessed by conducting a posterior predictive check (Gelman and Shirley 2011; Doll and Jacquemin 2019).

Results

Sampling at Sutton Lake in the fall of 2021 resulted in the collection of 1,333 individual fish representing 16 species. The fisheries resources of Sutton Lake observed in this survey predominantly consist of inland game fish, with inland game fish comprising 92.6% of captures in 2021 and Largemouth Bass and Bluegill *Lepomis macrochirus* comprising 65.7% of overall captures. The length frequency distribution by gear for species with greater than 15 captures is shown in Figure 2.

Boat electrofishing collected 1,181 individuals of 8 species (Table 2). Inland game fish accounted for 99% of the catch, composed of 1,173 individuals of 5 species. The most common species of inland game fish captured was Largemouth Bass (n = 527). Nongame fish accounted for 1% of the catch, with 8 individuals of 3 species captured. The most common species of nongame fish captured was American Eel *Anguilla rostrata* (n = 5).

Experimental gill nets collected 118 individuals of 12 species (Table 3). Inland game fish accounted for 25% of the captures, composed of 29 individuals of 4 species. The most common species of inland game fish captured was Largemouth Bass (n = 17). Nongame fish accounted for 75% of the captures, with 89 individuals of 8 species captured. The most common species of nongame fish captured was Gizzard Shad *Dorosoma cepedianum* (n = 50).

Mini-fyke nets collected 34 individuals of 6 species (Table 4). Inland game fish accounted for 97% of captures, with 33 individuals representing 5 species. Of those individuals, 15 were *Lepomis* spp. that could not be identified to the species level due to hybridization or size. The most common species of inland game fish captured was Bluegill (n = 11). Nongame fish accounted for 3% of the captures, with one American Eel captured.

Mean (SE) CPUE of all Largemouth Bass captured using boat electrofishing was 344.9 (88.5) fish/h (Figure 3; Table 5). Mean (SE) CPUE of stock size and larger (≥200 mm) Largemouth Bass using boat electrofishing was 10.6 (3.4) fish/h (Figure 4). Mean (SE) CPUE of harvestable (≥356 mm) Largemouth Bass using boat electrofishing was 6.0 (2.2) fish/h (Figure 5). Largemouth Bass CPUE using gill nets was 1.4 (0.4) fish/net night. One Largemouth Bass (0.2 fish/net night) was collected using mini-fyke nets. Overall, 545 individuals were captured.

Four species of sunfish, including Bluegill, Redbreast Sunfish *L. auratus*, Redear Sunfish *L. microlophus*, and Warmouth *L. gulosus*, were captured in the survey. Bluegill CPUE was 211.5 (76.7) fish/h using electrofishing, 0 fish/net night using gill nets, and 1.8 (1.0) fish/net night using mini-fyke nets. Redbreast Sunfish CPUE was 46.2 (19.5) fish/h using electrofishing, 0 fish/net night using gill nets, and 0.2 (0.2) fish/net night using mini-fyke nets. Redear Sunfish CPUE was 43.6 (17.2) fish/h using electrofishing, 0.2 (0.1) fish/net night using gill nets, and 0 fish/net night using mini-fyke nets. Warmouth CPUE was 71.4 (33.1) fish/h using electrofishing, 0.3 (0.1) fish/net night using gill nets, and 0.5 (0.3) fish/net night using mini-fyke nets. For Bluegill, the maximum total length of those captured and measured was 194mm, and the largest individual weighed 94g.

Three species of catfish, including Channel Catfish *Ictalurus punctatus*, Blue Catfish *I. furcatus*, and Flathead Catfish, were collected. Catfish were only captured using gill nets, with capture rates of 0.6 (0.1) Channel Catfish/net night, 0.3 (0.1) Blue Catfish/net night, and 0.3 (0.2) Flathead Catfish/net night. No native catfish were captured.

Largemouth Bass Age and Growth. Otolith ages from 70 Largemouth Bass were used to develop an age-length key that we applied to 457 unaged individuals with total length. Estimated growth was relatively rapid for Largemouth Bass, with Largemouth Bass reaching 356mm by age 3 (Figure 6). The oldest (age 8) and largest Largemouth Bass captured had a total length of 574mm and weighed 3056g (Table 6). The von Bertalanffy growth model indicated that $L\infty$ (90% credible interval) equaled 564.7 (541.6, 589.4), K (90% credible interval) equaled 0.41 (0.37, 0.46), and t_0 (90% credible interval) equaled 0.29 (0.25, 0.33).

Discussion

The warm temperatures in Sutton Lake allow for superb reproduction of Largemouth Bass and multiple sunfish species, which were encountered frequently in 2021. Sampling in 2021 and prior surveys indicate that Largemouth Bass reach approximately 355mm, and therefore become susceptible to harvest, as early as age 2 and as late as age 4 and can reach 508mm between age 6 and age 8, indicating one of the fastest growth rates of Largemouth Bass in North Carolina (Rundle et al. 2005; Fisk and Dycus 2014; Rachels 2018). Results from Duke Energy Progress surveys from 2013 to 2020 indicated similar length frequency distributions for Bluegill and Largemouth Bass, though several larger (total length >200mm) Bluegill were captured during 2013, 2015, and 2017 sampling events (Duke Energy Progress 2020; Duke Energy Progress 2023). Mean CPUE during 2021 was the highest recorded by NCWRC sampling; however, many age-0 individuals were encountered during the fall making direct comparisons to other years, when sampling occurred during the spring, inappropriate. CPUE for stock size and larger (≥ 200 mm) individuals and harvestable (≥ 356 mm) individuals were relatively low in 2021 but were comparable to CPUE values for many years of sampling. However, caution must be used when comparing CPUE values across years due to sampling being conducted in different seasons.

Various factors that may contribute to population fluctuations and missing age classes of Largemouth Bass and sunfish, including environmental conditions, lack of submerged vegetation, invasive species, and angler harvest, have been addressed throughout the years (Hammers et al. 1995; Hammers and Little 1996; Hammers and Herndon 1998; NCWRC 2010; Fisk and Dycus 2014). The L. V. Sutton Electric Plant switched its power supply from coal to natural gas in 2013 (Duke Energy Progress 2020), and it was thought that if thermal reductions were significant, environmental conditions may improve enough to positively impact long-term survival (Fisk and Dycus 2014). Though the L.V. Sutton Electric Plant switched its power supply from coal to natural gas, thermal fluctuations still occur due the use of Sutton Lake as a cooling reservoir. NCWRC and Duke Energy Progress have added fish attractors to Sutton Lake to improve habitat by providing feeding and nursery areas for fish, with an additional 250 Christmas trees added to fish attractor sites in 2011 (NCWRC 2010) and artificial fish attractors were added in 2017. Flathead Catfish persist in Sutton Lake and attain sizes that allow them to consume inland game fish and remain a concern, but do not appear to be the main factor driving Largemouth Bass abundance. During 2021 sampling, we only captured three Flathead Catfish using gill nets. Electrofishing efforts did not include the use of low-frequency electrofishing to target catfish. It is likely that more Flathead Catfish would have been observed if low-frequency electrofishing methods were used. Harvest of Largemouth Bass is relatively low, and fishing mortality is more likely to be associated with catch and release mortality, especially during fishing tournaments in warmer months (Fisk and Dycus 2014; Morgeson and Fisk 2018). Population fluctuations and missing age classes remain even though these factors have been addressed, but the lack of stability in the Largemouth Bass population has not proven to be detrimental to the population.

Sampling at Sutton Lake is not without challenges. The sandy/vegetated shoreline on the eastern side of Sutton Lake is shallow and difficult to sample using boat electrofishing, and many areas along the levies provide deeper water and woody structure where Largemouth Bass and other fish may not be susceptible to boat electrofishing. Further, targeting Largemouth Bass may require sampling specific rather than randomly chosen areas of Sutton Lake, longer electrofishing sites, and/or electrofishing at night, all of which should be considered when planning future sampling events. Boat electrofishing may not provide a complete view of the fisheries of Sutton Lake, considering that several species, including Black Crappie, Blue Catfish, Flathead Catfish, and Channel Catfish, were not observed using boat electrofishing or were only observed through gill netting. All Largemouth Bass (n = 17) captured using gill netting were stock size (≥ 200 mm) or larger and 13 of these individuals were harvestable (≥ 356 mm), compared to the 16 stock size and larger individuals captured using boat electrofishing, of which 9 were harvestable. However, gill netting in Sutton Lake proved to be difficult, as stumps and other woody debris tangled and tore several of the gill nets. Mini-fyke nets were beneficial but did not capture any species not captured by boat electrofishing or gill netting and were not an appropriate sampling gear for much of Sutton Lake due to shoreline characteristics and water depth. Sampling utilizing multiple gear types should continue to be conducted every three to five years to monitor the condition of Sutton Lake's fisheries resources.

Sutton Lake continues to have a dynamic population of Largemouth Bass and sunfish, even though measures have been taken to reduce the impact of invasive species, improve fish habitat, and reduce harvest of Largemouth Bass. The Largemouth Bass population in Sutton Lake, as shown by over 30 years of sampling and management, may drop one year and skyrocket the next, and various management actions and strategies have not been able to overcome the dynamic nature of the population. Efforts to improve habitat through fish attractor sites and aquatic vegetation may be necessary as the reservoir ages and woody debris decomposes. Methods for reducing Largemouth Bass catch and release mortality and encouraging Flathead Catfish harvest could be discussed with angler groups to help reduce mortality of Largemouth Bass and sunfish. Targeted sampling of Largemouth Bass in Sutton Lake should be conducted in future years to monitor the condition of the Largemouth Bass population and to evaluate the 2019 regulation change removing the winter closure on Largemouth Bass harvest. Environmental conditions, such as temperature, should continue to be monitored to determine if any trends relate to fish abundance, as environmental factors are a driving factor impacting the dynamic population of Largemouth Bass in Sutton Lake. Though population fluctuations are present, and the age structure of the population is shifted towards younger individuals, the Largemouth Bass fishery at Sutton Lake remains strong, with the higher temperatures encouraging fast growth rates and prolific reproduction that maintain the population.

Management Recommendations

1. Maintain existing fishing regulations for Sutton Lake.
2. Conduct sampling, including targeted sampling of catfish and Largemouth Bass, every three to five years utilizing multiple gear types to monitor the condition of Sutton Lake's fisheries resources and evaluate regulations.
3. Evaluate the status of Flathead Catfish in Lake Sutton using low frequency electrofishing.
4. Maintain fish attractor sites and encourage the retention of submersed vegetation where possible without impacting L.V. Sutton Electric Plant operations and in cooperation with Duke Energy Progress.
5. Examine summer water temperatures when fishing tournaments occur.
6. Discuss ways to reduce catch and release mortality of Largemouth Bass with angler groups and encourage the harvest of Flathead Catfish.

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References

Ashley, K. W., R. D. Barwick, and R. T. Rachels. 2007. Age, growth, and condition of Flathead Catfish in Sutton Lake, a thermally-influenced reservoir in coastal North Carolina. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Project F-22, Final Report, Raleigh.

Bache, S., and H. Wickham. 2022. magrittr: A Forward-Pipe Operator for R. R package version 2.0.3. Available: https://CRAN.R-project.org/package=magrittr (June 2023).

Beverton, R. J. H., and S. J. Holt. 1957. On the dynamics of exploited fish populations. Fishery Investigations, Series II, Marine Fisheries, Great Britton Ministry of Agriculture, Fisheries and Food 19.

Bonvechio, K. I., R. E. Sawyers, R. Bitz, and S. Crawford. 2014. Use of mini-fyke nets for sampling shallow-water fish communities in Florida Lakes. North American Journal of Fisheries Management 34:693–701.

Bürkner, P.-C. 2017. brms: An R Package for Bayesian Multilevel Models Using Stan. Journal of Statistical Software 80(1):1-28. Available: https://www.jstatsoft.org/article/view/v080i01 (June 2023).

CP&L (Carolina Power and Light Company). 1995. Sutton Steam Electric Plant 1993–1994 annual environmental monitoring report. New Hill, North Carolina.

Doll, J. C., and S. J. Jacquemin. 2019. Bayesian model selection in fisheries management and ecology. Journal of Fish and Wildlife Management 10:691–707.

Duke Energy Progress, Water Resources. 2020. L.V. Sutton Energy Complex 2013–2017 environmental monitoring report. Duke Energy Progress, Inc., Raleigh.

Duke Energy Progress, Water Resources. 2023. L.V. Sutton Energy Complex 2018–2020 environmental monitoring report. Duke Energy Progress, Inc., Raleigh.

Fisk II, J. M., and J. C. Dycus. 2014. Sutton Lake Largemouth Bass survey, 2010–2013. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Project F-108, Final Report, Raleigh.

Gabry, J., and T. Mahr. 2022. bayesplot: Plotting for Bayesian Models. R package version 1.10.0. Available: https://mc-stan.org/bayesplot/ (June 2023).

Gelman, A., and K. Shirley. 2011. Inference from simulations and monitoring convergence. Pages 163–174 *in* S. Brooks, A. Gelman, G. L. Jones, and X. Meng, editors. Handbook of Markov Chain Monte Carlo. Chapman and Hall/CRC Press, Boca Raton, Florida.

Gerritsen, H. D., D. McGrath, and C. Lordan. 2006. A simple method for comparing age length keys reveals significant regional differences within a single stock of Haddock (*Melanogrammus aeglefinus*). ICES Journal of Marine Science 63:1096–1100.

Hammers, B. E., M. B. Wynne, and A. E. Little. 1995. Sutton Lake Largemouth Bass survey, 1994–1995. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Project F-22, Final Report, Raleigh.

Hammers, B. E., and A. E. Little. 1996. Sutton Lake Sport Fishery Creel Survey, 1994–1995. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Project F-22, Final Report, Raleigh.

Hammers, B. E., and A. E. Little. 1996. Sutton Lake Largemouth Bass and sunfish survey, 1996. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Project F-22, Final Report, Raleigh.

Hammers, B. E., and T. M. Herndon. 1998. Sutton Lake Largemouth Bass and sunfish survey, 1997-1998. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Project F-22-23, Final Report, Raleigh.

Herndon, T. M., and C. T. Waters. 2000. Flathead Catfish stock assessment and removal in Sutton Lake, North Carolina. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Project F-22, Final Report, Raleigh.

Herndon, T. M., B. E. Hammers, and C. T. Waters. 2000. Sutton Lake Largemouth Bass and sunfish survey, 1999-2000. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Project F-22-23, Final Report, Raleigh.

Isermann, D. A., and C. T. Knight. 2005. A computer program for age-length keys incorporating age assignment to individual fish. North American Journal of Fisheries Management 25:1153–1160.

Kay, M. 2023. tidybayes: Tidy Data and Geoms for Bayesian Models. R package version 3.0.4. Available: http://mjskay.github.io/tidybayes/ (June 2023).

Kincaid, T. M., Olsen, A. R., and M. H. Weber. 2019. spsurvey: Spatial Survey Design and Analysis. R package version 4.1.0. Available: https://www.rdocumentation.org/packages/spsurvey/versions/4.1.4 (June 2023)

Miranda, L. E., and J. Boxrucker. 2009. Warmwater fish in large standing waters. Pages 29–42 *in* S. A. Bonar, W. A. Hubert, and D. W. Willis, editors. Standard methods for sampling North American freshwater fishes. American Fisheries Society, Bethesda, Maryland.

Morgeson, C., and J. M. Fisk II. 2018. Sutton Lake creel survey, 2015–2016. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Project F-108, Final Report, Raleigh.

Nelson, K. L., and A. E. Little. 1990. Sutton Lake Largemouth Bass Survey, 1987–1989. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Project F-22-14, Final Report, Raleigh.

NCWRC (North Carolina Wildlife Resources Commission). 2010. Sutton Lake Sportfish Assessment. Fisheries Research Summary. Division of Inland Fisheries, Raleigh.

Ogle, D. H. 2015. Introductory fisheries analyses with R. CRC Press, Taylor & Francis Group, Boca Raton, FL.

Ogle, D. H., J. C. Doll, A. P. Wheeler, and A. Dinno. FSA: Simple Fisheries Stock Assessment Methods. R package version 0.9.4. Available: https://CRAN.R-project.org/package=FSA (January 2023).

Rachels, K. T. 2018. Long-term assessment and adaptive management of Sutton Lake Largemouth Bass. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, fisheries research fact sheet. Raleigh.

Rachels, K. T., and J. M. Fisk II. 2021. Fisheries resources of the Cape Fear River. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Project F-108, Final Report, Raleigh.

Rundle, K. R. and C. T. Waters. 2003. Sutton Lake Largemouth Bass and sunfish survey, 2001-2002. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Project F-22, Final Report, Raleigh.

Rundle, K. R., R. D. Barwick, and C. T. Waters. 2005. Sutton Lake Largemouth Bass and sunfish survey, 2003-2004. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Project F-22, Final Report, Raleigh.

Taylor, A. T., J. M. Long, M. D. Tringali, and B. L. Barthel. 2019. Conservation of Black Bass Diversity: An Emerging Management Paradigm. Fisheries 44:20–36.

Venables, W. N., and B. D. Ripley. 2002. Modern applied statistics with S, fourth edition. Springer, New York.

Wheeler, P., and K. Rachels. 2023. NCIFD: Datasets and functions of the Inland Fisheries Division of the North Carolina Wildlife Resources Commission. R package version 23.02.24.

Wickham, H. 2016. ggplot2: elegant graphics for data analysis. Springer-Verlag, New York.

Wickham, H., M. Averick, J. Bryan, W. Chang, L. D'Agostino McGowan, R. François, G. Grolemund, A. Hayes, L. Henry, J. Hester, M. Kuhn, T. Lin Pedersen, E. Miller, S. M. Bache, K. Müller, J. Ooms, D. Robinson, D. P. Seidel, V. Spinu, K. Takahashi, D. Vaughan, C. Wilke, K. Woo, and H. Yutani. 2019. Welcome to the tidyverse. Journal of Open Source Software 4(43):1686. Available: https://doi.org/10.21105/joss.01686 (January 2023).

Wickham, H., R. François, L. Henry, and K. Müller. 2020. dplyr: A grammar of data manipulation. R package version 1.0.1. Available: https://CRAN.R-project.org/package=dplyr (January 2023).

Wickham, H., and J. Hester. 2020. readr: Read Rectangular Text Data. R package version 1.4.0. Available: https://CRAN.R-project.org/package=readr (January 2023).

Wilke, C. O. 2021. ggridges: Ridgeline Plots in 'ggplot2'. R package version 0.5.3. Available: https://CRAN.R-project.org/package=ggridges (January 2023).

Wynne, M. B., A. E. Little, and K. L. Nelson. 1993. Evaluation of a 305–406 mm protected slot regulation for Largemouth Bass in Lake Sutton, North Carolina. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Project F-22-17, Final Report, Raleigh.

TABLE 1. Sample site information, dates, and gear type for sampling of Sutton Lake conducted in 2021 (EF = electrofishing, GILL = gill net, and MFN = mini-fyke net).

Sample date	Site name	Waterbody	Gear Type	Latitude	Longitude
10/28/2021	SUT03	Sutton Lake	EF	34.286210	-77.995540
10/28/2021	SUT118	Sutton Lake	EF	34.292074	-78.002386
10/28/2021	SUT125	Sutton Lake	EF	34.289695	-77.990836
10/28/2021	SUT27	Sutton Lake	EF	34.305889	-78.011648
10/29/2021	SUT03G	Sutton Lake	GILL	34.286210	-77.995540
10/29/2021	SUT08G	Sutton Lake	GILL	34.286367	-77.997033
10/29/2021	SUT23G	Sutton Lake	GILL	34.302096	-78.010676
10/29/2021	SUT104G	Sutton Lake	GILL	34.308130	-78.008082
10/29/2021	SUT30G	Sutton Lake	GILL	34.310969	-78.011098
10/29/2021	SUT43G	Sutton Lake	GILL	34.314970	-77.995765
11/03/2021	SUT104	Sutton Lake	EF	34.308130	-78.008082
11/03/2021	SUT36	Sutton Lake	EF	34.313911	-78.005132
11/03/2021	SUT57	Sutton Lake	EF	34.306501	-78.004862
11/03/2021	SUT60	Sutton Lake	EF	34.306226	-77.999577
11/03/2021	SUT74	Sutton Lake	EF	34.291472	-77.997442
11/03/2021	SUT82	Sutton Lake	EF	34.298239	-78.008011
11/04/2021	SUT07	Sutton Lake	MFN	34.288139	-77.996934
11/04/2021	SUT114	Sutton Lake	MFN	34.294314	-78.008680
11/04/2021	SUT12	Sutton Lake	MFN	34.288869	-78.003090
11/04/2021	SUT28	Sutton Lake	MFN	34.307672	-78.011793
11/04/2021	SUT37	Sutton Lake	MFN	34.314906	-78.004065
11/04/2021	SUT61	Sutton Lake	MFN	34.306093	-77.997795
11/04/2021	SUT74G	Sutton Lake	GILL	34.291472	-77.997442
11/04/2021	SUT77G	Sutton Lake	GILL	34.292383	-78.002636
11/04/2021	SUT55G	Sutton Lake	GILL	34.306529	-78.001316
11/04/2021	SUT52G	Sutton Lake	GILL	34.306461	-77.995981
11/04/2021	SUT92G	Sutton Lake	GILL	34.311800	-78.001079
11/04/2021	SUT94G	Sutton Lake	GILL	34.312820	-77.997881

TABLE 2. Total catch and total length (TL) by species during boat-mounted electrofishing sampling of Sutton Lake conducted in 2021.

Common name	Scientific name	Number	Percent	Min TL (mm)	Max TL (mm)	Mean TL (mm)
Inland game fish						
Bluegill	*Lepomis macrochirus*	320	27.1	22	194	117
Hybrid Sunfish	*Lepomis* spp.	72	6.1	56	170	112
Largemouth Bass	*Micropterus salmoides*	527	44.6	64	574	121
Redbreast Sunfish	*Lepomis auritus*	71	6.0	40	172	127
Redear Sunfish	*Lepomis microlophus*	67	5.7	66	300	119
Sunfish	*Lepomis* spp.	8	0.7	30	54	43
Warmouth	*Lepomis gulosus*	108	9.1	44	124	93
Nongame fish						
American Eel	*Anguilla rostrata*	5	0.4	-	-	-
Common Carp	*Cyprinus carpio*	1	0.1	678	678	678
Grass Carp	*Ctenopharyngodon idella*	2	0.2	600	672	636
Total		1,181	100			

TABLE 3. Total catch and total length (TL) by species during gill net sampling of Sutton Lake conducted in 2021.

Common name	Scientific name	Number	Percent	Min TL (mm)	Max TL (mm)	Mean TL (mm)
Inland game fish						
Black Crappie	*Pomoxis nigromaculatus*	1	0.8	136	136	136
Hybrid Sunfish	*Lepomis* spp.	6	5.1	110	176	141
Largemouth Bass	*Micropterus salmoides*	17	14.4	256	530	418
Redear Sunfish	*Lepomis microlophus*	2	1.7	112	140	126
Warmouth	*Lepomis gulosus*	3	2.5	112	114	113
Nongame fish						
Atlantic Needlefish	*Strongylura marina*	4	3.4	498	576	531
Blue Catfish	*Ictalurus furcatus*	4	3.4	800	968	875
Channel Catfish	*Ictalurus punctatus*	7	5.9	314	606	512
Flathead Catfish	*Pylodictis olivaris*	3	2.5	630	736	675
Gizzard Shad	*Dorosoma cepedianum*	50	42.4	156	458	382
Grass Carp	*Ctenopharyngodon idella*	1	0.8			
Longnose Gar	*Lepisosteus osseus*	19	16.1	562	1300	865
Threadfin Shad	*Dorosoma petenense*	1	0.8	144	144	144
Total		118	100			

TABLE 4. Total catch and total length (TL) by species during mini-fyke net sampling of Sutton Lake conducted in 2021.

Common name	Scientific name	Number	Percent	Min TL (mm)	Max TL (mm)	Mean TL (mm)
Inland game fish						
Black Crappie	*Pomoxis nigromaculatus*	2	5.9	110	134	122
Bluegill	*Lepomis macrochirus*	11	32.4	44	138	84
Hybrid Sunfish	*Lepomis* spp.	10	29.4	36	164	79
Largemouth Bass	*Micropterus salmoides*	1	2.9	90	90	90
Redbreast Sunfish	*Lepomis auritus*	1	2.9	150	150	150
Lepomis spp.	*Lepomis* spp.	5	14.7	28	50	42
Warmouth	*Lepomis gulosus*	3	8.8	42	118	90
Nongame fish						
American Eel	*Anguilla rostrata*	1	2.9	-	-	-
Total		34	100			

TABLE 5. Largemouth Bass catch-per-unit effort (CPUE) and standard errors (SE) for boat electrofishing conducted by NCWRC at Sutton Lake since 1988. Mean CPUE values are reported for all, stock size and larger (≥200mm), and harvestable (≥356mm) individuals.

Year	Number Caught	Effort (h)	Overall Mean CPUE (SE)	Stock Size and Larger (≥200mm) Mean CPUE (SE)	Harvestable (≥356mm) Mean CPUE (SE)	Season
1988[1]	329[1]	14.1	20.7 (-)	17.2 (-)[2]	4.8 (-)[2]	Spring
1989[1]	178[1]	12.1	14.7 (-)	10.7 (-)[2]	5.0 (-)[2]	Spring
1990	171	10.4	17.2 (2.6)	14.0 (2.1)	4.0 (0.7)	Spring
1990	362	-	-	-	-	Fall
1991	558	9.4	62.3 (8.1)	52.9 (7.3)	22.0 (3.1)	Spring
1992	348	10.9	32.7 (3.5)	30.4 (3.3)	19.0 (2.7)	Spring
1993	285	3.6	76.9 (4.4)	73.0 (4.7)	48.6 (2.6)	Spring
1993	120	-	-	-	-	Fall
1994	549	4.7	114.8 (31.4)	82.9 (23.5)	15.1 (3.8)	Spring
1995	373	6.2	58.1 (7.0)	36.4 (3.9)	17.8 (1.9)	Spring
1996	198	6.4	31.0 (4.8)	25.4 (4.5)	12.1 (2.0)	Spring
1997	173	7.2	24.8 (7.6)	9.3 (2.5)	5.0 (1.3)	Spring
1998	236	6.1	37.3 (4.2)	17.0 (1.6)	7.5 (0.8)	Spring
1999	164	5.7	27.2 (3.1)	20.4 (2.6)	6.0 (1.2)	Spring
2000	290	7.5	38.5 (8.1)	16.6 (2.1)	7.4 (1.1)	Spring
2001	211	8.8	23.3 (2.3)	14.5 (1.6)	7.6 (0.5)	Spring
2002	833	8.1	108.3 (7.1)	58.6 (7.2)	10.6 (2.9)	Spring
2003	951	6.4	154.3 (21.5)	85.0 (7.6)	15.9 (2.4)	Spring
2004	255	6.1	42.2 (9.7)	21.7 (4.7)	3.4 (1.0)	Spring
2005	497	5.5	94.5 (16.9)	32.8 (7.2)	6.0 (1.3)	Spring
2006	510	4.9	100.6 (17.2)	25.9 (6.8)	7.8 (2.7)	Spring
2007	353	5.6	60.5 (12.1)	30.8 (6.4)	12.8 (3.4)	Spring
2008	654	5.2	126.3 (11.5)	78.3 (15.9)	31.2 (7.2)	Spring
2009	445	5.2	83.9 (9.4)	42.1 (6.1)	15.0 (2.8)	Spring
2010	322	4.9	61.5 (12.6)	34.2 (9.4)	9.4 (3.3)	Spring
2011	559	5.4	104.3 (10.5)	76.6 (12.1)	21.2 (4.5)	Spring
2012	347	4.6	76.2 (12.8)	49.3 (8.9)	16.7 (4.1)	Spring
2012	1005	3.7	267.0 (31.6)	33.0 (6.5)	9.9 (2.6)	Fall
2013	258	4.6	49.6 (14.3)	39.7 (14.1)	26.1 (11.0)	Spring
2013	361	3.7	89.2 (15.8)	11.5 (2.0)	6.9 (2.1)	Fall
2014	290	3.2	69.2 (20.4)	31.8 (10.9)	11.5 (4.4)	Spring
2015	298	4.1	72.8 (14.4)	56.4 (12.3)	29.7 (6.4)	Spring
2016	143	3.7	35.8 (9.1)	25.7 (6.1)	15.8 (4.0)	Spring
2017	274	3.5	91.6 (24.6)	24.9 (7.0)	6.1 (3.0)	Spring
2018	223	4.0	49.8 (8.9)	32.3 (7.4)	20.1 (4.0)	Spring
2019	115	0.9	128.5 (27.6)	23.4 (7.8)	7.2 (2.9)	Spring
2021[3]	524	1.5	344.9 (88.5)	10.6 (3.4)	6.0 (2.2)	Fall

[1]Includes fish captured by CP&L (34 in 1988 and 16 in 1989) that were not considered when calculating CPUE.
[2]Some values were approximated or unavailable due to data inconsistencies.
[3]No NCWRC sampling occurred at Sutton Lake in 2020.

TABLE 6. Largemouth Bass total length (mm), weight (g), and age data for electrofishing conducted by NCWRC at Sutton Lake since 1988.

Year	Median Total Length (mm)	Mean Total Length (mm)	Number with Total Length ≥356mm	Number Weighing >2267g	Max Age	Season
1988[1]	-	-	Scarce	-	6	Spring
1989[1]	306	287	61	0	-	Spring
1990	300	289	40	0	5	Spring
1990	282	264	128	4	-	Fall
1991	299	307	195	9	4	Spring
1992	367	362	200	6	5	Spring
1993	375	354	182	4	-	Spring
1993	142	207	29	0	-	Fall
1994	220	237	71	0	-	Spring
1995	308	280	114	0	-	Spring
1996	326	295	74	0	-	Spring
1997	178	211	36	0	-	Spring
1998	186	225	46	0	-	Spring
1999	263	277	35	0	-	Spring
2000	123	191	52	0	-	Spring
2001	227	266	67	0	-	Spring
2002	200	220	72	1	6	Spring
2003	207	227	90	2	-	Spring
2004	205	225	19	0	7	Spring
2005	176	193	33	1	-	Spring
2006	165	194	38	3	7	Spring
2007	206	250	81	4	6	Spring
2008	228	259	166	0	8	Spring
2009	204	239	87	0	5	Spring
2010	204	229	42	0	6	Spring
2011	282	276	115	1	7	Spring
2012	243	255	79	0	8	Spring
2012	95	130	45	2	-	Fall
2013	356	323	130	1	7	Spring
2013	130	157	28	0	-	Fall
2014	211	264	82	0	8	Spring
2015	330	304	113	2	7	Spring
2016	251	301	61	1	7	Spring
2017	174	194	21	0	7	Spring
2018	256	307	93	4	-	Spring
2019	162	186	8	0	-	Spring
2020[2]	-	-	-	-	-	-
2021	108	121	11	1	8	Fall

[1]Includes fish captured by CP&L.

[2]No NCWRC sampling occurred at Sutton Lake in 2020.

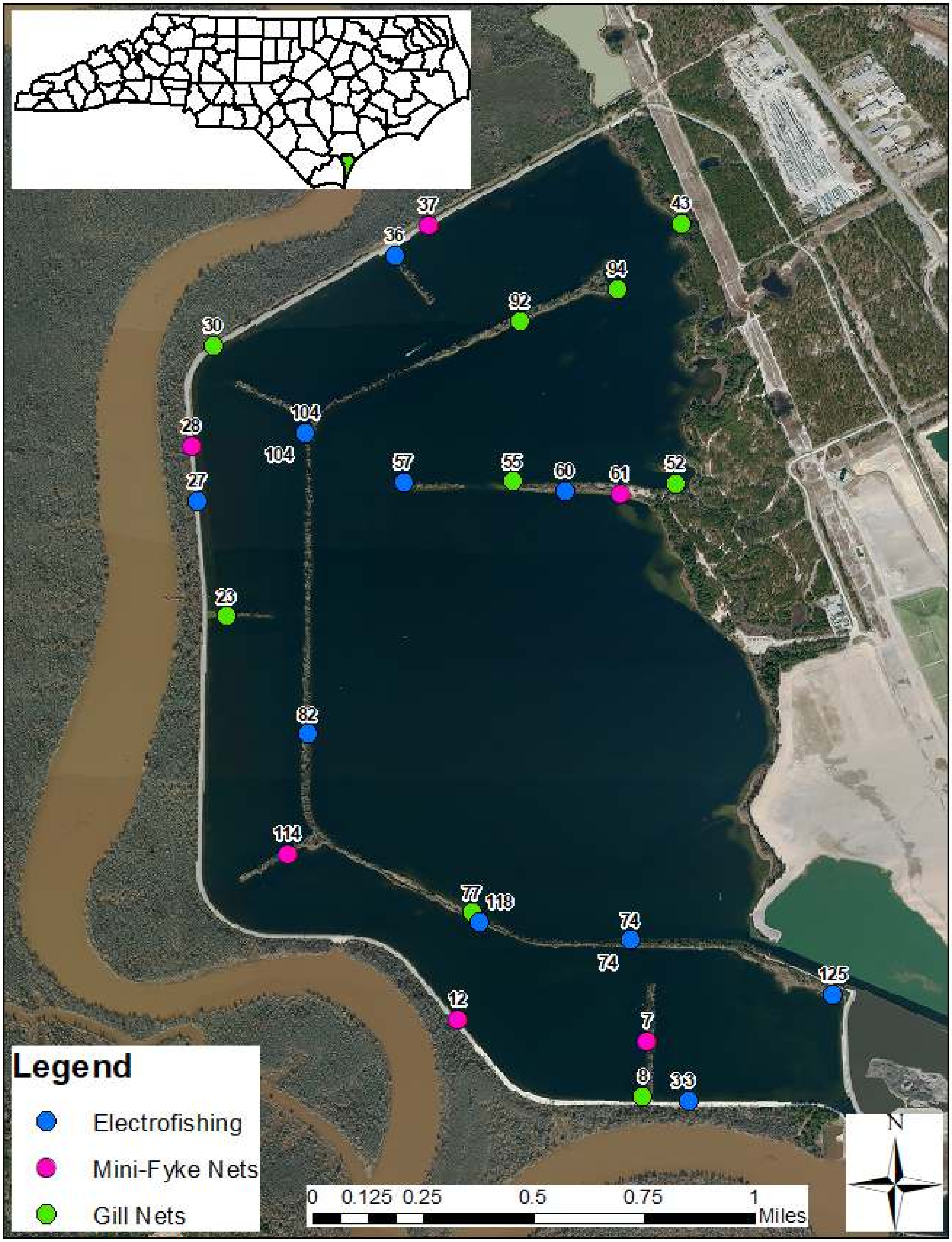

FIGURE 1. Map of sites sampled on Sutton Lake by gear type in 2021.

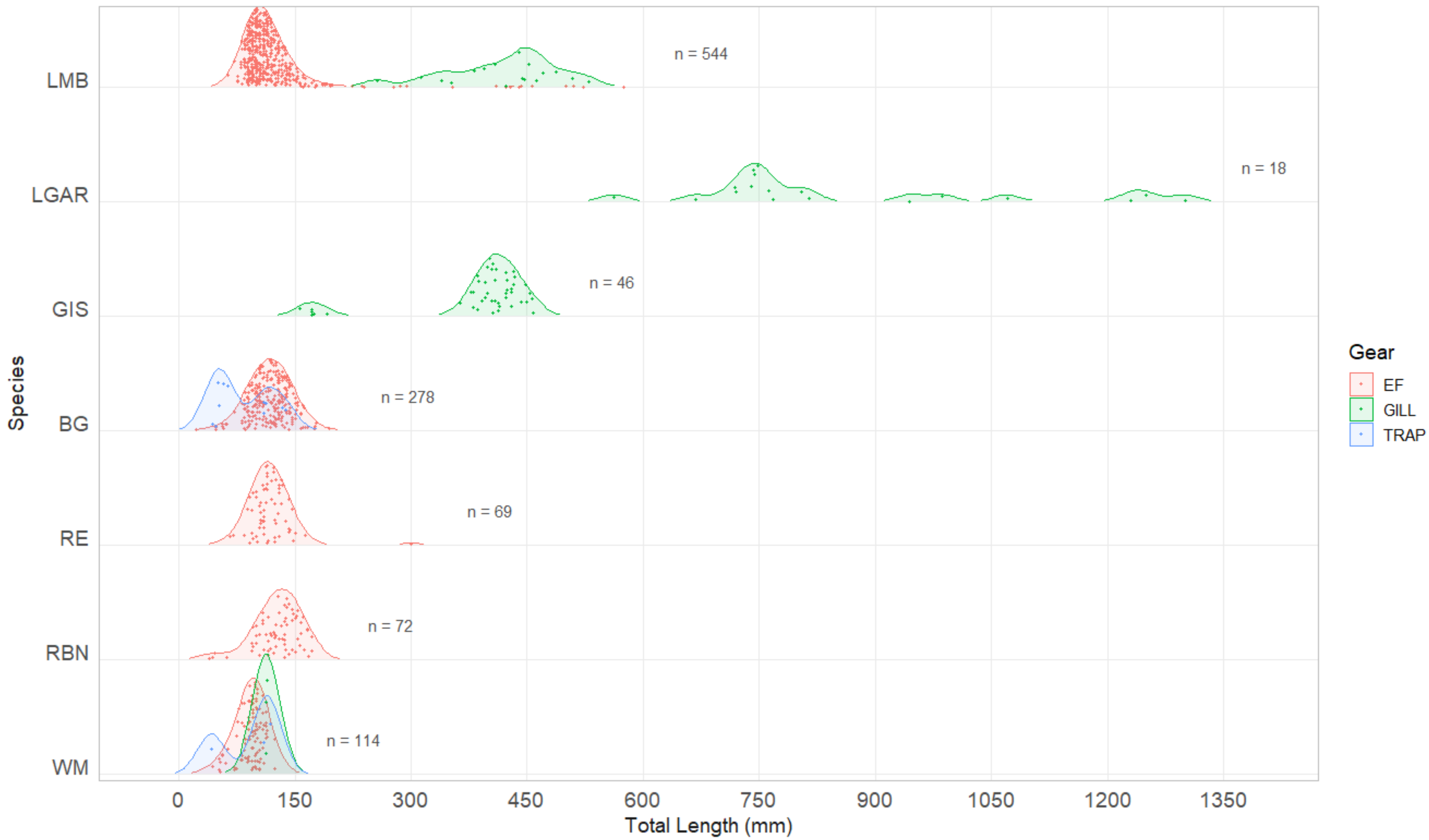

FIGURE 2. Length frequency distribution by gear type for Largemouth Bass (LMB), Longnose Gar (LGAR), Gizzard Shad (GIS), Bluegill (BG), Redear Sunfish (RE), Redbreast Sunfish (RBN), and Warmouth (WM) captured in 2021. Sample size may not equal total catch for each species as some captured individuals were not measured for length.

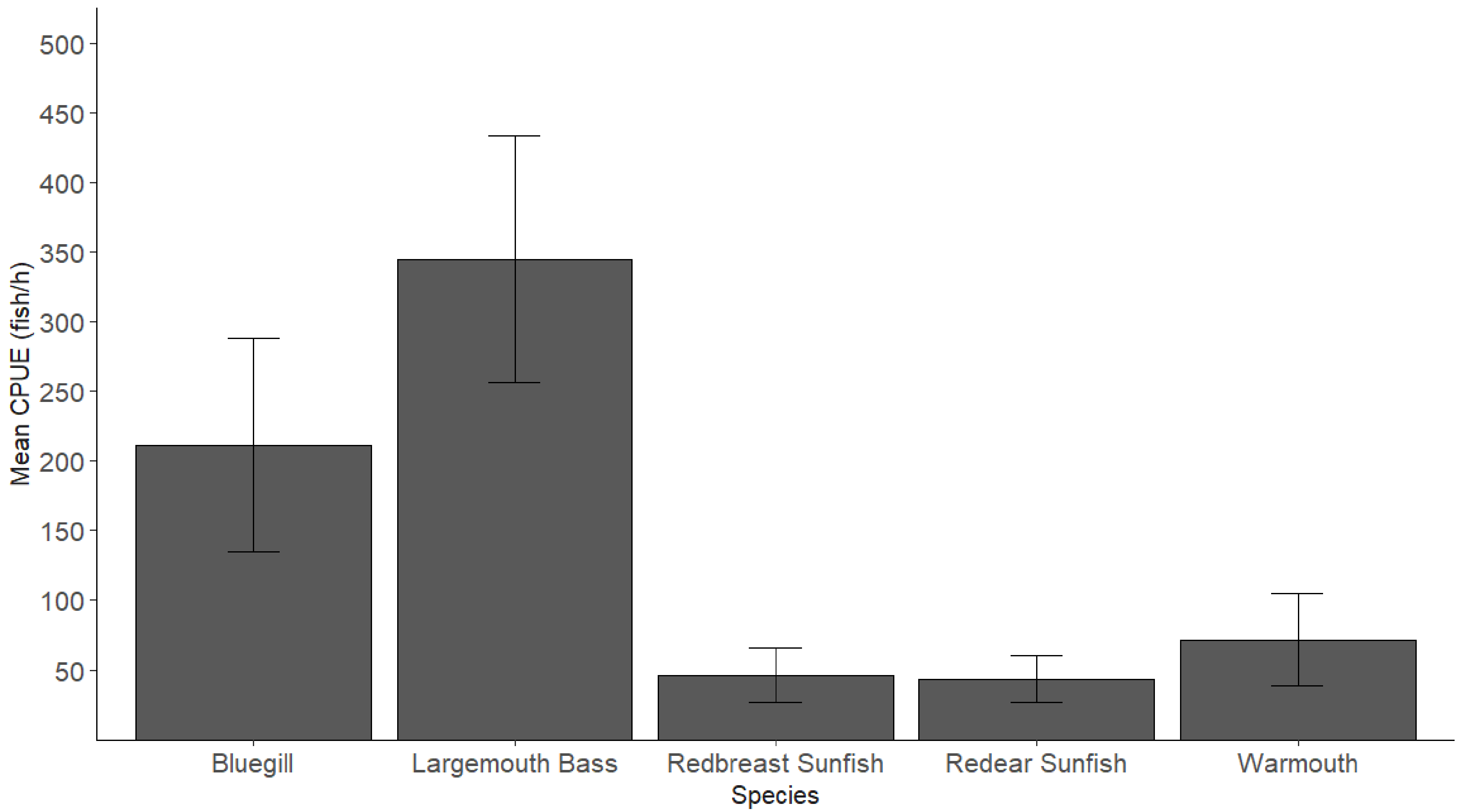

FIGURE 3. Overall catch per unit effort (CPUE)(±SE) for the most commonly observed inland game fish during boat electrofishing of Sutton Lake, 2021.

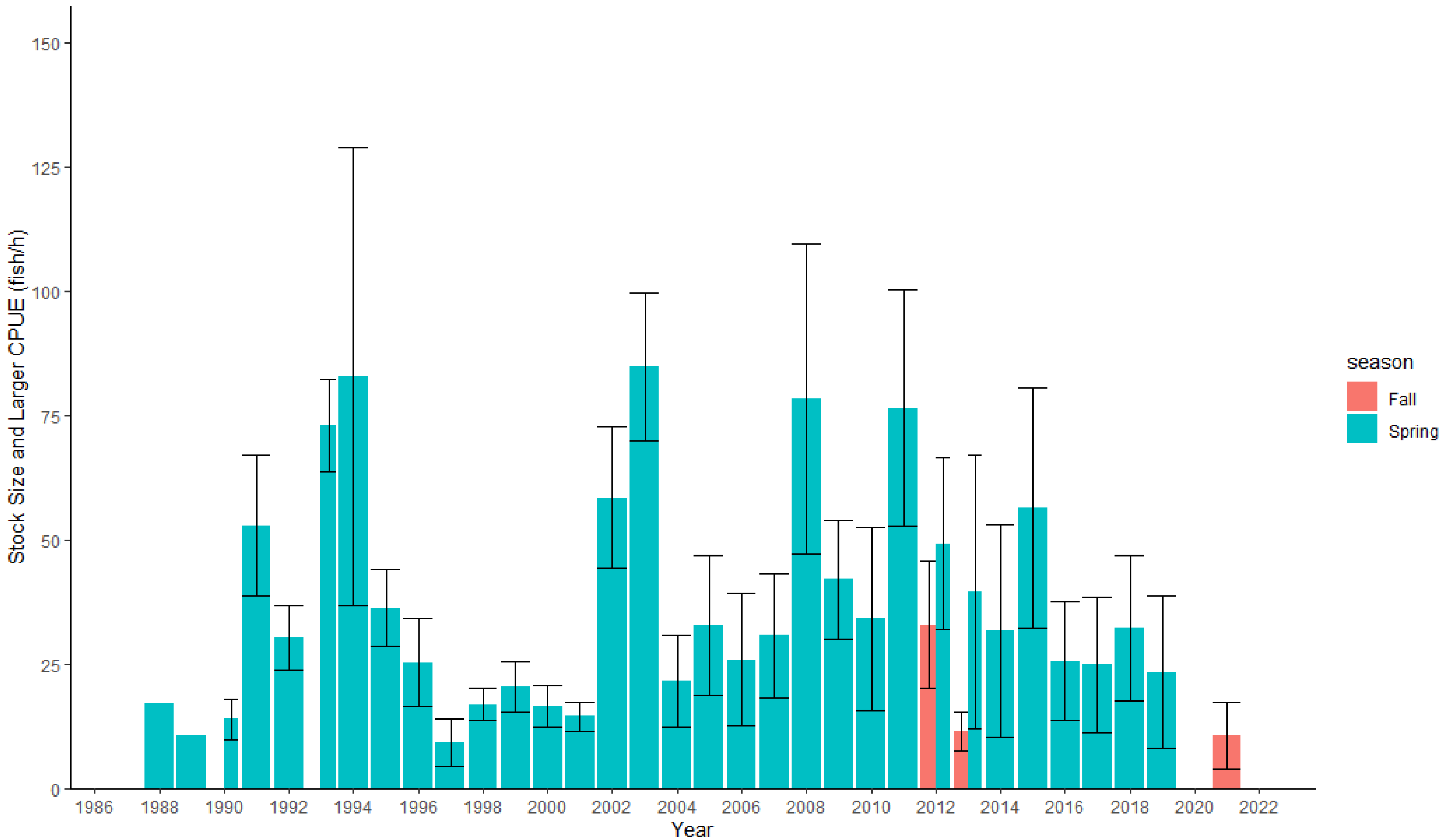

FIGURE 4. Catch per unit effort (CPUE) (± 95% confidence interval) for stock size and larger (≥ 200 mm) Largemouth Bass by season and year during boat electrofishing of Sutton Lake, 1988–2021. Fall sampling occurred in 1990 and 1993 and catch values were available, but no effort was available to calculate CPUE.

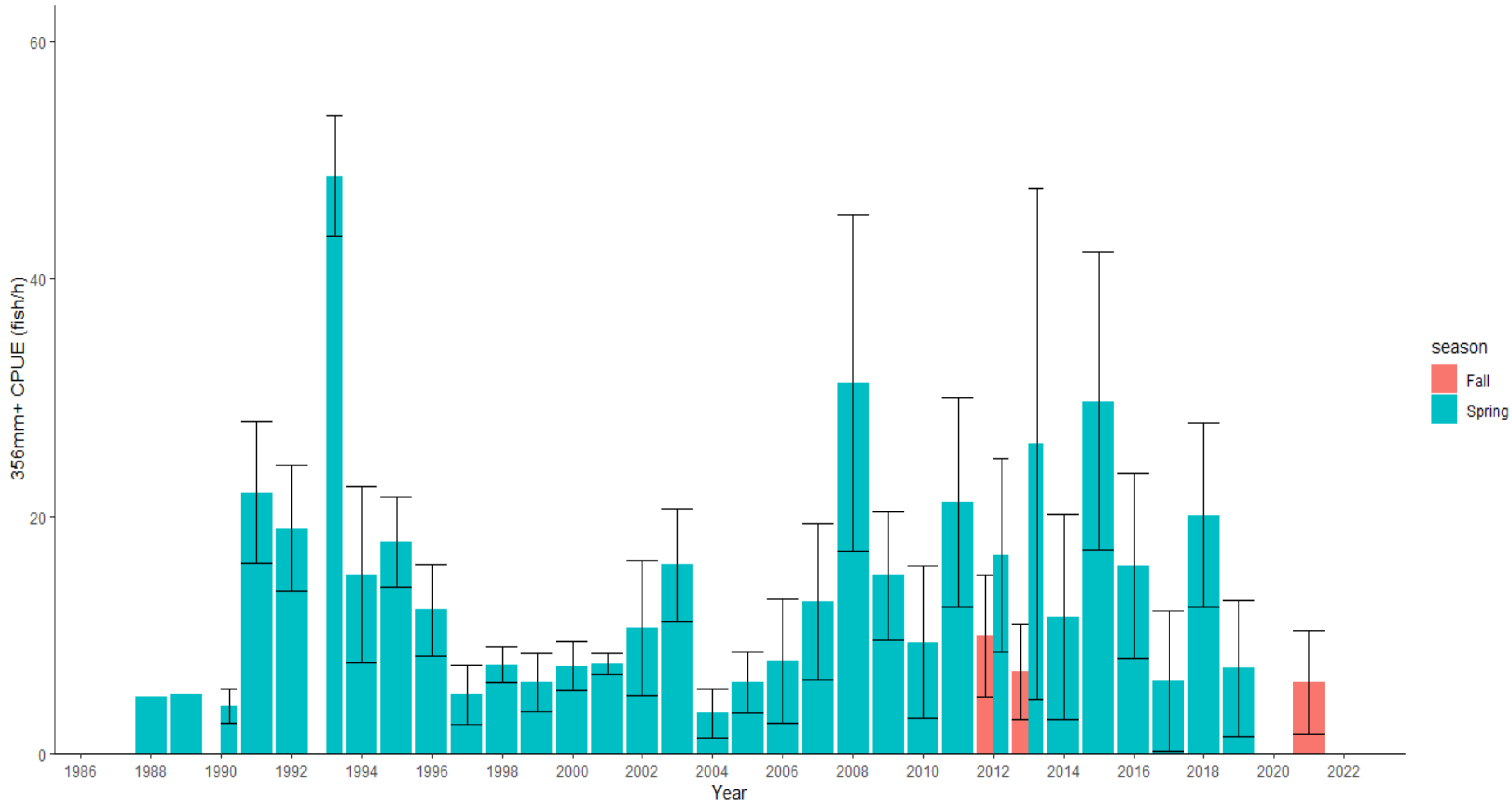

FIGURE 5. Catch per unit effort (CPUE) (± 95% confidence interval) for harvestable (≥ 356 mm) Largemouth Bass by season and year during boat electrofishing of Sutton Lake, 1988–2021. Fall sampling occurred in 1990 and 1993 and catch values were available, but no effort was available to calculate CPUE.

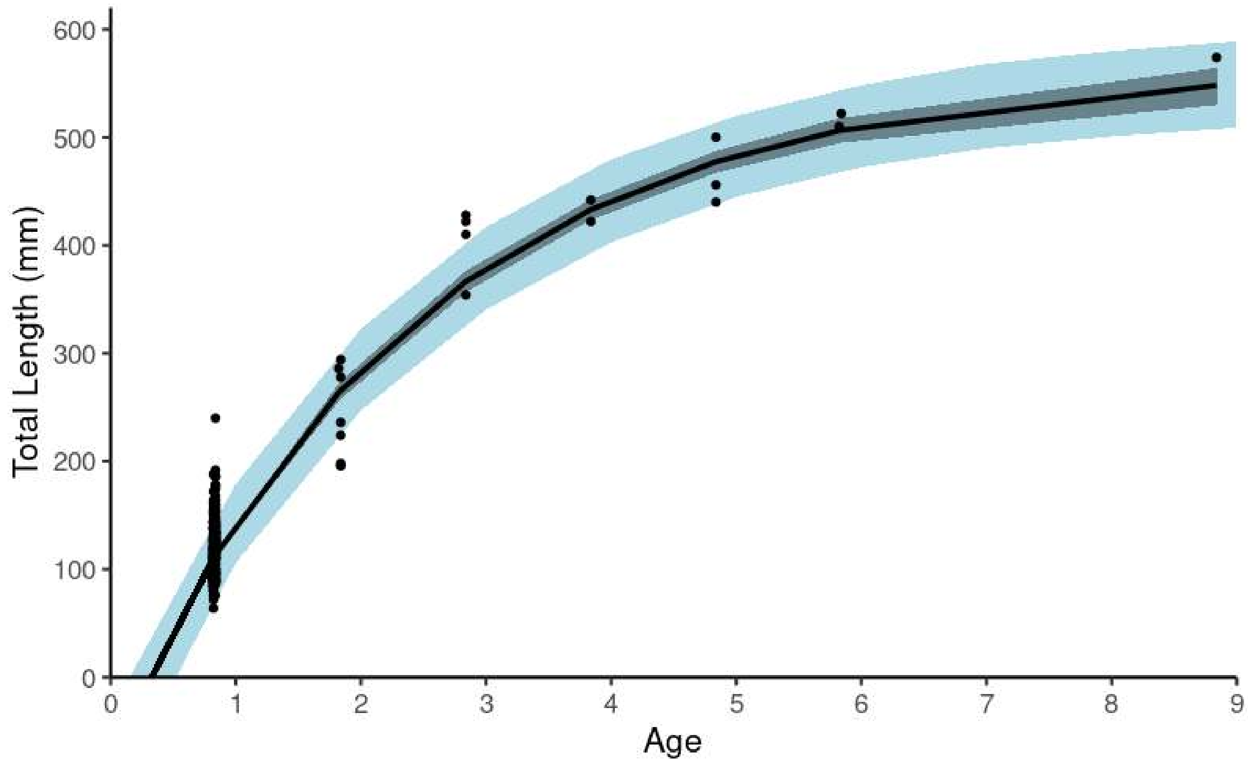

FIGURE 6. Predicted median length-at-age for Largemouth Bass from von Bertalanffy growth models (black line) and observed individuals (point markers). The light shaded area denotes the 90% credible interval of the posterior predictive distribution, while the dark shaded region denotes the 90% credible interval of the model.