

STATE MANAGED SPECIES – ESTUARINE STRIPED BASS

**FISHERY MANAGEMENT PLAN UPDATE
ESTUARINE STRIPED BASS
AUGUST 2022**

STATUS OF THE FISHERY MANAGEMENT PLAN

Fishery Management Plan History

Original FMP Adoption:	January 1994 May 2004
Amendments:	Amendment 1 May 2013 Amendment 2 In Progress
Revisions:	Revision to Amendment 1 November 2014 Revision to Amendment 1 November 2020
Supplements:	Supplement A February 2019
Information Updates:	None
Schedule Changes:	August 2016
Comprehensive Review:	Review started in 2017; Amendment 2 is currently in development

Estuarine striped bass (*Morone saxatilis*) in North Carolina are managed under Amendment 1 to the N.C. Estuarine Striped Bass FMP, its subsequent revisions, and Supplement A. It is a joint plan between the North Carolina Marine Fisheries Commission (NCMFC) and the North Carolina Wildlife Resources Commission (NCWRC). The Striped Bass FMP, Revisions, Amendments, and Supplement A (NCDMF 1994, 2004, 2013, 2014, 2019, and 2020) are available on the NCDMF website at: <https://deq.nc.gov/about/divisions/marine-fisheries/managing-fisheries/fishery-management-plans#state-managed-species>

The NCMFC and the NCWRC implemented a Memorandum of Agreement in 1990 to address management of the striped bass stock in the Albemarle Sound and Roanoke River (A-R). The original Estuarine Striped Bass FMP was approved by the NCMFC in November 1993 and was targeted at the continued recovery of the A-R stock, which was at historically low levels of abundance and experiencing chronic spawning failures (Laney et. al. 1993). The comprehensive plan addressed the management of all estuarine striped bass stocks in the state, satisfying a recommendation contained in the Report to Congress for the North Carolina Striped Bass Study (U.S. Fish and Wildlife Service 1992) that such a plan be prepared.

The North Carolina Estuarine Striped Bass FMP approved in May 2004 was the first FMP developed under the criteria and standards of the 1997 Fisheries Reform Act (NCDMF 2004). The plan focused on identifying water flow, water quality, and habitat issues throughout the state, reducing discard mortality in the commercial anchored gill net fisheries, continued stocking of

striped bass in the Central and Southern areas of the state, and developing creel surveys in the Tar-Pamlico, Neuse, and Cape Fear rivers to estimate recreational harvest in those systems.

Amendment 1, adopted in 2013, lays out separate management strategies for the A-R stock and the Central and Southern stocks in the Tar-Pamlico, Neuse, and Cape Fear rivers. Management programs in Amendment 1 consist of daily possession limits, open and closed harvest seasons, gill net mesh size and yardage restrictions, seasonal attendance requirements, barbless hook requirements in some areas, minimum size limits, and slot limits to maintain a sustainable harvest and reduce regulatory discard mortality in all sectors. Amendment 1 also maintains the stocking regime in the Central and Southern systems (Central Southern Management Area, CSMA) and the harvest moratorium on striped bass in the Cape Fear River and its tributaries (NCDMF 2013). Striped bass fisheries in the Atlantic Ocean of North Carolina are managed under the Atlantic States Marine Fisheries Commission's (ASMFC) Amendment 7 to the Interstate FMP for Atlantic Striped Bass.

In response to the 2013 benchmark A-R striped bass stock assessment that indicated fishing mortality was above the target, the NCMFC approved a Revision to Amendment 1 in November 2014 (NCDMF 2014). The November 2014 Revision reduced the total allowable landings (TAL) for the A-R stock from 550,000 pounds to 275,000 pounds, split evenly between the commercial and recreational sectors. Stock assessment projections indicated a TAL of 275,000 pounds would maintain fishing mortality and spawning stock at their respective targets, providing a sustainable harvest. The November 2014 Revision maintained the 25,00-pound commercial TAL for the CSMA, daily possession limits and a closed summer season to control recreational harvest, and a total harvest moratorium in the Cape Fear River and its tributaries. The November 2014 Revision utilizes TAL instead of total allowable catch (TAC). The term TAC does not accurately describe the existing management strategy, because the term "catch" refers to landings and discards. Since its inception the quota used to maintain striped bass harvest at sustainable levels in the A-R and the CSMA is for landings only, not landings and discards. Discards are accounted for in the stock assessment model but are not part of the TAL.

In August 2016, the NCMFC approved a change to the FMP review schedule so the comprehensive review of the Estuarine Striped Bass FMP would begin in July 2017 instead of July 2018 due to concerns about the high percentage of stocked fish and minimal natural recruitment in the CSMA systems. Review of the plan began in 2017 and development of Amendment 2 is ongoing.

On June 1, 2018, a NCWRC rule change implementing a 26-inch total length minimum size limit in the Inland Fishing Waters of the Tar-Pamlico and Neuse rivers became effective. At the November 2018 NCMFC business meeting, the division recommended development of temporary management measures to supplement the FMP providing for a no-possession provision for striped bass in the internal coastal and joint waters of the CSMA to protect important year classes of striped bass while Amendment 2 to the N.C. Estuarine Striped Bass Fishery Management Plan is developed. Supplement A to the Estuarine Striped Bass FMP was adopted by the NCMFC at their February 2019 business meeting and by the NCWRC in March 2019. Supplement actions in the FMP implemented March 29, 2019, consisted of the following:

- Commercial and recreational no possession measure for striped bass (including hybrids) in coastal and inland fishing waters of the CSMA (FF-6-2019). The NCWRC hook and line

closure proclamation had the effect of suspending rules 15A NCAC 10C .0107 (l) and 10C .0314 (g). A no-possession requirement already exists for the Cape Fear River by rule.

- Additionally, consistent with Amendment 1, commercial anchored gill-net restrictions requiring tie-downs and distance from shore (DFS) measures will apply year-round (M-5-2019).

On March 13, 2019, the Marine Fisheries Commission held an emergency meeting that directed the division to issue a proclamation regarding gill nets, beyond what was contained in Supplement A. Proclamation (M-6-2019) implemented the following:

- Prohibits the use of ALL gill nets upstream of the ferry lines from the Bayview Ferry to Aurora Ferry on the Pamlico River and the Minnesott Beach Ferry to Cherry Branch Ferry on the Neuse River.
- Maintains tie-down (vertical net height restrictions) and distance from shore restrictions for gill nets with a stretched mesh length 5 inches and greater in the western Pamlico Sound and rivers (superseded M-5-2019).

An emergency meeting called under North Carolina General Statute section 113-221.1(d), authorizes the commission to review the desirability of directing the fisheries director to issue a proclamation. Once the commission votes under this provision to direct issuance of a proclamation, the fisheries director has no discretion to choose another management option and is bound by law to follow the commission decision. In these cases, under existing law, the decision of the commission to direct the director to issue a proclamation is final and can only be overruled by the courts.

The most recent A-R striped bass benchmark stock assessment (Lee et al. 2020) was completed and approved for management use in 2020. The assessment indicated the resource is overfished and is experiencing overfishing (Lee et al. 2020). In response to the overfished and overfishing stock status, the NCMFC approved a Revision to Amendment 1 in November 2020 (NCDMF 2020). The November 2020 Revision to Amendment 1 to the North Carolina Estuarine Striped Bass Fishery Management Plan reduced the striped bass TAL from 275,000 pounds to 51,216 pounds in the Albemarle Sound and Roanoke River Management Areas to remain in compliance with Amendment 1 to the North Carolina Estuarine Striped Bass Fishery Management Plan (FMP) and the Atlantic States Marine Fisheries Commission (ASMFC) Addendum IV to Amendment 6 to the Interstate FMP for Atlantic Striped Bass. The new TAL was effective January 1, 2021.

The CSMA Estuarine Striped Bass Stocks report (Mathes et al. 2020), completed in 2020, is a collection of (1) all data that have been collected, (2) all management effort, and (3) all major analyses that have been completed for CSMA stocks to serve as an aid in development of Amendment 2. No stock status determination was performed, and no biological reference points were generated for CSMA striped bass stocks.

NCDMF and NCWRC staffs continue to work collaboratively in development of Amendment 2 to the N.C. Estuarine Striped Bass FMP.

Management Unit

There are two geographic management units and four striped bass stocks included in Amendment 1 to the North Carolina Estuarine Striped Bass FMP. The northern management unit is comprised of two striped bass harvest management areas: the Albemarle Sound Management Area (ASMA) and the Roanoke River Management Area (RRMA). The ASMA includes the Albemarle Sound and all its coastal, joint and inland water tributaries, (except for the Roanoke, Middle, Eastmost and Cashie rivers), Currituck, Roanoke and Croatan sounds and all their joint and inland water tributaries, including Oregon Inlet, north of a line from Roanoke Marshes Point across to the north point of Eagle Nest Bay in Dare County. The RRMA includes the Roanoke River and its joint and inland water tributaries, including Middle, Eastmost and Cashie rivers, up to the Roanoke Rapids Dam. The striped bass stock in these two harvest management areas is referred to as the A-R stock, and its spawning grounds are in the Roanoke River in the vicinity of Weldon, NC. Implementation of recreational and commercial striped bass regulations within the ASMA is the responsibility of the NCMFC. Within the RRMA, commercial regulations are the responsibility of the NCMFC while recreational regulations are the responsibility of the NCWRC. The A-R stock is also included in the management unit of Amendment 7 to the ASMFC Interstate FMP for Atlantic Striped Bass.

The southern geographic management unit is the CSMA and includes all internal coastal, joint, and contiguous inland waters of North Carolina south of the ASMA to the South Carolina state line. There are spawning stocks in each of the major river systems within the CSMA; the Tar-Pamlico, the Neuse, and the Cape Fear. These stocks are collectively referred to as the CSMA stocks. Spawning grounds are not clearly defined in these systems as access to spawning areas is influenced by river flows as well as impediments to migration. Management of striped bass within the CSMA is the sole responsibility of the NCMFC and the NCWRC and is not subject to compliance with the ASMFC Interstate FMP for Atlantic Striped Bass.

To ensure compliance with interstate requirements, North Carolina also manages the A-R striped bass stock under the North Carolina Fishery Management Plan for Interjurisdictional Fisheries (IJ FMP). The goal of the IJ FMP is to adopt fishery management plans, consistent with N.C. law, approved by the Mid-Atlantic Fishery Management Council, South Atlantic Fishery Management Council, or the ASMFC by reference and implement corresponding fishery regulations in North Carolina to provide compliance or compatibility with approved fishery management plans and amendments, now and in the future. The goal of these plans established under the Magnuson-Stevens Fishery Conservation and Management Act (federal council plans) and the Atlantic Coastal Fisheries Cooperative Management Act (ASMFC plans) are like the goals of the Fisheries Reform Act of 1997 to “ensure long-term viability” of these fisheries (NCDMF 2015).

Goal and Objectives

The goal of Amendment 1 to the North Carolina Estuarine Striped Bass FMP is to achieve sustainable harvest through science based decision-making processes that conserve adequate spawning stock, provide and maintain a broad age structure, and protect the integrity of critical habitats. To achieve this goal, the following objectives must be met:

- Identify and describe population attributes, including age structure, necessary to achieve sustainable harvest.

- Restore, improve, and protect striped bass habitat and environmental quality consistent with the Coastal Habitat Protection Plan (CHPP) to increase growth, survival, and reproduction.
- Manage the fishery in a manner that considers biological, social, and economic factors.
- Initiate, enhance, and/or continue programs to collect and analyze biological, social, economic, fishery, habitat, and environmental data needed to effectively monitor and manage the fishery.
- Initiate, enhance, and/or continue information and education programs to elevate public awareness of the causes and nature of issues in the striped bass stocks, habitat, and fisheries, and explain management programs.
- Develop management measures, including regulations that consider the needs of all user groups and provide sustainable harvest.
- Promote practices that minimize bycatch and discard mortality in recreational and commercial fisheries.

DESCRIPTION OF THE STOCK

Biological Profile

Striped bass are an estuarine dependent species found from the lower St. Lawrence River in Canada to the west coast of Florida through the northern shore of the Gulf of Mexico to Texas. In North Carolina, the species is also known as striper, rockfish, or rock. The only stocks considered migratory are the stocks from Maine to the Albemarle Sound-Roanoke River in North Carolina. Migratory striped bass are considered anadromous, meaning they spend most of their adult life in the waters of the estuaries and nearshore ocean, migrating to fresh water to spawn in the spring. For more southern stocks down through Florida, including the CSMA (Tar-Pamlico, Neuse, and Cape Fear stocks), striped bass are riverine, meaning they do not migrate to the ocean like northern striped bass stocks and, instead, spend their entire life in the upper estuary and riverine system.

Females in the A-R stock are 29% mature at age 3 and 97% mature at age 4, while females in the Tar-Pamlico and Neuse rivers are 50% mature at 2.7 years and 98% mature by age 3 (Knight 2015). The length at 50% maturity for striped bass in the A-R stock is 16.8 inches (Boyd 2011). Female striped bass in both systems produce large quantities of eggs which are broadcast into riverine spawning areas and fertilized by mature males, age 2 and older. In the Tar-Pamlico and Neuse rivers, fecundity ranges from 223,110 eggs for Age-3 females to 3,273,206 eggs for Age-10 females (Knight 2015). Fertilized eggs drift with downstream currents and need 1.5 to 3 days to hatch and then continue to develop through the larval stage for several more days, eventually arriving at river mouths and the inland portions of coastal estuaries where they develop into juveniles. Striped bass require flowing, freshwater habitats to spawn successfully, allowing the eggs to remain suspended until they hatch, and to transport larvae to nursery areas. Environmental conditions including temperature, rainfall and river flows are important factors in determining the number of juveniles produced annually. Spawning in North Carolina takes place from late March until early June. Peak spawning activity for the A-R stock occurs when water temperature reaches 62 to 67 degrees Fahrenheit in the Roanoke River at Weldon. Spawning grounds are not clearly defined in CSMA systems as access to spawning areas is influenced by river flows as well as impediments to migration. Natural reproduction and successful juvenile recruitment occur

infrequently and at low levels in the Tar-Pamlico, Neuse and Cape Fear rivers. The CSMA stocks are supported by continuous stocking efforts as evidenced by stocked fish comprising nearly 100% of the striped bass on the spawning grounds and in internal coastal fishing waters of the Tar-Pamlico, Neuse, and Cape Fear rivers (O'Donnell and Farrae 2017).

Striped bass are relatively long-lived and capable of attaining moderately large sizes. Fish weighing 50 or 60 pounds are not exceptional. In general, females grow larger than males with reported maximum lengths of 60 inches and 45 inches. The oldest observed striped bass in the A-R stock was 31 years. The oldest observed striped bass within the CSMA were 7 years in the Cape Fear River and 12 years in the Tar-Pamlico and Neuse rivers. The largest striped bass on record are several females caught in the early 1900s in Albemarle Sound which weighed 125 pounds each. Large Roanoke River striped bass (>900 mm TL) rapidly emigrate (~59 km/d) after spawning to distant (>1,000 km) northern ocean waters (New Jersey to Massachusetts), where they spend their summers and migrate southward in the fall to overwintering habitats off Virginia and North Carolina and complete their migration circuit the following spring by returning to the Roanoke River to spawn (Callihan et al. 2015). Estuarine striped bass from the A-R stock contribute minimally to the total coastal migratory stock when compared to the contributions from larger systems like the Chesapeake Bay, Delaware, and Hudson rivers. Striped bass populations in the CSMA are considered to have a primarily endemic riverine life history, having limited or no adult oceanic migration (Setzler et al. 1980; Rulifson et al. 1982a; Callihan 2012).

Striped bass can form large schools feeding on whatever fishes are seasonally and geographically available. They also feed on a wide variety of invertebrates. In general, oily fish such as Atlantic menhaden, herrings and shads are very important prey items, but they will also readily eat spot, mullet, Atlantic croaker, American eel, and various invertebrates like blue crab.

Stock Status: A-R Stock

The most recent assessment of the A-R striped bass stock was completed in 2020, utilizing data from 1991–2017. Results from the 2020 A-R striped bass benchmark stock assessment indicate the stock is overfished and overfishing is occurring (Lee et. al 2020). The estimate of F in the terminal year of the assessment (2017) was 0.27, above the $F_{35\%SPR}$ Threshold of 0.18 (Figure 1) and the estimate of SSB was 78,576 pounds, below the $SSB_{35\%SPR}$ Threshold of 267,390 pounds (Figure 2). Estimates of F have been above the $F_{35\%SPR}$ Threshold in 24 out of the 27 years of the time period of the assessment (Figure 1). Female SSB has declined steadily from a high of 587,516 pounds in 2000 to a low of 45,418 pounds in 2013. Female SSB increased through 2015 to 167,053 pounds and has declined since (Figure 2). Results of the assessment also show a period of strong recruitment (as measured by the number of age-0 fish coming into the stock each year) from 1993 to 2000, then a period of much lower recruitment from 2001 to 2017, which has contributed to the decline in SSB since 2003. Average recruitment during 1993–2000 was 1,127,646 age-0 fish per year while average recruitment for years 2001–2017 was 428,796 age-0 fish per year (Figure 2).

Several years of poor recruitment occurred during 2001–2004 at a time when SSB was at high levels, indicating factors other than abundance of SSB may be contributing to poor spawning success in some years. Appropriate river flow during the spawning period has long been recognized as an important factor in spawning success for A-R striped bass (Hassler et. al 1981; Rulifson and Manooch 1990). Low to moderate flows have been identified as favorable to strong

year-class production while high flows (10,000 cubic feet per second or greater) are unfavorable to the formation of strong year classes. The peer reviewers of the 2020 benchmark assessment recognized the importance of river flow on recruitment and noted declining recruitment in the time series does not appear to result solely from reduced abundance due to harvest (Lee et. al 2020).

Stock Assessment: A-R Stock

Stock Synthesis text version 3.30 (Methot 2000, 2012; Methot and Wetzel 2013) was used to model the striped bass stock and to calculate reference points (Lee et al. 2020). The Stock Synthesis model incorporates information from multiple fisheries and surveys and both length and age composition data. The structure of the model allows for a wide range of model complexity depending upon available data. The strength of the model is that it explicitly models both the dynamics of the population and the processes by which one observes the population and its fisheries. That is, the comparison between the model and the data is kept close to the natural basis of the observations, instead of manipulating the observations into the format of a simpler model. Another important advantage is the model allows for (and estimates) selectivity patterns for each fishing fleet and survey. The model was peer reviewed and approved for use in management by an outside panel of experts and the ASMFC Atlantic Striped Bass Management Board. The NCDMF also approved it for management use.

DESCRIPTION OF THE FISHERY: ASMA/RRMA

Annual spawning success of striped bass is largely dependent upon environmental conditions, both natural and manmade. Even when female spawning stock biomass is high, poor reproductive success can occur due to unfavorable environmental conditions. This fact is important to keep in mind when discussing trends in landings data and stock abundance. For species that have long term juvenile abundance surveys, this phenomenon is evident when we observe a year with above average spawning success (termed a “strong year class”) followed by a year when practically no eggs survive to the juvenile stage (a “weak year class”). This cycle of spawning success and failure results in annual harvests that increase and decrease depending on the abundance of the year classes available to the fishery.

Current Regulations: ASMA/RRMA

Harvest in the ASMA commercial sector in 2021 was limited by an annual TAL of 25,608 pounds. There is also an 18-inch minimum total length (TL) size limit. The commercial fishery is prosecuted as a non-directed bycatch fishery, with most landings occurring in large mesh (\geq 5-inch stretched mesh) floating gill nets during the spring American shad fishery. Pound nets and flounder nets account for the remainder of the harvest. Harvest in the newly developing strike net fishery for blue catfish has also increased in recent years. Daily trip limits are set by proclamation. Daily reporting of the number and pounds of striped bass landed from all licensed striped bass dealers ensure the TAL is not exceeded. Dependent on available quota, a fall harvest season can be opened from October 1 through December 31 and a spring harvest season can be opened from January 1 through April 30. The harvest season is closed from May 1 through September 30 each year. The seasons may be closed early by proclamation if the TAL is reached. There is mandatory attendance of all small mesh ($<$ 5-inch stretched mesh) gill nets during May–November to reduce discard

mortality in that fishery. There are areas within the ASMA that are closed to all gill netting to further reduce undersize discards and to protect females as they enter the mouth of the Roanoke River during their spring spawning migration.

Harvest by the ASMA recreational sector in 2021 was limited by an annual TAL of 12,804 pounds. The recreational sector also has an 18-inch total length minimum size limit and a one fish per person daily possession limit. The harvest seasons are the same as the commercial sector. Harvest is estimated via a creel survey designed for striped bass in the ASMA. The daily possession limit may be changed and/or seasons closed early by proclamation to ensure the TAL is not exceeded.

Check with the NCDMF for the most recent proclamation on striped bass harvest limits including trip limits and bycatch requirements.

Commercial harvest in the RRMA is prohibited. The RRMA recreational sector also had a TAL of 12,804 pounds in 2021. Due to the reduced TAL, the 2021 harvest season for striped bass in the RRMA was open April 10–April 16, and April 24–April 30, 2021. There is an 18-inch total length minimum size limit and a no possession slot where fish between 22- and 27-inches TL may not be possessed. There was a one fish per person daily possession limit and only one of those fish may be greater than 27 inches total length. Only a single barbless hook may be used in inland waters of the RRMA upstream of the U.S. Highway 258 Bridge April 1–June 30.

Commercial Fishery: ASMA

Commercial landings in the ASMA have been controlled by an annual TAL since 1991 (Table 1). Due to gill net mesh regulations and minimum size limits in place, most harvest consists of fish 4–6 years of age. From 1990 through 1997 the TAL was set at 98,000 pounds because the A-R stock was at historical low levels of abundance. The stock was declared recovered in 1997 and the TAL was gradually increased as stock abundance increased. The TAL reached its maximum level of 275,000 pounds in 2003 as the stock reached record levels of abundance.

Through 2004, the TAL was reached easily. As stock abundance declined, commercial landings no longer reached the annual TAL, even with increases in the number of harvest days and daily possession limits. During 2005–2009 landings steadily declined and averaged about 150,000 pounds, even though gill net trips remained steady during that period (Figure 3).

The decline in landings during 2005–2009 was due to poor year classes produced from 2001 to 2004. An increase in landings in 2010 to over 200,000 pounds was due to the strong 2005-year class. Since 2013 landings have been reduced in part because of a shortened American shad season resulting from sustainability parameters being exceeded in the American Shad Sustainable Fishery Plan. Most landings traditionally have come during the American shad season. Length frequency distribution in 2021 is presented in Figure 4. Length at age for all commercial samples collected 1972–2021 are presented in Figure 5. Commercial length frequencies are represented in Figure 6. Modal length increased in 1991 and has stayed steady due to the 18-inch minimum. A larger abundance of older fish was present in 2004 and there was a decrease in modal length in 2018. Fish between 18–24 inches TL dominate the fishery.

Recreational Fishery: ASMA/RRMA

The recreational sector's landings in the ASMA are dominated by fish aged 3 to 5. Landings in the ASMA have been controlled by a TAL since 1991 (Table 1). Starting in 1998 the TAL was split evenly between the commercial and recreational sectors. The recreational TAL increased incrementally from 29,400 pounds in 1997 to 137,500 pounds in 2003. The recreational sector reached its TAL consistently until 2002, when landings started declining. Recreational landings peaked in 2001 at 118,506 pounds. (Figure 3). The harvest season increased from four days a week to seven in the fall of 2005 and the daily recreational possession limit increased from two to three fish in the fall of 2006, but landings continued to decline. Several poor year classes produced since 2001 have accounted for the decline in stock abundance and recreational harvest since 2006. The recreational limit was decreased to two fish per person per day in January 2016 and further to one fish in January 2021. Recreational harvest during 1991–2021 has averaged 43,708 pounds in the ASMA. Releases are usually greater than harvest and are dominated by fish less than the 18-inch minimum length limit. Undersized releases during the last 10 years have averaged 21,247 fish (Table 2). Length frequency distribution in 2021 is presented in Figure 4. ASMA recreational length frequencies for 1996–2021 are presented in Figure 7. Since 1996 the shift in abundance of younger fish is apparent with older fish still showing up in the fishery. Since 2014 the abundance of younger fish has increased likely due to the large 2014- and 2015-yearclasses with a slight uptick in landings for 2019 and 2020 from the previous several years (2016–2019). Landings were substantially lower in 2021 than previous years as a result of a reduced TAL.

The recreational sector's landings in the RRMA are dominated by fish aged 3 to 5 due to a no possession rule of fish 22–27 inches TL in the RRMA, a statewide rule that prohibits possession of river herring cut bait or whole river herring over six inches in length while engaged in fishing activities, and general angling techniques in the RRMA. Very few anglers use the large size artificial lures or natural bait required to catch striped bass over 28 inches, so very few fish over nine or 10 years old are observed in the creel survey. Plus, these older fish make up a relatively small portion of the total overall stock abundance. Harvest from 1991 through 2019 has averaged 66,189 pounds in the RRMA (Table 1). Many more striped bass are caught and released by recreational anglers each year than are harvested, especially in the RRMA where concentrations of fish on the spawning grounds can be dense. Annual discards from 2011 through 2021 in the RRMA have averaged 83,286 fish (Table 2).

Landings in the RRMA followed the TAL closely through 2002. From 2003 through 2016 landings averaged 64,389 pounds, with a few noticeable low years (2003, 2008, 2013 and 2014; Figure 3). The total number of fish caught per angler during the spring fishery in the RRMA can be large; catches of 100 fish per day are not uncommon, but angler catch rates can be impacted by spring water flows. The hydropower company operating the dams on the Roanoke River, along with the U.S. Army Corps of Engineers and biologists with the USFWS and NCWRC, coordinate releases to best mimic natural flow conditions during the spring spawn. However, droughts or heavy rainfall may still result in very low, i.e., 2,000–3,000 cubic feet per second (cfs) or very high, ($\geq 20,000$ cfs) flood stage flow conditions in some years. During these low or high flow years, angler success can be greatly diminished. Length frequency distribution in 2021 is presented in Figure 4. RRMA recreational length frequencies for 2005–2021 are presented in Figure 8. Since 2005 abundance of older fish in the recreational creel survey has decreased.

MONITORING PROGRAM DATA: A-R STOCK

Fishery-Dependent Monitoring: A-R Stock

The length, weight, sex, and age of the commercial harvest of striped bass has been consistently monitored through sampling at fish houses conducted by the division since 1972. Since 1994 anchored gill nets have accounted for 87.8% of the harvest in the ASMA (Figure 9). Pound nets account for most of the remaining landings with minor catches coming from fyke nets, hoop nets, and pots. The mean total length from 2005 to 2021 was 21.6 inches (Table 3).

The recreational harvest of striped bass in the ASMA and RRMA has been consistently monitored by the NCDMF since 1990 and the NCWRC since 1988 respectively. The mean total length during 2005–2021 was 20 inches total length for the ASMA and RRMA (Tables 4 and 5). Age data from the dependent and independent surveys in the ASMA are presented in Table 6. The minimum and maximum age for the independent and dependent surveys are 1 and 17 years respectively with an average age of 5.

Fishery-Independent Monitoring: A-R Stock

A young-of-year (age-0) A-R striped bass juvenile abundance survey used to calculate a juvenile abundance index (JAI) was initiated by Dr. William Hassler of North Carolina State University in 1955. The NCDMF took over this critical long-term survey in 1987 at Dr. Hassler's retirement. Sampling occurs at seven fixed stations in the western Albemarle Sound July–October. Sampling gear is an 18-foot semi-balloon trawl towed for 15 minutes. Catch per unit effort is the number of striped bass captured per tow. The JAI provided by the survey is usually a reliable indicator of relative abundance and future harvest potential. Data from the survey reveal the highly variable inter-annual spawning success of striped bass. The long time-series of data also clearly shows the extended period of spawning failure that occurred when the stock was at historical levels of low abundance during the 1980s. Starting in 1993 the stock began producing successful spawns once again, due to improved water quality, agreements about water flow regimes on the Roanoke River during the spawning season, favorable environmental conditions during the spawning season, and severe management restrictions that allowed stock abundance to increase. Within an eight-year period spanning 1993–2000, the stock produced the four highest JAI values in the entire 46-year time series. The average JAI during 1993–2000 was 24.04, over three times higher than the average of the JAI prior to the stock crashing (1955–1977 JAI = 7.9; Figure 10). However, from 2001 to 2010 the JAI was below average for most years, above average for only one year (2010), and several years including some back-to-back (2003 and 2004), which were considered spawning failures. This cycle starting in 1993 led to overall stock abundance increasing steadily through the mid-2000s to all-time highs, followed by a period of stock decline. From 2010 to 2016 the stock saw improved annual spawning success, with above average JAI values in 2011, 2014, and 2015, with one year (2013) below the spawning failure threshold. However, the JAI values for 2018, 2019, 2020, and 2021 were 0.4, 1.18, 0.20, and 0.7 respectively and are below the spawning failure threshold of 1.33 (ASMFC 2010) (Figure 10).

A fall/winter fishery independent gill net survey has been conducted by the NCDMF throughout the Albemarle and Croatan sounds since the fall of 1990 (Program 135). The survey utilizes a stratified random sampling design, employing mesh sizes from 2½-inch to 10-inch stretch mesh to

characterize the resident and overwintering portion of the A-R stock. The survey is conducted from November through February. Catch per unit of effort is measured as the abundance of fish per 40-yard net soaked for 24 hours.

A spring survey employs the same methodology as the fall/winter survey but is conducted in the western Albemarle Sound only, near the mouth of the Roanoke River. The goal of the survey is to characterize the spawning portion of the A-R stock. The survey is conducted from March 1 through the end of May. Data from the surveys are used in the A-R stock assessment as an independent measure of stock abundance. No index of abundance is available for the spring survey in 2020 and 2021 or the winter survey in 2021. Sampling in 2020 was suspended due to COVID-19 restrictions and Atlantic sturgeon protected species interactions but resumed in the fall of 2021.

The independent gill net surveys do a good job of tracking relative abundance, but the trend in total abundance is often masked by the highly variable and often very large number of two- and three-year-old fish captured in the survey, so trends in total abundance are often less informative than trends in 4–6-year-old abundance. The trend in abundance of 4–6-year-old show the stock increasing in abundance through the 1990s, to a high in 1999 of about 90 fish per 100 net days for the spring survey and 72 fish in the fall/winter survey. The 4–6-year-old abundance has fluctuated since 2000 but has been on a general downward trend with abundance for both surveys at about 20 fish per 100 net days in 2014 (Figure 11). One weakness of the gill net surveys is they collect very few older fish and under-represent the expansion of fish in the 9+ age group that has occurred since 2000. They also don't capture the decline in abundance of age 9+ fish that has occurred since the period of poor spawning success during 2001–2010. In 2019 the abundance of 4–6-year-old fish was below average in the fall/winter portion of the survey and increased in the spring. The 2020 fall/winter portion of the survey showed a continued increase in numbers of 4–6-year-old fish (Figure 11). This is due to the above average 2014- and 2015-yearclasses reaching the 4–6-year-old range in 2021. Expectations are the abundance of 4–6-year-old fish will decline over the next few years because of the repeated spawning failures the stock has experienced since 2018 (Figure 10).

An electrofishing survey has been conducted by the NCWRC on the spawning grounds since the spring of 1990. The survey goals are the same as the spring gill net survey but takes place on the Roanoke River in the vicinity of Weldon, the location of the fall line and historical center of spawning activity for A-R striped bass. The survey uses a stratified random sampling design. Catch per unit of effort is measured as the number of fish captured per hour of electrofishing. The survey is used in the A-R stock assessment as an independent measure of stock abundance.

The trend in total abundance from the electrofishing survey is similar to the trends of age 4–6 fish in the gill net surveys, increasing from low levels of abundance in the early 1990s to a peak in the early 2000s of 380 fish per hour, then decreasing since to a low in 2017 of 50 fish per hour (Figure 12). The abundance of fish in 2021 (140 fish per hour) was the highest since 2015 but below the time series average of 192 fish per hour. Both surveys exhibit a few years with high inter-annual variability, but this is common with fisheries surveys in which environmental conditions affect relative abundance in the survey area and the catch efficiency of the gear. The electrofishing survey does a better job at tracking the abundance of the age 9+ group, and clearly shows the emergence of the 1993 cohort into this age group in 2002. The age 9+ group has been on a downward trend since the 2006 peak of 14 fish per hour. In 2018 no age 9+ fish were captured. In 2021 the survey

caught 0.72 fish per hour which was the highest rate since 2016 but well below the time series average of 3.97 fish per hour (Figure 13). The strong year classes produced from 1993–2000 supported the increased abundance of fish in the 9+ age group, but since the below average spawning and several years of spawning failure during 2001-2011, the abundance of the 9+ age group is declining. The oldest fish seen recently in the population is a 31-year-old fish based on a tag returned by an angler in 2019 in the Roanoke River. When the survey started in 1990 fish older than seven were rarely observed in the survey. Age 9+ fish abundance has decreased in recent years and for years 2016–2021 is similar to the abundance levels seen in the early 90's.

RESEARCH NEEDS: A-R STOCK

The research recommendations listed below (in no particular order) are intended to improve future assessments of the A-R striped bass stock. The bulleted items outline the specific issue and are organized by priority ranking.

High

- Improve estimates of discard mortality rates and discard losses from the ASMA commercial gill-net fisheries (ongoing through observer program)
- Collect data to estimate catch-and-release discard losses in the ASMA recreational fishery during the closed harvest season
- Investigate relationship between river flow and striped bass recruitment for consideration of input into future stock assessment models

Medium

- Transition to an assessment that is based on ages derived from otoliths
- Improve estimates of catch-and-release discard losses in the RRMA recreational fishery during the closed harvest season
- Incorporate tagging data directly into the statistical catch-at-age model
- Improve the collection of length and age data to characterize commercial and recreational discards
- Explore the direct input of empirical weight-at-age data into the stock assessment model in lieu of depending on the estimated growth relationships

Low

- Re-evaluate catch-and-release mortality rates from the ASMA and RRMA recreational fisheries incorporating different hook types and angling methods at various water temperatures (e.g., live bait, artificial bait, and fly fishing)
- Investigate the potential impact of blue catfish on the A-R striped bass population (e.g., habitat, predation, forage)

MANAGEMENT STRATEGY: A-R STOCK

Estuarine striped bass in North Carolina are managed under Amendment 1 to the North Carolina Estuarine Striped Bass FMP and subsequent revisions (Table 7). Striped bass fisheries in the Atlantic Ocean of North Carolina are managed under ASMFC's Amendment 7 to the Interstate FMP for Atlantic Striped Bass. The A-R stock is managed using biological reference points for spawning stock biomass and fishing mortality that are aimed at maintaining a sustainable harvest and adequate spawning stock biomass. Stock status is determined through a formal, peer reviewed stock assessment process that evaluates annual estimates of fishing mortality and biomass against their target and threshold values. The 2020 A-R striped bass stock assessment indicated that the A-R striped bass stock is overfished with overfishing occurring in the terminal year (2017). Adaptive management measures within Amendment 1 to the Striped Bass FMP required a reduction in TAL to reduce fishing mortality (F) to the target level. This reduction was implemented through a revision to Amendment 1 which reduced the TAL from 275,000 to 51,216 pounds starting in January of 2021 (NCDMF 2020). Juvenile abundance data generated from the survey is used in the A-R stock assessment as an independent measure of stock abundance. The index is also used as a recruitment failure trigger. If the JAI is below 75 % of all values from a fixed time series for three consecutive years, the ASMFC Striped Bass Technical Committee will make a recommendation to the ASMFC Striped Bass Management Board about possible causes and if management action is needed. The JAI values for 2018, 2019, 2020, and 2021 were 0.4, 1.18, 0.20, and 0.7 respectively and are below the spawning failure threshold of 1.33 indicating that the recruitment failure trigger has been met (ASMFC 2010). Amendment 2 to the N.C. Estuarine Striped Bass Fishery Management Plan is being jointly developed with the Wildlife Resources Commission.

Stock Status: CSMA Stocks

There is no stock status determination for the CSMA stocks in the Tar-Pamlico, Neuse, and Cape Fear rivers. No formal peer-reviewed stock assessments have been conducted for CSMA striped bass.

A demographic matrix model was developed to evaluate different stocking and management measures for striped bass in all three CSMA river systems. Results from the matrix model indicate that striped bass populations in the CSMA are depressed to an extent that sustainability is unlikely at any level of fishing mortality, and it also provides evidence that natural recruitment is the primary limiting factor influencing Tar-Pamlico and Neuse River stocks and if stocking was stopped the populations would decline (Mathes et al. 2020). The demographic matrix model does not provide population abundance or mortality estimates. A tagging model was developed to estimate striped bass abundance in the Cape Fear River. Tagging model results showed a consistent decline in abundance estimates for striped bass (2012–2018), and that abundance in 2018 was reduced to less than 20% of the abundance in 2012, even with a total no-possession provision for striped bass in place in the Cape Fear River since 2008.

Stock Assessment: CSMA Stocks

A stock assessment is not available for this species.

DESCRIPTION OF THE FISHERY: CSMA

Current Regulations: CSMA

Commercial and recreational harvest in the CSMA is prohibited. Supplement A to the Estuarine Striped Bass FMP was adopted by the NCMFC at their February 2019 business meeting and by the NCWRC in March 2019. The NCWRC hook-and-line closure proclamation had the effect of suspending rules 15A NCAC 10C .0107 (l) and 10C .0314 (g), and Supplement A actions consisted of the following:

- Commercial and recreational no possession measure for striped bass (including hybrids) in coastal and inland fishing waters of the CSMA (FF-6-2019). A no-possession requirement already exists for the Cape Fear River by rule.
- Additionally, consistent with Amendment 1, commercial set gill-net restrictions requiring tie-downs and distance from shore (DFS) measures will apply year-round (M-5-2019).

Commercial Fishery: CSMA

Due to the no possession measure approved in Supplement A, the commercial striped bass fishery was closed in 2019 while Amendment 2 is developed. During 1994–2018 commercial landings in the CSMA were constrained by an annual TAL of 25,000 pounds. Landings closely follow the annual TAL, except for 2008 when less than half of the TAL was landed. From 2004 through 2018 striped bass commercial landings in the CSMA averaged 24,179 pounds and ranged from a low of 10,115 pounds in 2008 to a high of 32,479 pounds in 2004 (Table 7, Figure 14A). Most commercial landings come from the Tar-Pamlico and Pungo rivers and the Neuse and Bay rivers, with the remainder coming from the Pamlico Sound. From 2004 to 2018, there was only a spring harvest season, opening March 1 each year and closing when the TAL was reached.

Recreational Fishery: CSMA

The NCDMF started collecting recreational striped bass data in the major rivers of the CSMA in 2004. In 2013, due to comparatively low recreational striped bass catch in the Cape Fear River, creel survey methodology was adjusted for American and hickory shad to become the target species. Due to the recreational no possession measure approved as part of Supplement A in February 2019, there was minimal recreational harvest in 2019 (959 pounds) until the recreational season closed in March 2019, with the no recreational possession measure continuing through 2021. Recreational landings fluctuated during 2004–2018, ranging from lows in 2008 and 2009 to a high of 26,973 pounds in 2017 (Table 7; Figure 14B).

Since 2011, harvest in the Tar-Pamlico and Neuse rivers has fluctuated little, ranging from 4,000 pounds to 9,000 pounds, however in 2016 and 2017 there was a sharp increase in recreational harvest (25,260 and 26,973 pounds, respectively). In 2018, recreational harvest dropped sharply by more than half of the 2016 and 2017 values (Table 7). Harvest on the Pungo River has remained consistent at a relatively low level compared to fluctuations in the Tar-Pamlico and Neuse rivers. In 2016 and 2017 the number of trips and hours spent targeting striped bass in the CSMA increased although there was a moderate decline observed in 2018 (Table 8).

Although the recreational striped bass season in the CSMA was closed in March of 2019, data collection characterizing fishing effort and release dispositions have continued. Within the CSMA there is a significant catch-and-release fishery and releases during the last ten years have averaged 48,842 fish annually (Table 8; Figure 15). Undersized discards peaked in 2017 mainly due to the large number of undersized striped bass available in the Tar-Pamlico River system. In 2021, the number of under sized discards was 24,825, which was slightly above the past three-year average (2018–2020; 23,562 fish). In 2021, discards of legal sized striped bass returned to more normal levels (n=9,822), after a high of 26,501 in 2017. Fish released that were within the slot limit, have fluctuated since 2004 and have ranged from lows in 2004, 2006, and 2007 of zero fish to a high of 6,779 fish in 2016 (Table 8). In 2021, there were approximately 3,912 discarded striped bass that were within the slot limit. CSMA recreational length frequencies are presented in Figure 16. In 2018, the modal length of striped bass in the recreational harvest from the Tar-Pamlico/Pungo rivers was 18 inches with few fish over 22 inches harvested, and the modal length from the Neuse River was 19 inches with few fish over 20 inches harvested (Figure 17).

MONITORING PROGRAM DATA: CSMA STOCKS

Fishery-Dependent Monitoring: CSMA

Monitoring of the commercial fishery in the CSMA follows the same methodology as in the ASMA. There has been a commercial and recreational harvest moratorium in the Cape Fear River since 2008 and in the CSMA since March 2019. From 2004 to 2018, length data from the commercial harvest shows that on average striped bass harvested in the Neuse and Bay rivers are slightly larger than fish harvested in the Pamlico and Pungo rivers (Table 9). Additionally, maximum lengths are generally larger in the Neuse and Bay rivers compared to the Pamlico and Pungo rivers.

In 2018, the modal length of CSMA striped bass in the commercial harvest from the Tar-Pamlico/Pungo rivers was 20 inches with few fish over 25 inches harvested and, in the Neuse/Bay rivers striped bass modal length was 23 inches with few fish over 27 inches harvested (Figure 17). CSMA commercial length frequencies are represented in Figure 18 and show that striped bass are routinely harvested up to 30 inches total length, and that few fish under the 18-inch total length minimum size limit are harvested.

From 2004 to 2018, the CSMA recreational creel survey sampled on average 160 striped bass per year. In 2018, the creel survey measured 155 striped bass that averaged 19 inches and ranged in length from 16 to 29 inches, however, only 27 striped bass were measured in 2019 that averaged 20 inches and ranged in length from 16 to 26 inches due to the season closure in March 2019 (Table 10).

Fishery-Independent Monitoring: CSMA

The fishery independent gill net survey (P915) was initiated by the NCDMF in May of 2001 in Pamlico Sound. The survey was expanded to the Tar-Pamlico, Pungo, and Neuse rivers in 2003, expanded to the Cape Fear and New rivers in 2008, and expanded into Core Sound, Bogue Sound and the White Oak River in May 2018. Precision of the relative abundance estimates appear to be good for most strata, months, and years, with some exceptions. Overall, the percent frequency of

occurrence is lower and PSE values are typically higher in the deep stratum; thus, only the shallow stratum was used in the relative abundance calculation. The months of April and October–November are used in index calculation because striped bass are most available to the survey during these months. The Pamlico Sound data were not used due to low catch numbers and concerns about stock assignment. Pungo River data were also excluded due to mixed stock concerns. In the Cape Fear River, although striped bass catch rates were very low, data were used to calculate relative abundance. New River data were not used to calculate relative abundance because striped bass were seldom captured there. Limited abundance data is available for striped bass from the Fishery Independent Gill Net Survey (Program 915) for 2021. Sampling in 2020 was suspended due to COVID-19 restrictions and protected species interactions and was not resumed until the fall of 2021. Over the past fourteen years (2004–2021), striped bass relative abundance has been higher in the Tar-Pamlico and Neuse rivers when compared to the Cape Fear River and New rivers (Table 11). Since 2004, striped bass relative abundance in the Tar-Pamlico and Neuse rivers ranged from 2 to 9 fish per sample, whereas relative abundance in the Cape Fear and New rivers ranged from 0 to 0.14 fish per sample (Table 11). In 2021, striped bass relative abundance in the Tar-Pamlico River (0.92 fish per set) was well below the time series average of 4.4 striped bass per set (Table 11; Figure 19). However, the low relative abundance value is likely a result of only including two months of data in the analysis (October–November). From July to December, a total of 277 striped bass were captured in shallow water gillnet sets, and only 79 were captured in shallow water sets during October–November and included in calculations of relative abundance. In the Neuse River, striped bass relative abundance was 4.25 fish per set, which was above the time series average of 3.6 striped bass per set (Table 11; Figure 20). In 2021, relative abundance in the Cape Fear River (0.03 fish per set) was near the time series average of 0.45 striped bass per set (Table 11; Figure 21). Length frequencies from P915 are represented in Figure 22. Length frequency distributions are variable between years but generally range 10–25 inches TL, however in 2016–2017 in the Tar-Pamlico/Pungo River and 2015–2017 in the Neuse River there was a higher percentage of small fish that could represent the two year classes of striped bass thought to be the result of successful natural reproduction in 2014 and 2015. In 2018 and 2019, there were larger fish in the Tar-Pamlico/Pungo and Neuse rivers that could represent growth and perpetuation of the two year classes of striped bass. Length frequency distributions are not provided for the Cape Fear and New rivers due to low numbers of striped bass captured in the fishery independent gill net survey. Samples collected from P915 on the Tar-Pamlico and Neuse rivers show most striped bass were captured in the upper and middle portions of the rivers.

In 2017, the Juvenile Anadromous Survey (P100) which was developed in the Albemarle Sound to determine relative abundance, growth, and distribution of juvenile alosines and striped bass was expanded to include the Tar-Pamlico, Neuse, Cape Fear, and Northeast Cape Fear rivers. The survey employs seines (June–July) and trawls (July–October) to monitor the status of the striped bass stocks in North Carolina and to assess the effectiveness of management measures aimed at promoting natural reproduction within the CSMA. From 2017 to 2021 young-of-year sampling in the Central Southern Management Area (CSMA) has captured very few individuals. In the Northeast Cape Fear River, 24 juvenile striped bass were captured in 2018, four in 2019, and one in 2020. In 2021, the first two juvenile striped bass were captured on the Tar-Pamlico River, whereas sampling on the Neuse River and Cape Fear River system has not capture any juvenile striped bass.

Age data from are presented in Table 12 and Figure 23; from 2004 to 2021, a total of 2,372 otolith samples were collected and from 2016 to 2021, 1,375 genetic samples were collected to provide striped bass ages (Table 12). Figure 23 shows an increasing trend of size at length with a maximum age of 12 years old. Limited age data was collected in 2019 from the recreational creel survey (n=15) and no commercial samples were collected. Otolith age data from 2021 are considered preliminary, and genetic ages for 2020 and 2021 are not currently available.

RESEARCH NEEDS: CSMA

The research recommendations listed below are intended to improve future assessments of the CSMA striped bass stocks. The bulleted items outline the specific issue and are organized by priority ranking.

High

- Acquire life history information: maturity, fecundity, size and weight at age, egg, and larval survival (ongoing through CRFL funded projects and NCDMF P930 data collection; see Knight, 2015 for recent work on maturation and fecundity in the Neuse and Tar-Pamlico rivers)
- Conduct delayed mortality studies for recreational and commercial gear during all seasons factoring in relationships between salinity, dissolved oxygen, and water temperature
- Develop better estimates of life-history parameters, especially growth and factors influencing rates of natural mortality for all striped bass life stages (growth is ongoing through NCDMF P930 data collection; for natural mortality, see recent publications Bradley 2016 and Bradley et al. 2018b)

Medium

- Determine factors impacting survivability of stocked fish in each system (Bradley et al. 2018b)
- Implement a random component to NCDMF program 100 juvenile sampling in the CSMA
- Conduct a power analysis to determine minimum sample sizes needed for determining the representative age structure

Low

- Determine if contaminants are present in striped bass habitats and identify those that are potentially detrimental to various life history stages (ongoing through N.C. Division of Water Quality but could be expanded; in 2017, NCSU was awarded a CRFL grant to conduct research on striped bass eggs, including evaluating for Gen X)
- Identify minimum flow requirements in the Tar-Pamlico, Neuse, and Cape Fear rivers necessary for successful spawning, egg development, and larval transport to nursery grounds
- Evaluate factors influencing catchability of striped bass, particularly larger striped bass, in electrofishing surveys conducted on the spawning grounds

- Obtain improved commercial discard estimates from the estuarine gill-net fisheries (i.e., anchored, runaround, and strike gill nets) in the CSMA systems to better characterize harvest and discards
- Investigate factors influencing mixing rates between A-R and CSMA striped bass stocks
- Identify water quality parameters that impact spawning, hatching, and survival of striped bass in CSMA systems
- Develop a consistent ageing approach across agency sampling programs
- Continue PIT tagging striped bass in the Cape Fear River and expand PIT tagging to the Tar-Pamlico and Neuse rivers to estimates of spawning population size
- Investigate factors influencing rates of natural mortality for all striped bass life stages in the CSMA systems

MANAGEMENT STRATEGY: CSMA STOCKS

Estuarine striped bass in North Carolina are managed under Amendment 1 to the North Carolina Estuarine Striped Bass FMP and subsequent revisions and supplement. Due to concerns about the high percentage of stocked fish and minimal natural recruitment in the CSMA systems, the comprehensive review of the Estuarine Striped Bass FMP began in July 2017 instead of as originally scheduled in 2018. Since adoption of the 2004 FMP there has been little change in the size and age distribution, with few age-6 and older fish observed in any system. The need for continued conservation management efforts is supported by the constrained size and age distributions, low abundance, the absence of older fish in all stocks, and the high percentage of stocked fish in the population (Cushman et al. 2018; Farrae et al. 2018). Results from genetic testing of sampled fish in 2017 suggest there were two recent naturally spawned year classes and in February 2019, Supplement A to Amendment 1 to the North Carolina Estuarine Striped Bass FMP was approved instituting a recreational and commercial no-possession limit in the CSMA. The no-possession measure provides additional protection for non-hatchery fish until Amendment 2 to the North Carolina Estuarine Striped Bass FMP is adopted. The stocks were evaluated using a matrix model for the Tar-Pamlico and Neuse rivers and a tagging model for the Cape Fear River. This evaluation will inform recovery metrics for the CSMA stocks in Amendment 2.

FISHERY MANAGEMENT PLAN SCHEDULE RECOMMENDATIONS

The comprehensive FMP review is underway, and the division is continuing joint development of Amendment 2 with the NCWRC.

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TABLES

Table 1. ASMA and RRMA recreational harvest (number of fish landed and weight in pounds) and releases (number of fish) and ASMA commercial harvest (weight in pounds) of striped bass from North Carolina, 1990–2021.

Year	ASMA Recreational			RRMA Recreational			ASMA Commercial	Total Weight (lb)
	Numbers Landed	Numbers Released	Weight Landed (lb)	Numbers Landed	Numbers Released	Weight Landed (lb)	Weight Landed (lb)	
1990	-	-	-	-	-	-	103,757	103,757
1991	14,395	23,540	35,344	26,934	-	72,529	108,555	216,428
1992	10,542	19,981	30,758	13,372	-	36,016	100,641	167,415
1993	11,404	13,241	36,049	14,325	-	45,145	109,570	190,764
1994	8,591	-	30,217	8,284	-	28,089	102,471	160,777
1995	7,343	-	30,564	7,471	-	28,883	87,920	147,367
1996	7,433	-	29,186	8,367	15,230	28,178	90,213	147,577
1997	6,901	30,771	26,581	9,364	20,437	29,997	96,210	152,788
1998	19,566	91,888	64,580	23,109	87,679	73,541	124,032	262,153
1999	16,967	40,321	61,338	22,479	50,161	72,967	163,010	297,315
2000	38,085	78,941	116,158	38,206	93,148	120,091	214,223	450,472
2001	40,127	61,418	118,506	35,231	71,003	112,805	220,462	451,773
2002	27,896	51,555	92,649	36,422	55,775	112,698	223,108	428,455
2003	15,124	25,281	51,794	11,157	38,256	39,170	266,539	357,503
2004	28,004	41,041	97,097	26,506	187,331	90,191	273,814	461,102
2005	17,954	21,220	63,477	34,122	89,550	107,530	232,808	403,815
2006	10,711	9,455	35,997	25,355	40,805	84,521	186,555	307,073
2007	7,143	13,599	26,633	19,306	40,879	62,492	171,828	260,953
2008	10,048	36,975	31,628	10,541	141,646	32,725	74,979	139,332
2009	12,069	40,563	37,313	23,248	135,964	69,581	95,879	202,773
2010	3,504	16,200	11,470	22,445	77,882	72,037	200,003	283,510
2011	13,341	21,572	42,536	22,102	80,828	71,561	136,378	250,475
2012	22,345	24,971	71,456	28,847	40,772	88,271	115,698	275,425
2013	4,299	16,381	14,897	7,718	49,148	25,197	68,409	108,503
2014	5,529	23,086	16,867	11,058	93,471	33,717	71,055	121,639
2015	23,240	49,534	70,008	20,031	78,401	58,962	114,596	243,566
2016	4,794	10,352	14,487	21,260	34,753	65,218	123,216	202,921
2017	4,214	24,659	15,480	9,899	68,693	32,569	76,059	124,108
2018	3,465	25,639	11,762	8,741	121,969	26,796	116,144	154,702
2019	8,502	34,968	29,005	16,582	117,550	53,379	136,820	219,204
2020*	6,849	50,009	22,951	20,376	54,622	27,243	124,385	174,579
2021	2,258	7,782	8,258	7,795	57,188	27,546	27,930	63,734
Mean	13,409	32,303	43,708	19,053	74,736	66,189	136,165	235,064

*Due to Covid restrictions, the creel surveys during the spring of 2020 were cut short. Creel estimate for the spring ASMA survey is for the period January 1–March 27, 2020. Creel estimate for the spring RRMA survey is for the period March 1 to March 18, 2020 with data imputed for April based on harvest in April 2015 and 2016...

Table 2. Recreational striped bass effort, harvest, and discards from the ASMA and RRMA (2011–2021).

Year	Striped Bass Fishing Angler Trips	Striped Bass Effort Angler Hours	Number Harvested	Pounds Harvested	Striped Bass Discard (#over-creel)	Striped Bass Discard (#under-sized)	Striped Bass Discard (#legal-sized)	Striped Bass Discard (# slot-sized)	Total Discards
ASMA									
2011	13,114	85,325	13,341	42,536	317	20,114	1,141	N/A	21,572
2012	14,490	102,787	22,345	71,456	1,024	19,977	3,970	N/A	24,971
2013	7,053	50,643	4,299	14,897	31	16,034	316	N/A	16,381
2014	7,264	40,478	5,529	16,867	18	22,558	510	N/A	23,086
2015	11,132	75,009	23,240	70,008	1,573	45,559	2,402	N/A	49,534
2016	7,023	42,276	4,794	14,486	252	8,822	1,278	N/A	10,352
2017	8,822	41,371	4,214	15,479	55	24,003	599	N/A	24,659
2018	9,057	34,764	3,465	11,763	281	21,388	3,970	N/A	25,639
2019	19,864	61,645	8,502	34,968	2,301	34,452	1,625	N/A	38,378
2020#	20,559	84,584	6,849	22,951	32,805	15,256	1,947	N/A	50,009
2021	8,080	29,174	2,258	8,258	689	5,684	1,408	N/A	7,782
Total	127,197	664,892	101,864	327,551	37,305	232,587	18,597	0	288,492
RRMA									
2011	27,311	122,876	22,102	71,561	Disposition of discards not available for all years.				80,828
2012	27,151	110,982	28,847	88,539					40,772
2013	19,539	100,391	7,718	25,197					49,148
2014	15,960	80,256	11,058	33,717					93,471
2015	22,827	111,419	20,031	58,962					78,401
2016	25,036	129,132	21,260	65,218					34,753
2017	19,688	101,565	9,899	32,569					68,693
2018	18,280	95,447	8,741	26,797					121,969
2019	20,633	99,259	16,582	53,379					117,550
2020†	26,648	131,565	20,376	27,243					54,622
2021	12,976	69,281	7,795	27,546	57,188				
Total	219,659	1,068,695	159,567	500,811					916,148

* Estimates of discards not available for the post-harvest season period.

Creel estimate for the spring survey is for the period January 1–March 27, 2020.

† Creel estimate for the spring survey is for the period March 1 to March 18, 2020 with data imputed for April based on harvest in April 2015 and 2016.

Table 3. Striped bass total length (inches) data from commercial fish house sampling from the Albemarle Sound Management Area (ASMA), NC, 2005–2021.

Year	Mean Length	Minimum Length	Maximum Length	Total Number Measured
2005	21	17	43	719
2006	22	17	44	926
2007	22	17	47	860
2008	22	18	46	547
2009	21	18	41	813
2010	21	17	48	940
2011	21	18	39	990
2012	22	18	39	648
2013	22	18	45	543
2014	23	18	43	484
2015	22	18	43	794
2016	22	18	43	604
2017	22	18	41	246
2018	20	16	41	456
2019	20	17	40	566
2020	22	17	40	191
2021	22	19	28	165

Table 4. Striped bass total length (inches) data from recreational landings from the Albemarle Sound Management Area (ASMA), NC, 2005–2021.

Year	Mean Length	Minimum Length	Maximum Length	Total Number Measured
2005	20	16	36	1,653
2006	20	17	32	743
2007	20	17	39	412
2008	20	18	30	632
2009	20	18	42	549
2010	20	17	28	337
2011	20	18	34	979
2012	20	18	36	1,059
2013	20	18	32	527
2014	19	18	28	802
2015	20	17	30	1,523
2016	21	18	28	423
2017	21	18	32	489
2018	18	17	29	312
2019	18	17	27	555
2020	20	16	30	683
2021	21	17	28	290

Table 5. Striped bass total length (inches) data from recreational landings from the Roanoke River Management Area (RRMA), NC, 2005–2021.

Year	Mean Length	Minimum Length	Maximum Length	Total Number Measured
2005	20	17	40	981
2006	20	17	39	1,059
2007	20	18	39	709
2008	19	17	35	667
2009	19	17	32	1,049
2010	20	18	28	954
2011	20	18	31	679
2012	20	17	28	688
2013	20	17	27	512
2014	19	17	30	559
2015	19	16	27	1,340
2016	20	17	29	1,133
2017	20	17	34	498
2018	20	17	28	688
2019	20	17	30	1,032
2020	19	18	24	155
2021	20	18	40	630

Table 6. Striped bass age data from dependent (commercial) and independent (independent gill net survey) surveys from the ASMA, NC, 2005–2021.

Year	Modal Age	Minimum Age	Maximum Age	Total Number Aged
2005	4	1	14	1,258
2006	5	1	14	1,262
2007	5	1	14	1,188
2008	3	1	16	1,191
2009	4	1	14	1,040
2010	5	1	17	885
2011	5	1	11	1,429
2012	2	1	14	802
2013	5	1	13	921
2014	4	2	11	728
2015	4	1	11	713
2016	5	2	12	555
2017	2	2	13	504
2018	4	1	10	674
2019	5	1	14	482
2020	5	1	11	301
2021	5	4	9	120

Table 7. Recreational harvest (number of fish landed and weight in pounds) and releases (number of fish) and commercial harvest (weight in pounds) of CSMA striped bass from North Carolina, 1994–2021.

Year	Recreational			Commercial	Total Weight (lb)
	Numbers Landed	Numbers Released	Weight Landed (lb)	Weight Landed (lb)	
1994				19,858	19,858
1995				14,325	14,325
1996				33,250	33,250
1997				28,520	28,520
1998				25,973	25,973
1999				33,959	33,959
2000				31,048	31,048
2001				24,705	24,705
2002				37,585	37,585
2003				41,384	41,384
2004	6,141	13,557	22,958	32,479	55,437
2005	3,832	16,854	14,965	27,132	42,097
2006	2,481	14,895	7,352	21,149	28,501
2007	3,597	23,527	10,794	25,008	35,802
2008	843	17,966	2,990	10,115	13,105
2009	895	6,965	3,061	24,847	27,908
2010	1,757	7,990	5,537	23,888	29,425
2011	2,728	24,188	9,474	28,054	37,528
2012	3,922	43,313	15,240	22,725	37,964
2013	5,467	32,816	19,537	28,597	48,134
2014	3,301	30,209	13,368	25,245	38,613
2015	3,934	31,353	14,269	27,336	41,605
2016	6,697	75,461	25,260	23,041	48,301
2017	7,334	131,129	26,973	23,018	49,991
2018	3,371	49,122	10,884	20,057	30,941
2019	959	36,080	3,562	0	3,562
2020	0	19,420	0	0	0
2021	0	38,559	0	0	0
Mean	3,181	34,078	11,457	23,332	30,697

Table 8. Recreational striped bass effort, harvest, and discards from the CSMA (2004–2021). In the CSMA, there was a limited recreational harvest season in 2019 prior to closing (January 1–March 19, 2019). The recreational season remained closed in 2021.

Year	Striped Bass Fishing (Angler Trips)	Striped Bass Effort (Angler Hours)	Number Harvested	Pounds Harvested	Striped Bass Discards				Total Discards
					Number Over-Creel	Number Under-Sized	Number Legal-Sized	Number Slot-Sized	
2004	12,782	63,791	6,141	22,958	85	11,729	1,743	0	13,557
2005	16,414	69,370	3,832	14,965	152	15,609	1,016	77	16,854
2006	10,611	42,066	2,481	7,352	33	12,548	2,314	0	14,895
2007	10,971	46,655	3,597	10,794	147	21,673	1,707	0	23,527
2008	6,621	28,413	843	2,990	2,838	11,721	3,316	91	17,966
2009	5,642	26,611	895	3,061	7	4,471	1,769	718	6,965
2010	6,559	25,354	1,757	5,537	29	5,200	2,401	360	7,990
2011	12,606	51,540	2,728	9,474	9	16,659	5,397	2,123	24,188
2012	18,338	71,964	3,922	15,240	439	26,343	13,621	2,910	43,313
2013	20,394	86,918	5,467	19,537	539	19,302	10,619	2,357	32,816
2014	15,682	70,316	3,301	13,368	1,449	19,185	7,934	1,641	30,209
2015	18,159	79,398	3,934	14,269	217	22,272	8,052	813	31,353
2016	23,675	110,453	6,697	25,260	215	57,874	10,593	6,779	75,461
2017	26,125	119,680	7,334	26,973	549	101,787	26,501	2,293	131,129
2018	16,393	69,917	3,371	10,884	871	34,128	12,232	1,890	49,122
2019*	8,820	40,580	959	3,562	924	24,857	7,817	2,481	37,039
2020**	2,846	13,272	0	0	0	10,439	7,575	1,406	19,420
2021**	15,628	60,424	0	0	0	24,825	9,822	3,912	38,559
Total	248,266	1,076,721	57,259	206,224	8,503	440,623	134,429	29,850	614,636

* Limited harvest season (Jan 1–March 19, 2020)

** Closed harvest season

Table 9. Mean, minimum, and maximum length of striped bass (total length – inches) and number collected from the commercial harvest, 2000–2021.

Year	Tar-Pamlico/Pungo rivers				Neuse/Bay rivers			
	Length (inches)			N	Length (inches)			N
	Mean	Min	Max		Mean	Min	Max	
2000	23	20	35	126	25	22	31	5
2001	23	21	26	116	25	23	31	12
2002	24	19	39	96	25	19	29	31
2003	23	18	37	173	24	19	37	19
2004	24	20	42	131	25	19	37	74
2005	23	20	37	127	24	20	36	70
2006	22	18	37	119	24	19	36	144
2007	22	19	33	112	22	19	27	63
2008	22	18	43	84	23	19	44	39
2009	22	19	31	99	22	18	31	85
2010	22	19	26	194	23	19	32	263
2011	23	18	27	284	23	19	42	195
2012	24	15	30	254	24	19	29	96
2013	25	18	40	225	25	18	39	301
2014	22	18	39	52	24	20	38	56
2015	24	19	40	97	24	19	44	97
2016	24	17	29	257	23	19	28	78
2017	24	19	31	151	24	19	50	97
2018	23	19	32	76	24	18	38	163
2019	-	-	-	-	-	-	-	-
2020	-	-	-	-	-	-	-	-
2021	-	-	-	-	-	-	-	-

Table 10. Mean, minimum and maximum length of striped bass (total length – inches) and number collected from the recreational harvest, 2004–2021 (includes striped bass and hybrid striped bass). There was a limited recreational season in 2019 (Jan 1-March 19) and the season remained closed in 2021.

Year	Mean Total Length	Minimum Total Length	Maximum Total Length	Total Number Measured
2004	22	17	32	430
2005	22	18	32	318
2006	22	18	30	132
2007	22	17	30	129
2008	21	18	26	50
2009	21	17	24	95
2010	21	18	26	74
2011	21	18	28	140
2012	21	18	28	153
2013	20	17	28	169
2014	21	18	30	115
2015	21	16	27	106
2016	20	18	33	144
2017	20	17	30	202
2018	19	16	29	155
2019	20	17	26	27
2020	-	-	-	-
2021	-	-	-	-

Table 11. Relative abundance of striped bass (number of individuals per sample), total number of striped bass collected, and the number of gill net samples (N) in the Tar-Pamlico and Neuse rivers (April, and October–November, shallow water sets (2004–2021), and in the Cape Fear and New rivers (February–December, all sets; 2008–2021) The Percent Standard Error (PSE) represents a measure of precision. No sampling occurred in 2020 and limited sampling occurred in 2021 (July–December).

Year	Tar-Pamlico River				Neuse River				Cape Fear and New Rivers			
	CPUE	No. of Striped Bass	N	PSE	CPUE	No. of Striped Bass	N	PSE	CPUE	No. of Striped Bass	N	PSE
2004	3.94	71	18	24	2.83	68	24	44	-	-	-	-
2005	4.61	83	18	17	3.75	90	24	42	-	-	-	-
2006	4.06	73	18	41	2.33	56	24	25	-	-	-	-
2007	3.56	64	18	49	2.83	68	24	28	-	-	-	-
2008	4.61	83	18	37	3.21	77	24	44	0.04	3	84	100
2009	2.78	50	18	36	2.13	51	24	41	0.03	3	119	67
2010	5.67	102	18	26	6.25	150	24	39	0.01	1	120	100
2011	7.72	139	18	32	4.75	114	24	30	0.04	4	120	50
2012	3.28	59	18	39	2.25	54	24	36	0.03	3	120	67
2013	3.22	58	18	36	2.54	61	24	31	0.02	2	120	50
2014	4.56	82	18	20	6.75	162	24	28	0	0	120	-
2015	2.67	48	18	33	5.33	128	24	27	0.14	15	120	36
2016	2.44	44	18	27	2.04	49	24	24	0.11	12	120	45
2017	2.44	44	18	29	3.21	77	24	24	0.08	9	120	50
2018	9.00	162	18	29	3.75	90	24	31	0.03	3	113	67
2019	5.06	91	18	33	4.21	101	24	32	0.01	1	120	100
2020	-	-	-	-	-	-	-	-	-	-	-	-
2021	0.92	11	12	43	4.25	68	16	38	0.03	3	88	67

Table 12. CSMA striped bass otolith and genetic age data from fishery dependent (commercial and recreational creel survey) and independent (independent gill net survey) surveys, 2004–2021. Otolith age data from 2021 are considered preliminary, and genetic ages for 2020 and 2021 are not currently available.

Year	Modal Age		Minimum Age		Maximum Age		Total Number Aged	
	Otolith	Genetic	Otolith	Genetic	Otolith	Genetic	Otolith	Genetic
2004	3	-	1	-	11	-	50	-
2005	2	-	1	-	9	-	78	-
2006	3	-	1	-	9	-	111	-
2007	3	-	1	-	9	-	86	-
2008	3	-	1	-	8	-	103	-
2009	4	-	1	-	6	-	37	-
2010	5	-	1	-	9	-	154	-
2011	3	-	2	-	6	-	56	-
2012	3	-	1	-	7	-	205	-
2013	3	-	1	-	8	-	156	-
2014	3	-	1	-	11	-	172	-
2015	3	-	1	-	9	-	113	-
2016	2	3	1	2	8	6	38	323
2017	2	4	1	1	9	7	98	247
2018	3	4	1	1	12	8	109	201
2019	4	3	1	1	11	9	307	183
2020	5	-	1	-	9	-	147	-
2021	3	-	1	-	10	-	352	-

FIGURES

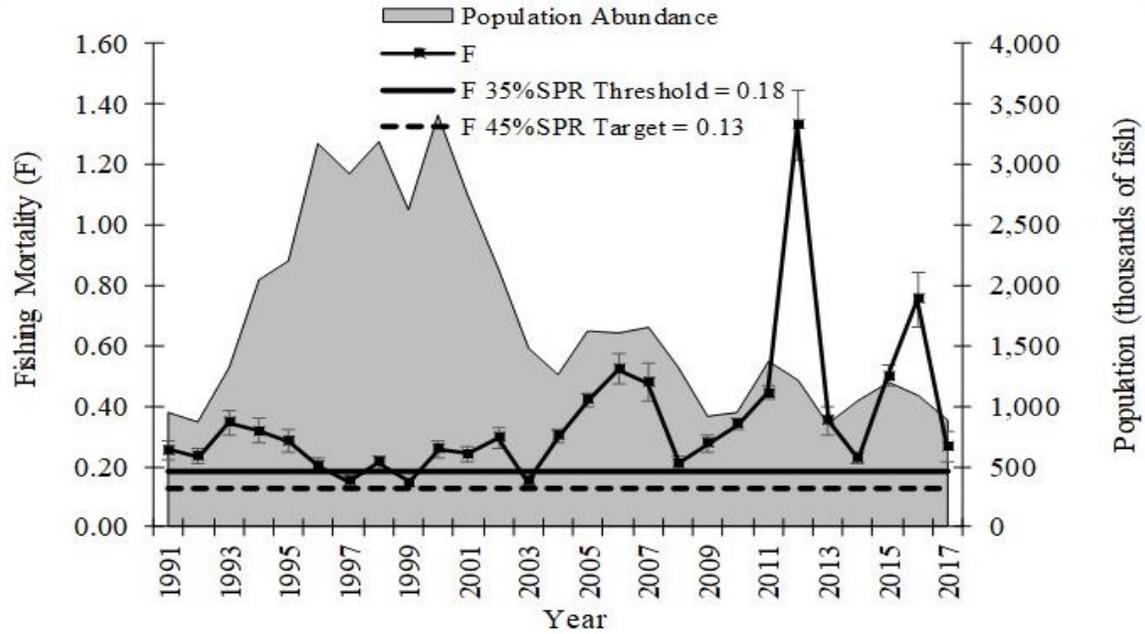


Figure 1. Estimates of fishing mortality (F) and population abundance for the Albemarle-Roanoke striped bass stock, 1991–2017. Error bars represent \pm two standard errors. Source: Lee et al. 2020.

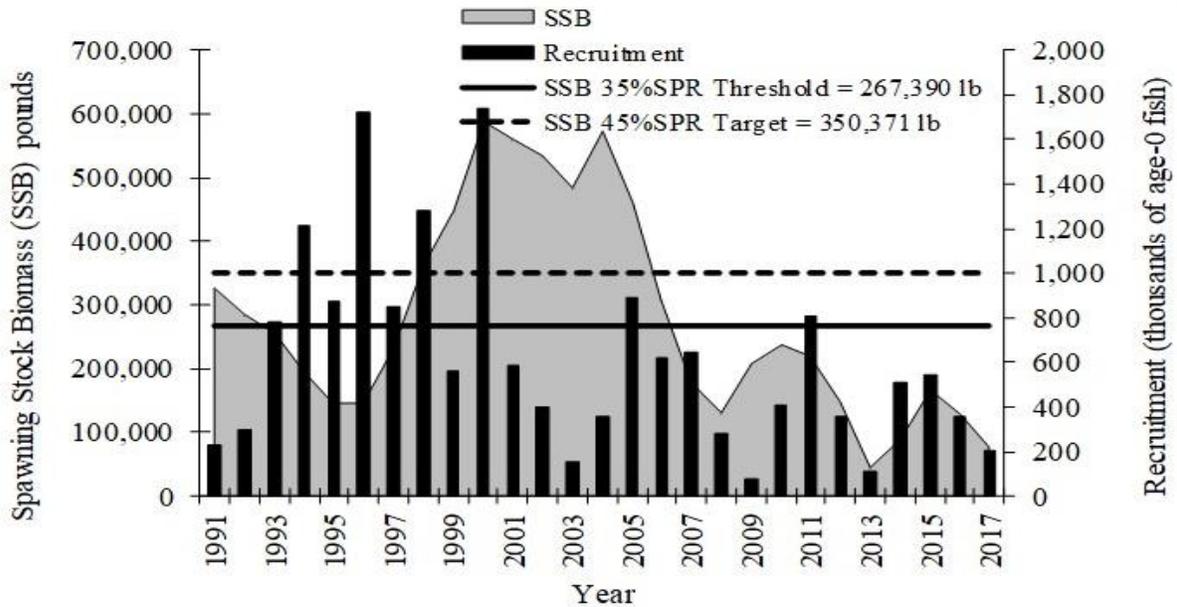


Figure 2. Estimates of spawning stock biomass (SSB) and recruitment of age-0 fish coming into the population each year for the Albemarle-Roanoke striped bass stock, 1991–2017. Source: Lee et al. 2020

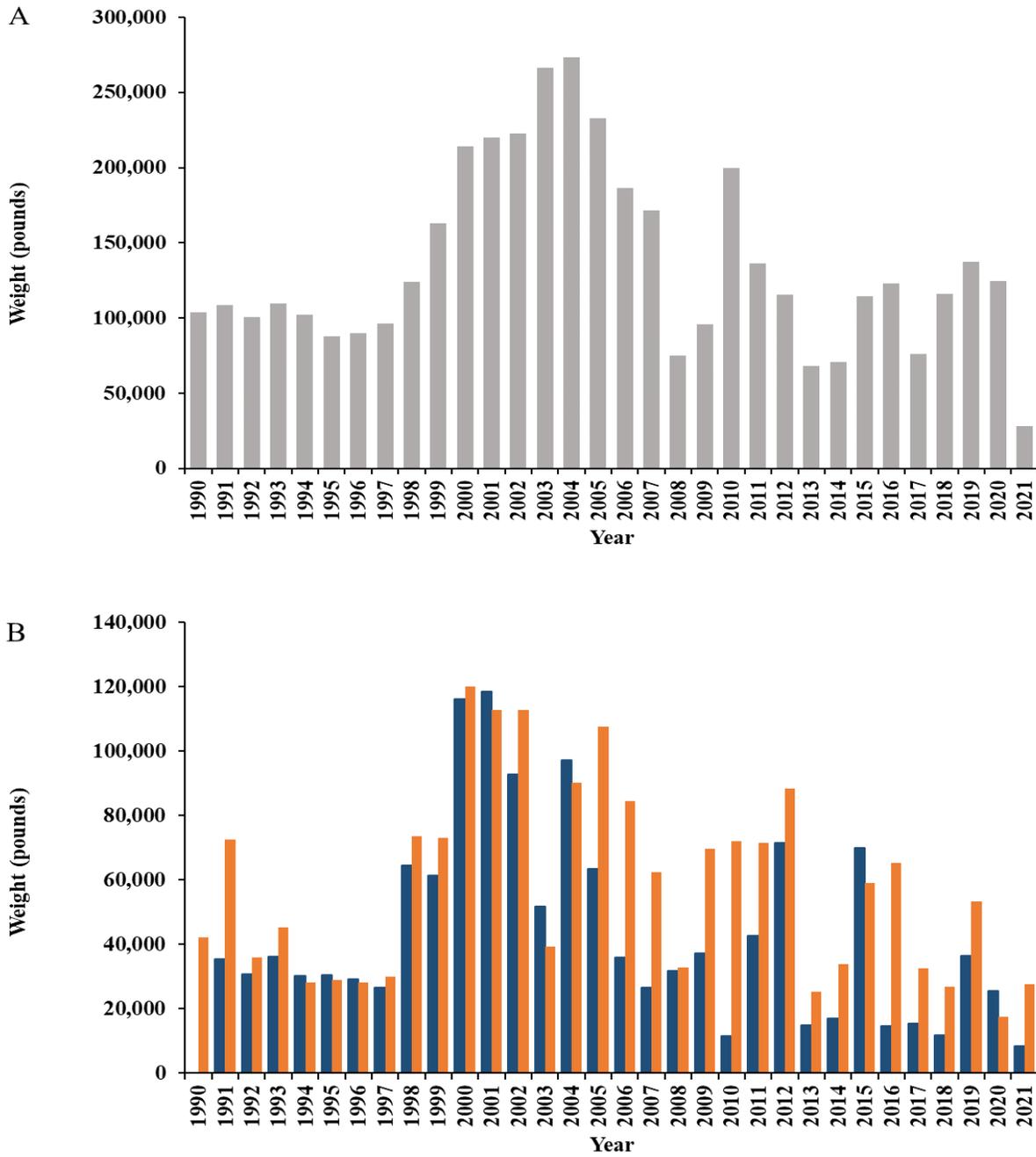


Figure 3. ASMA commercial (A), ASMA recreational, and RRMA recreational (B) striped bass landings in pounds, NC, 1990–2021. RRMA 2020 recreational landings are for March only. ASMA 2020 landings are from January–March.

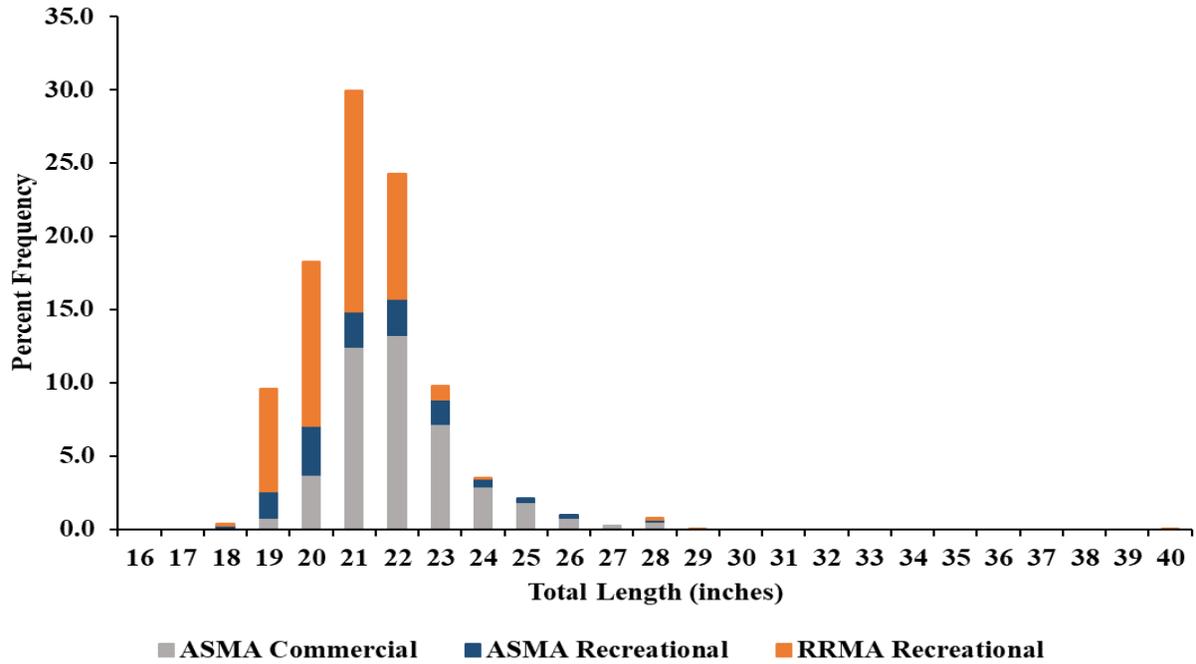


Figure 4. ASMA commercial and recreational length frequency distribution from striped bass harvested in 2021.

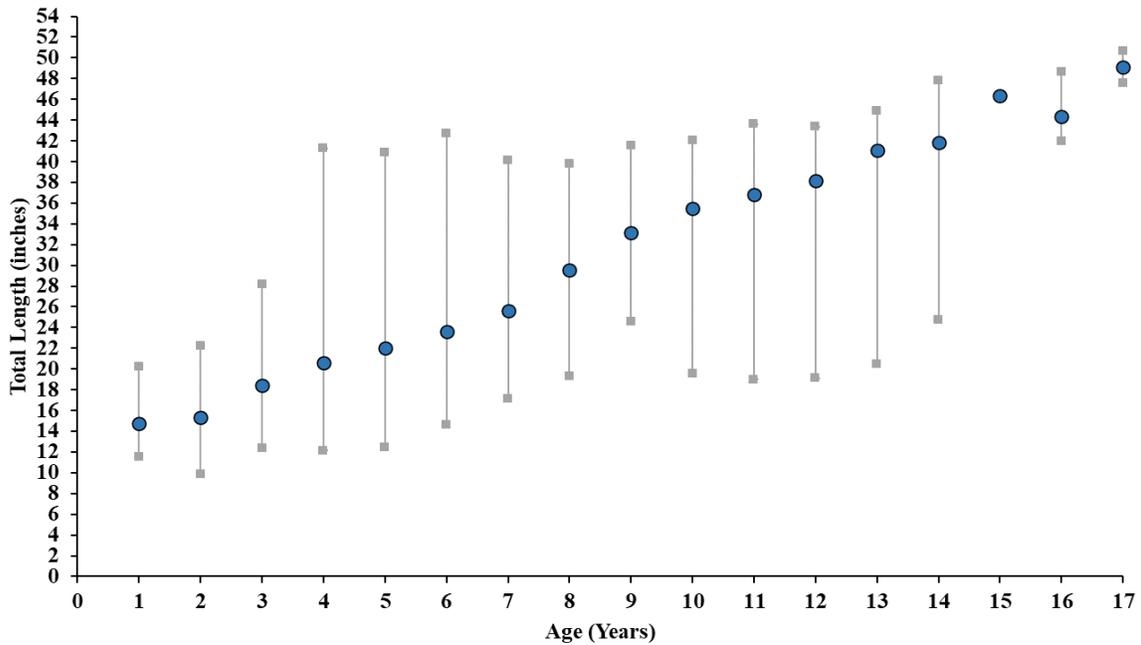


Figure 5. Striped bass length at age based on all commercial samples, 1972–2021. Blue circles represent the mean size at a given age while the grey squares represent the minimum and maximum observed size for each age.

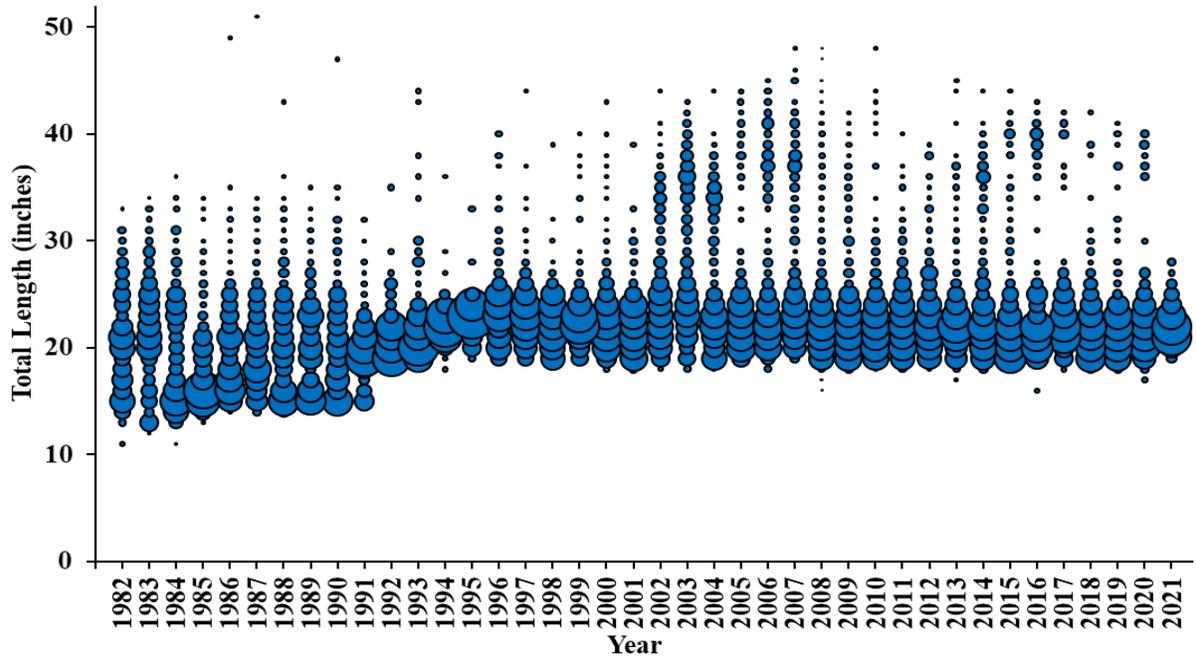


Figure 6. Commercial length frequency (total length, inches) of striped bass harvested in the ASMA, NC, 1982–2021. Bubble size represents the proportion of fish at length.

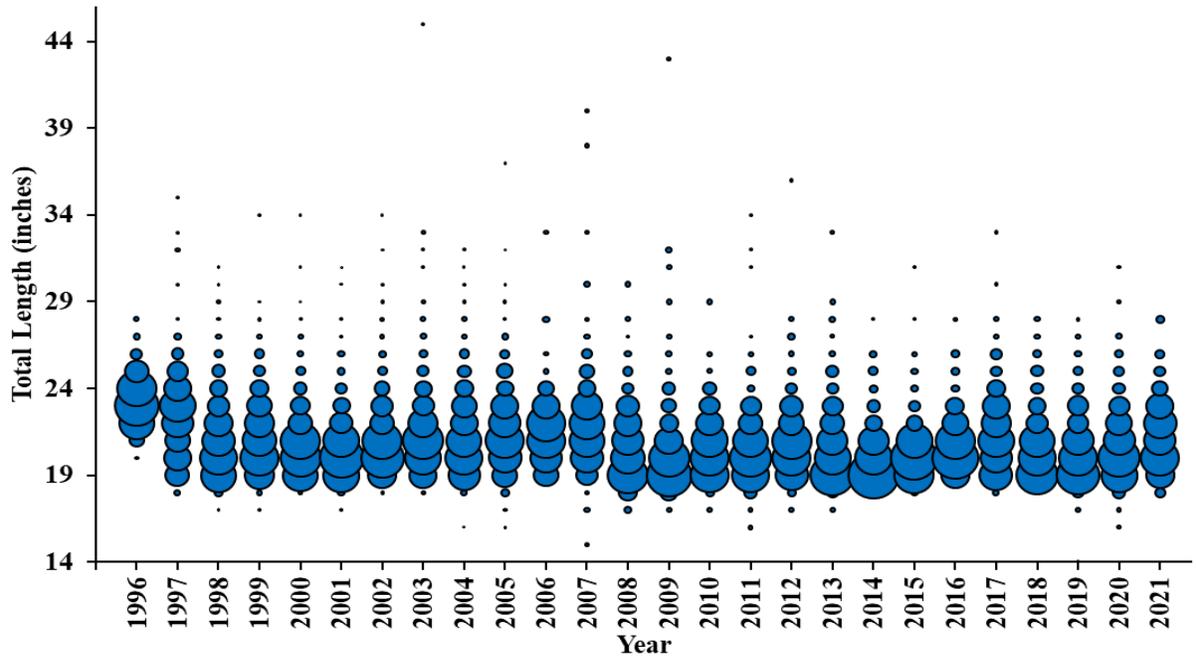


Figure 7. Recreational length frequency (total length, inches) of striped bass harvested in the ASMA, NC, 1996–2021. Bubble size represents the proportion of fish at length.

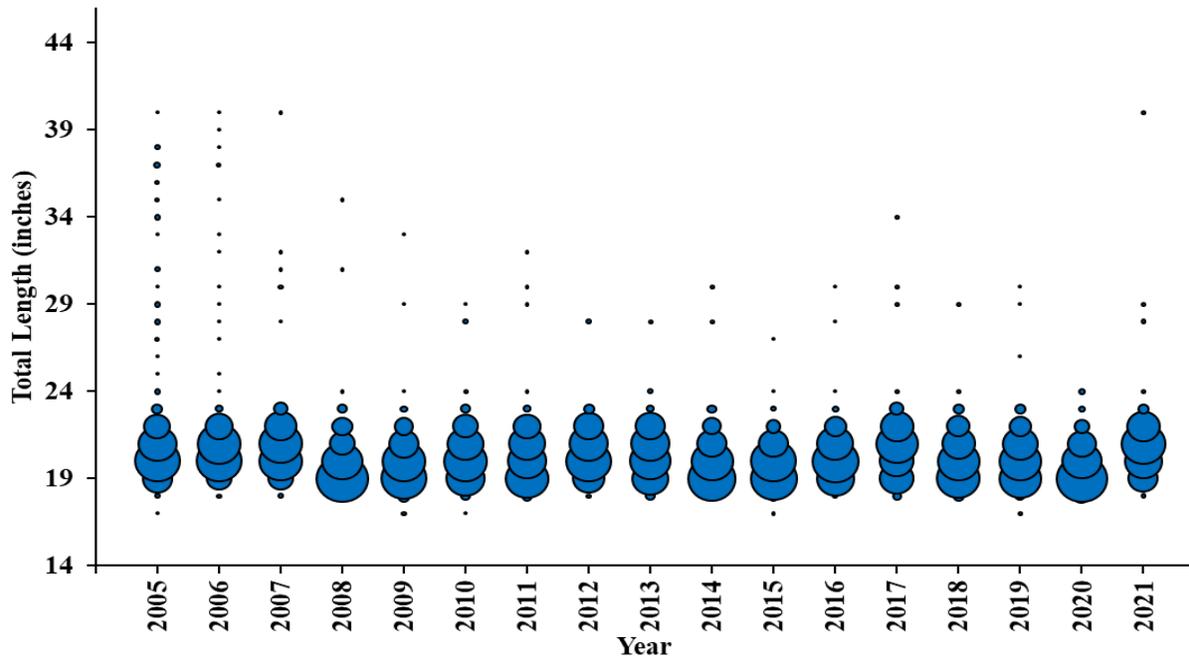


Figure 8. Recreational length frequency (total length, inches) of striped bass harvested in the RRMA, NC, 2005–2021. Bubble size represents the proportion of fish at length.

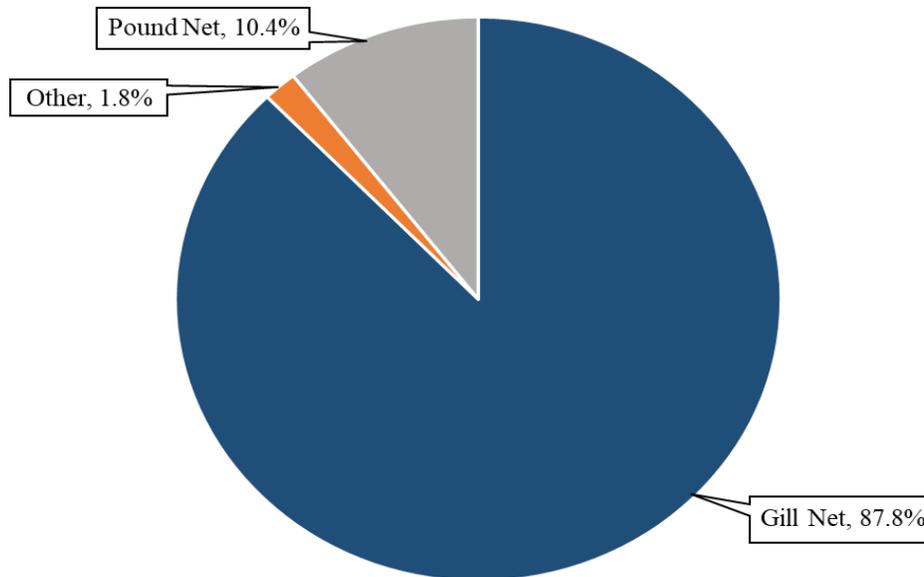


Figure 9. Commercial striped bass landings broken out by major gears in the ASMA, NC, 1994–2021.

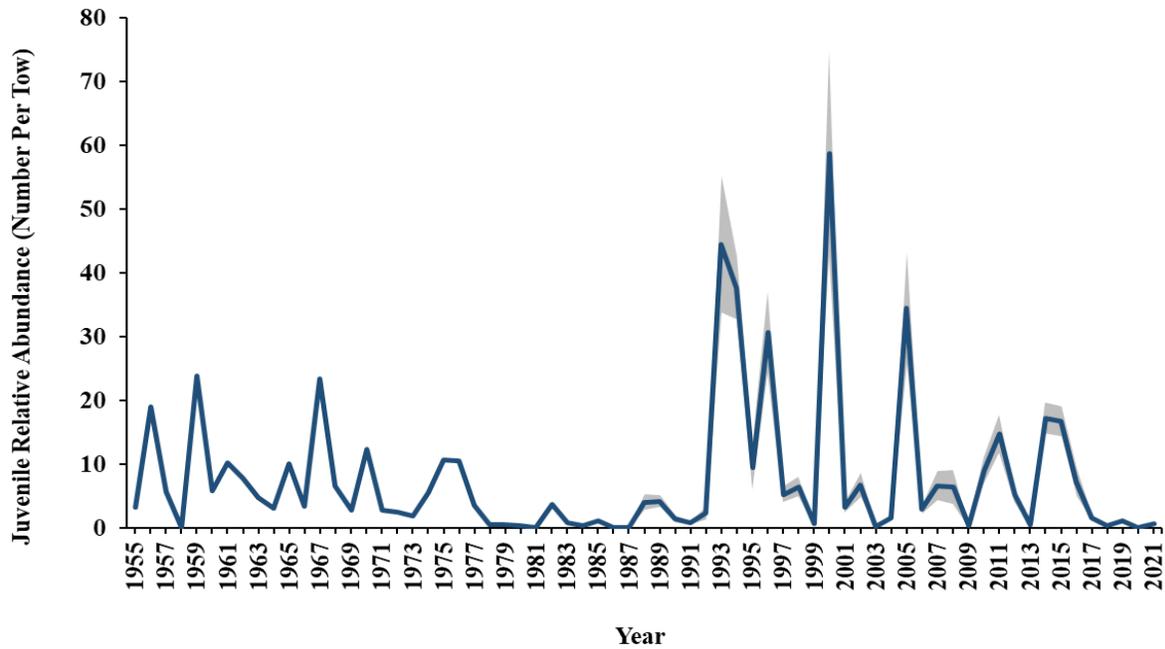


Figure 10. Juvenile abundance index (JAI) of Albemarle-Roanoke striped bass from the NCDMF juvenile trawl survey, western Albemarle Sound, NC, 1955–2021.

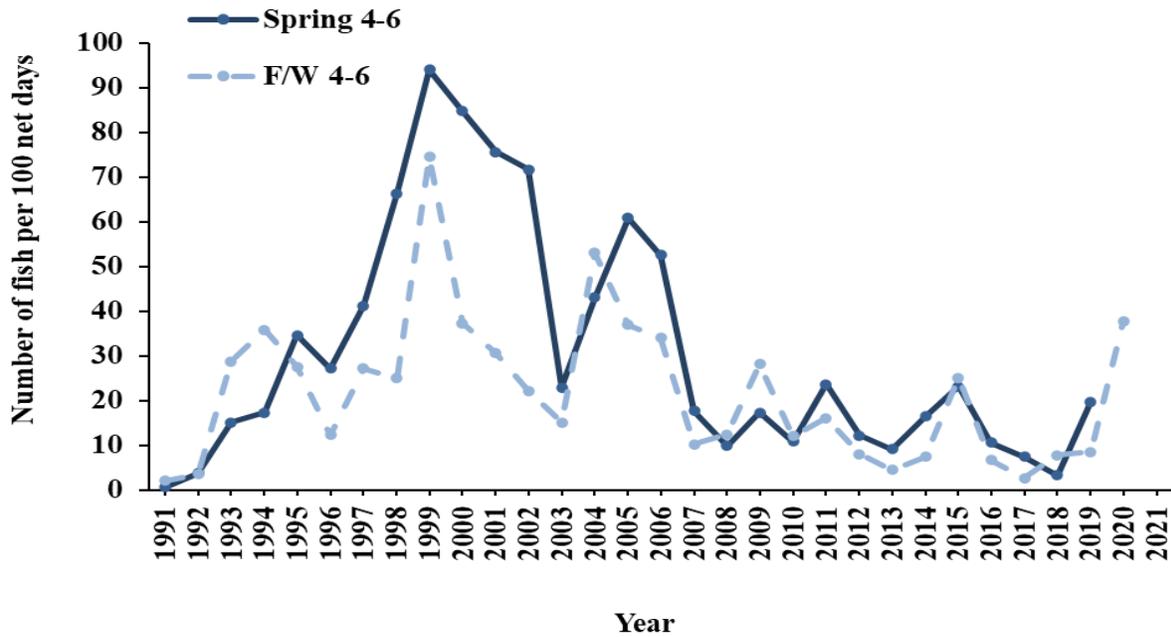


Figure 11. Relative abundance of age 4–6 Albemarle-Roanoke striped bass from the NCDMF fall/winter and spring independent gill net surveys, Albemarle Sound area, NC, 1991–2021.

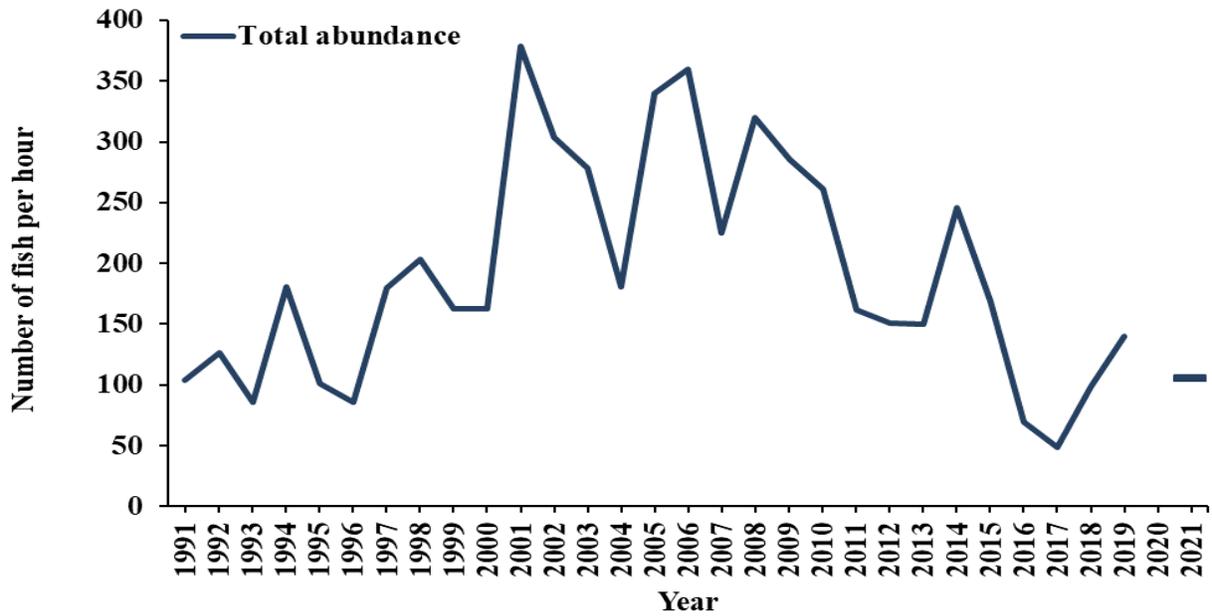


Figure 12. Relative abundance of Albemarle-Roanoke striped bass from the NCWRC spawning grounds electrofishing survey, Roanoke River at Weldon, NC, 1991–2021.

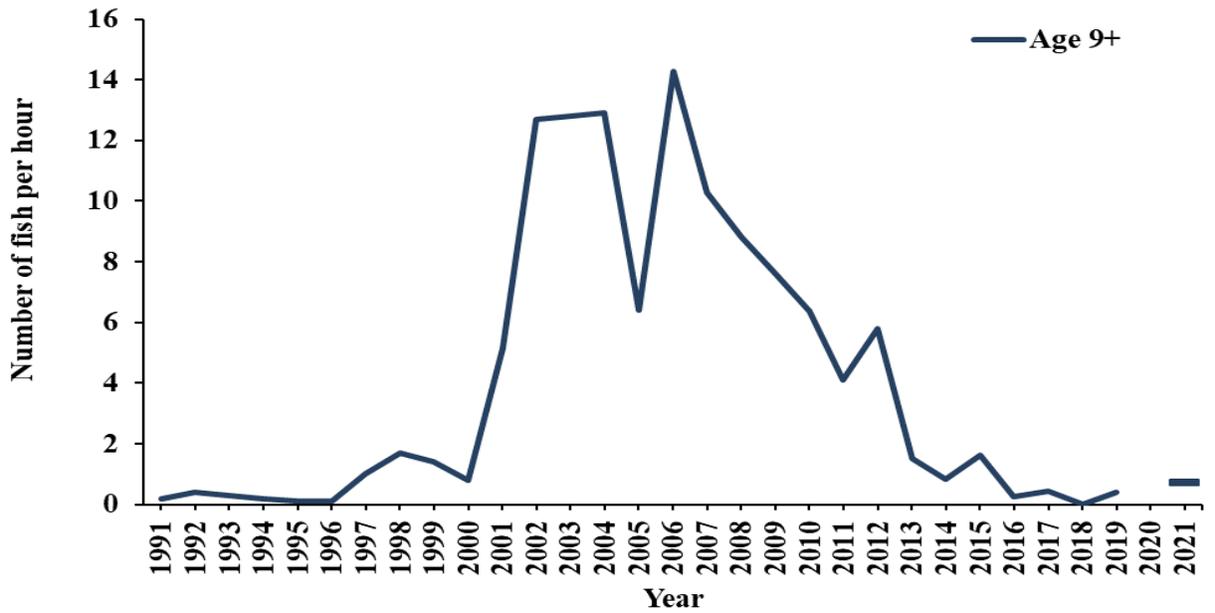


Figure 13. Relative abundance of age 9+ Albemarle-Roanoke striped bass from the NCWRC spawning grounds electrofishing survey, Roanoke River at Weldon, NC, 1991–2021.

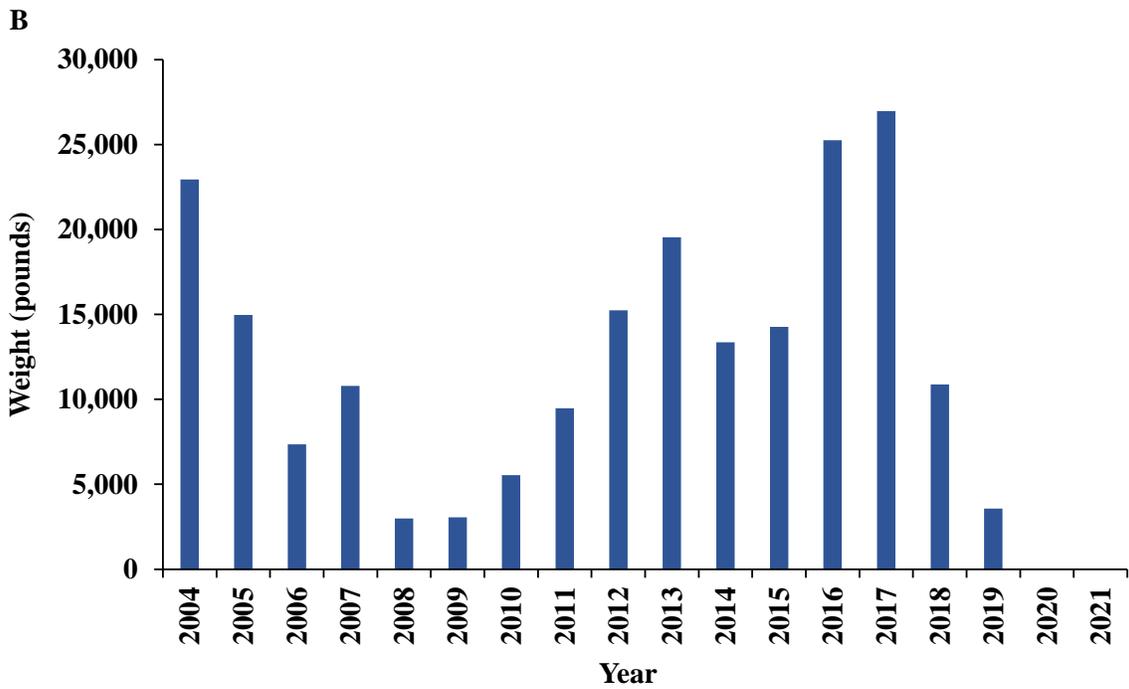
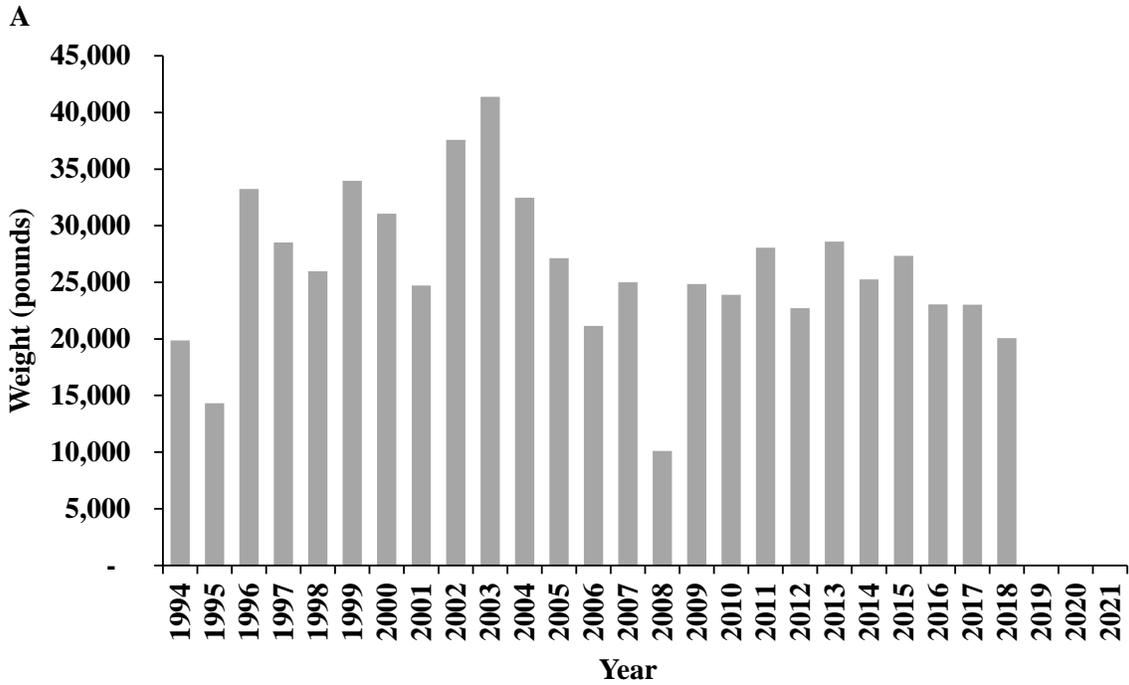


Figure 14. Annual commercial landings (pounds) reported through the North Carolina Trip Ticket Program, 1994–2021 (A), and recreational landings (pounds) estimated from the CSMA Recreational Creel Survey, 2004–2021. There was no commercial season and a limited recreational season in 2019, lasting from January 1 to March 19, 2019. Commercial and recreational seasons remained closed in 2021.

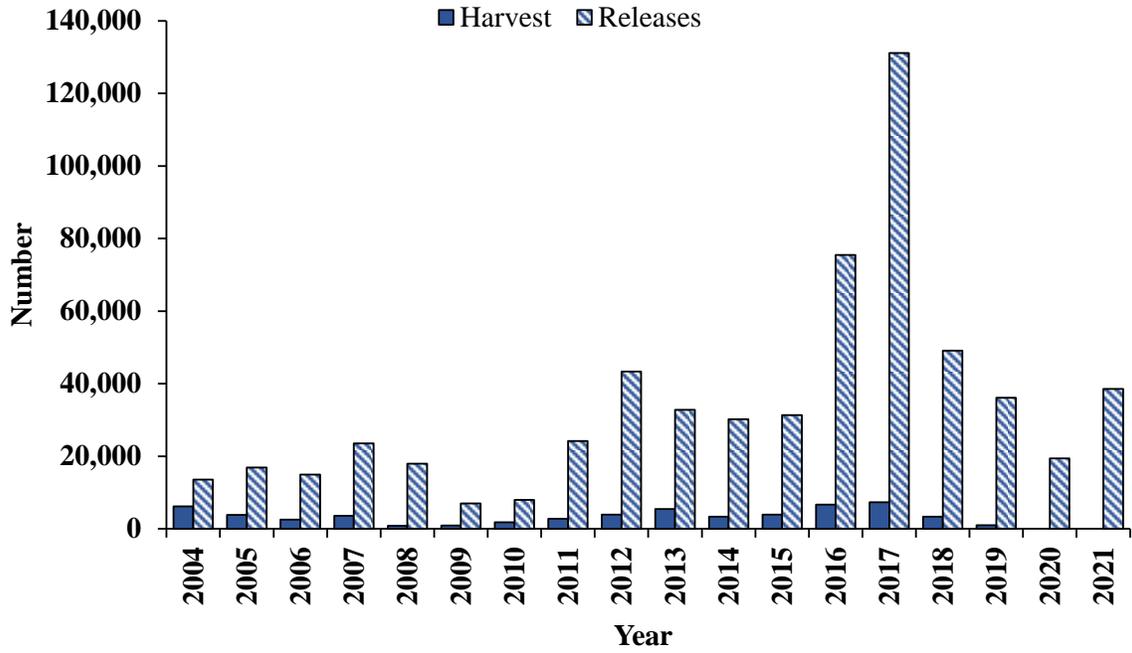


Figure 15. Annual recreational catch (harvested and/or released) of striped bass in the CSMA, 2004–2021. There was a limited recreational harvest season in 2019 prior to the closure, lasting from Jan 1 to Mar 19, 2019. The harvest season remained closed in 2021.

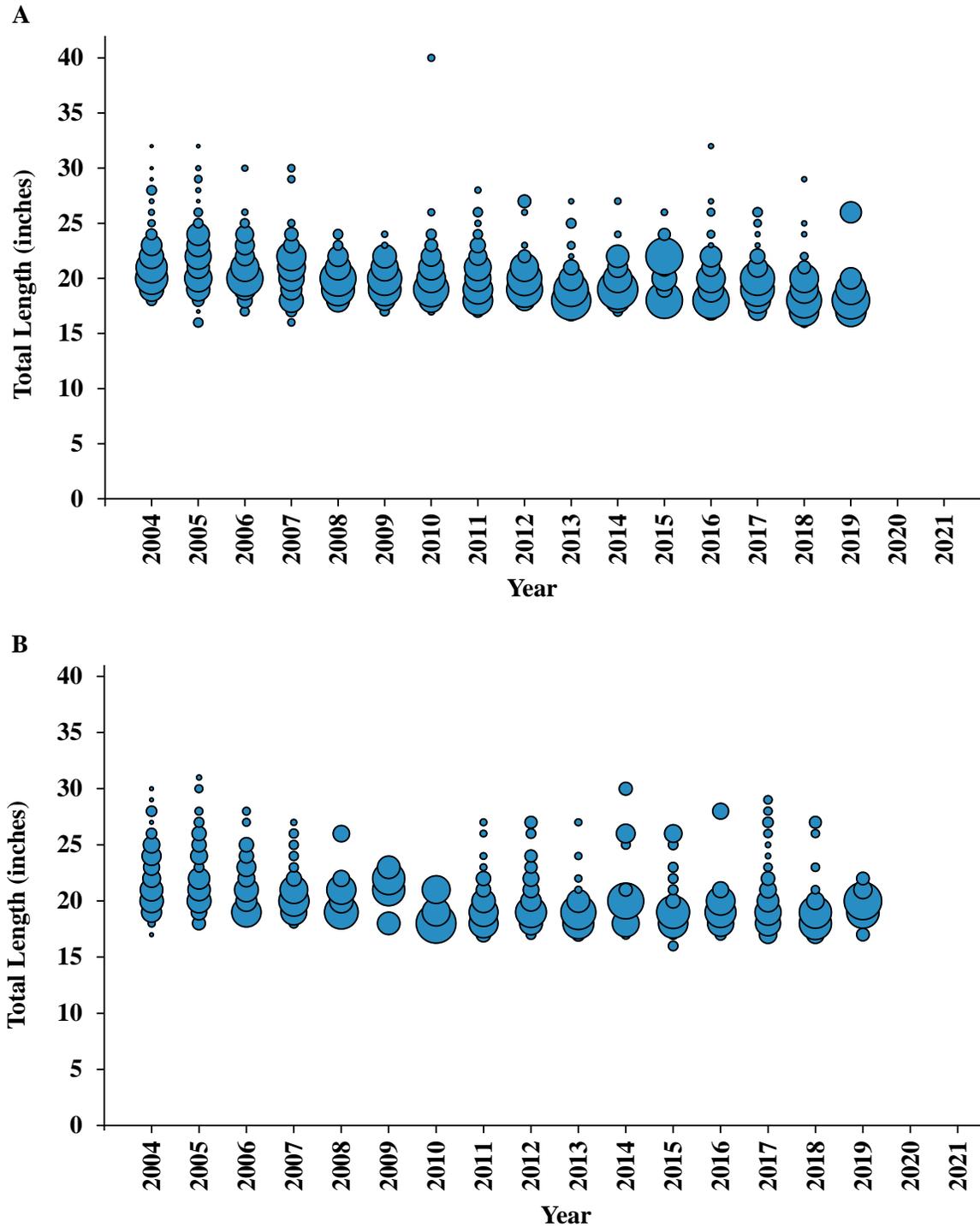


Figure 16. Recreational length frequency of CSMA striped bass harvested in the Tar-Pamlico/Pungo rivers (A), and the Neuse River (B), 2004–2021. Bubble size represents the proportion of fish at length. There was a limited recreational season in 2019 prior to the closure, lasting from Jan 1 to Mar 19, 2019. The recreational season remained closed in 2021.

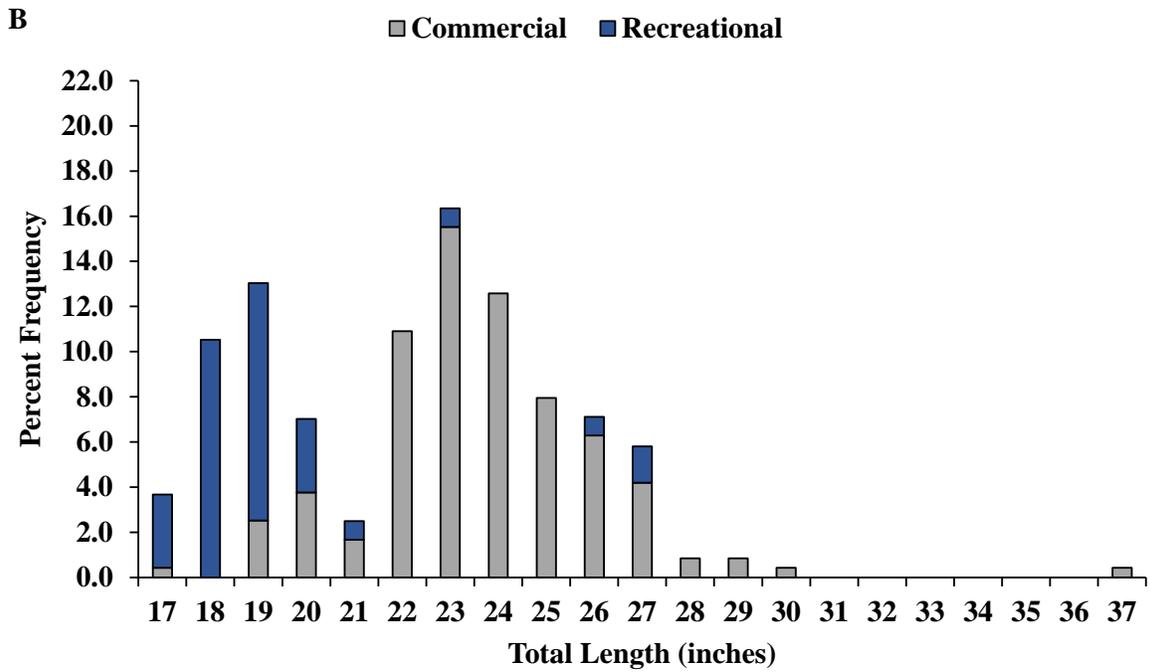
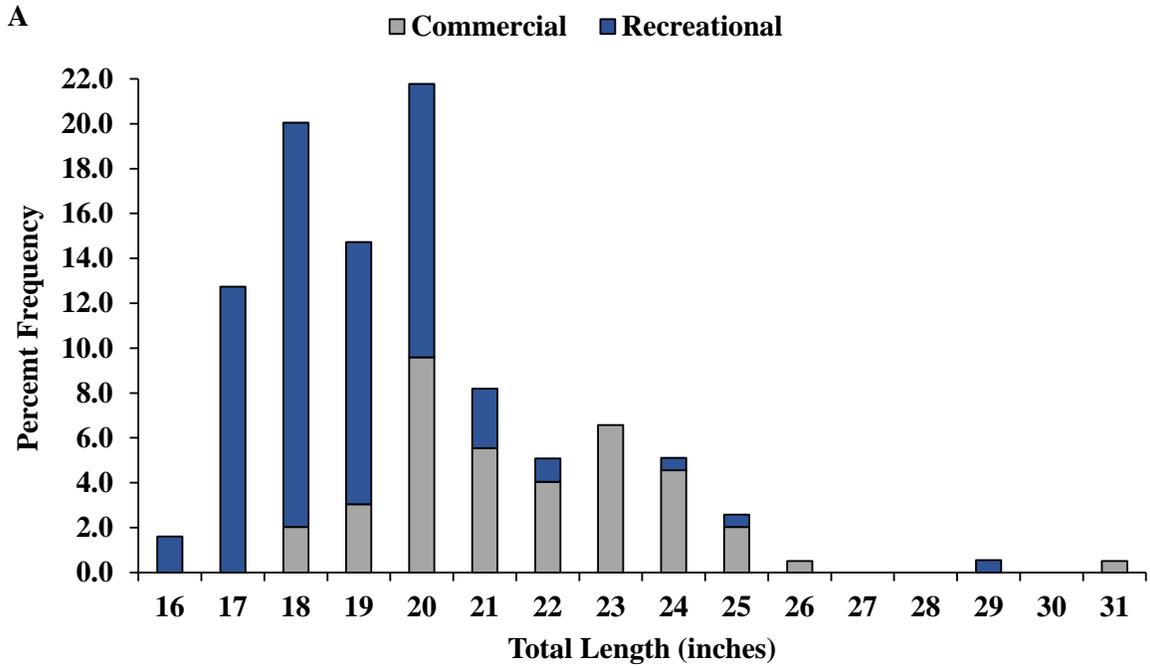


Figure 17. Commercial and recreational length frequency distributions from CSMA striped bass harvested in 2018 from the Tar-Pamlico/Pungo rivers (A) and the Neuse/Bay rivers (B).

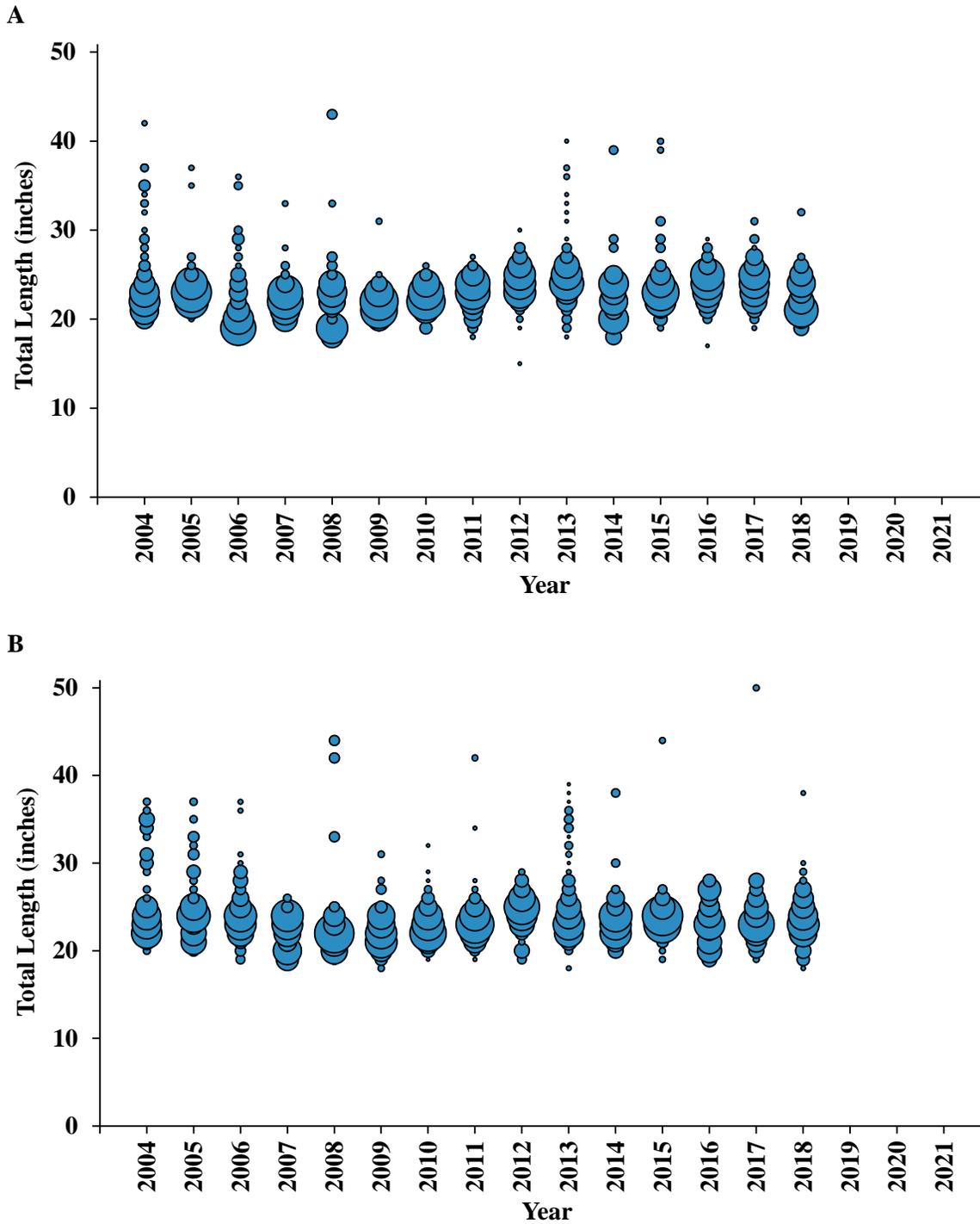


Figure 18. Commercial length frequency of CSMA striped bass landed in the Tar-Pamlico/Pungo rivers (A), and the Neuse/Bay rivers (B) from 2004–2021. Bubble size represents the proportion of fish at length. The commercial season remained closed in 2021.

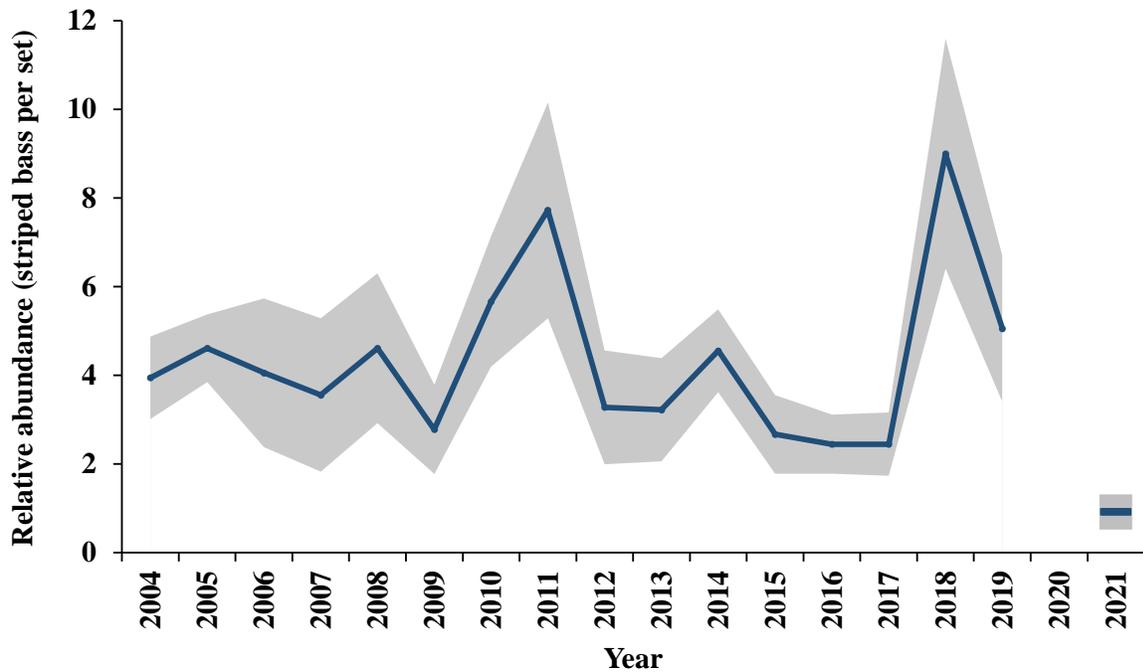


Figure 19. Annual index of adult striped bass relative abundance from the Fisheries Independent Gill Net Survey (P915) in the Tar-Pamlico River during April, and October-November, in shallow water sets, 2004–2021. No sampling occurred in 2020 and limited sampling occurred in 2021 (July–December). Error bars represent ± 1 standard error.

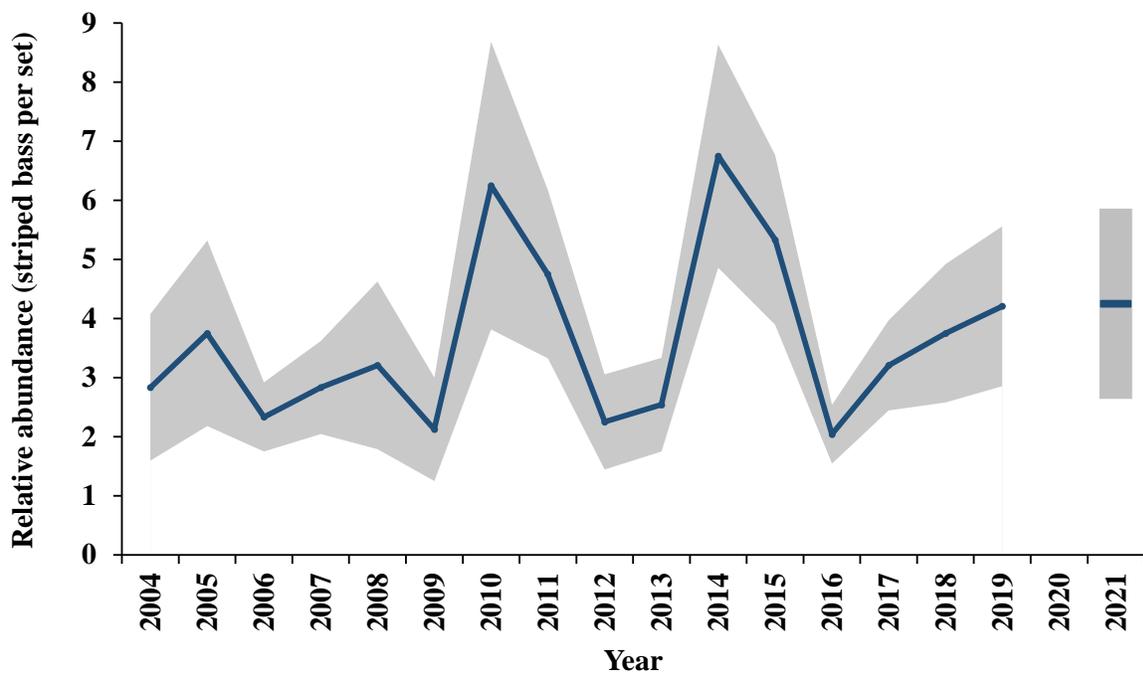


Figure 20. Annual index of adult striped bass relative abundance in the Fisheries Independent Gill Net Survey (P915) in the Neuse River during April, and October-November, in shallow water sets, 2004–2021. No sampling occurred in 2020 and limited sampling occurred in 2021 (July–December). Error bars represent ± 1 standard error.

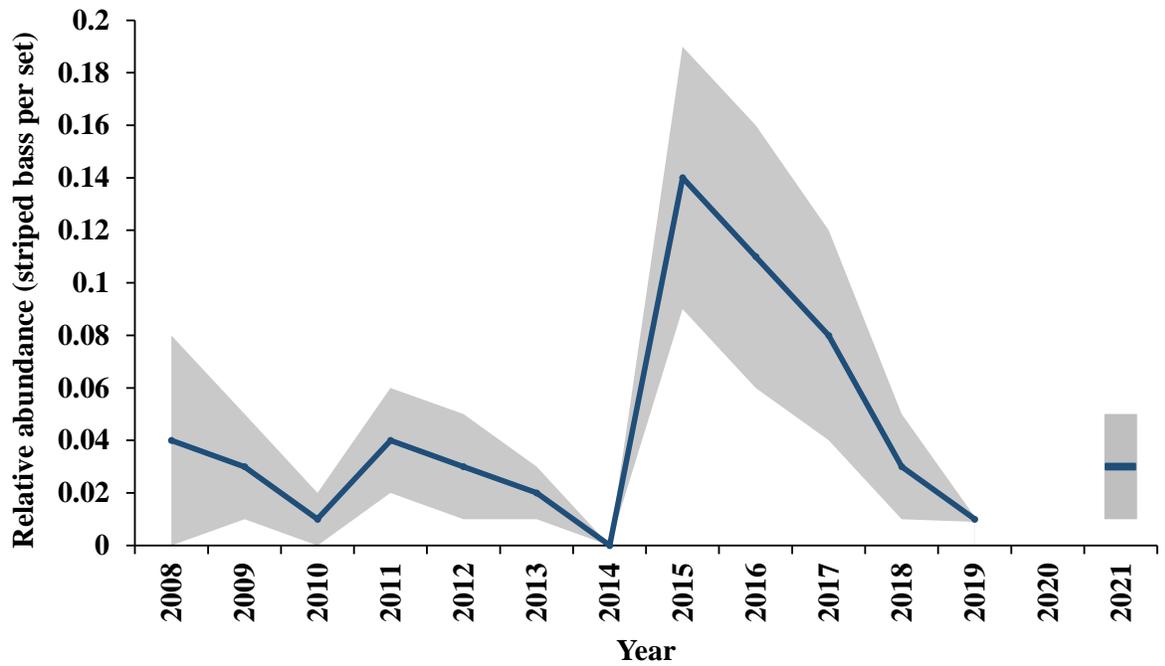


Figure 21. Annual index of adult striped bass relative abundance in the Fisheries Independent Gill Net Survey (P915) in the Cape Fear and New rivers, 2008–2021. No sampling occurred in 2020 and limited sampling occurred in 2021 (July–December). Error bars represent ± 1 standard error.

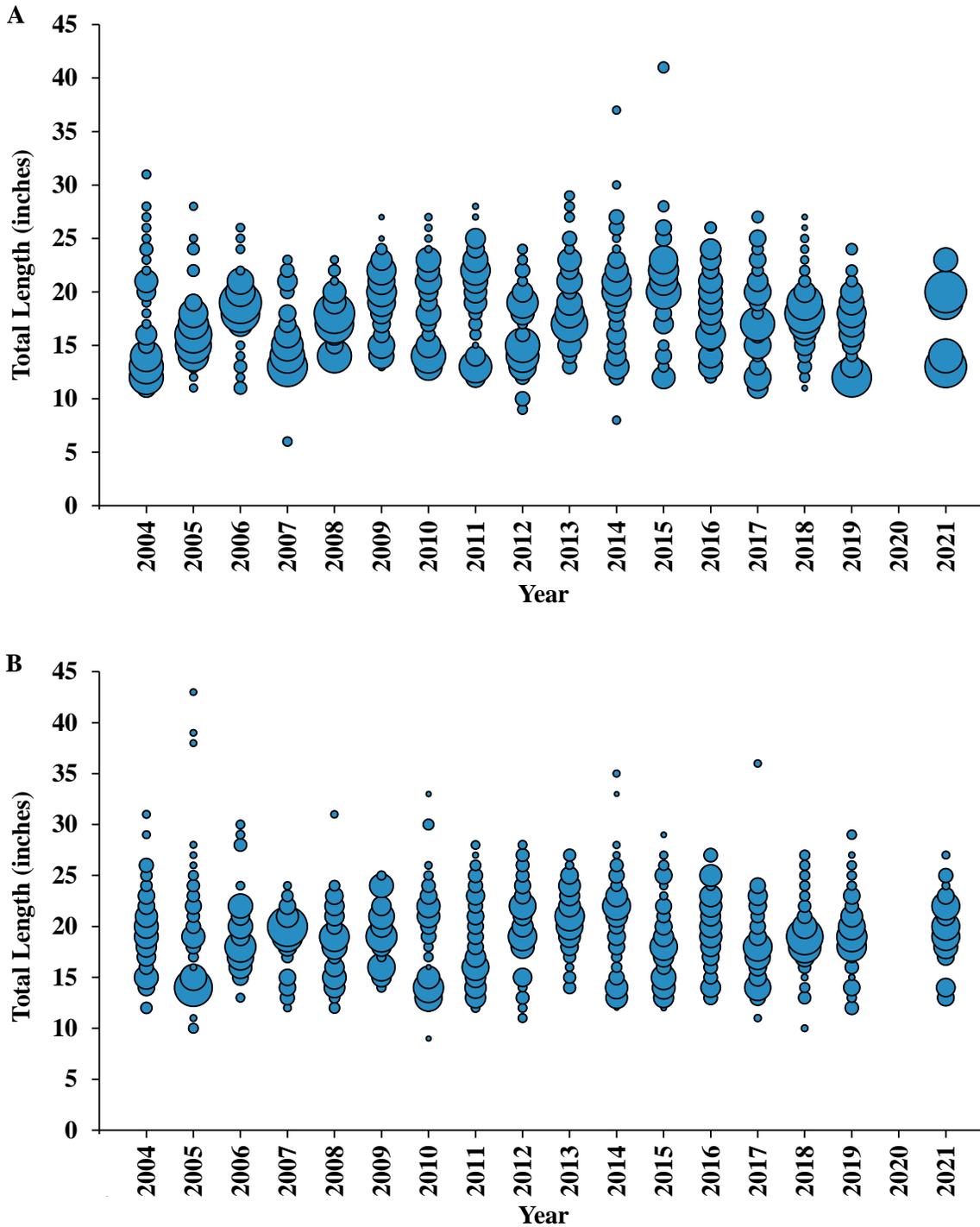


Figure 22. Length frequency of striped bass captured in the Fisheries Independent Gill Net Survey (P915) in the Tar-Pamlico River (A), and the Neuse River (B) during April, and October–November, in shallow water sets (2004–2021). No sampling occurred in 2020 and limited sampling occurred in 2021 (July–December). Bubble size represents the proportion of fish at length.

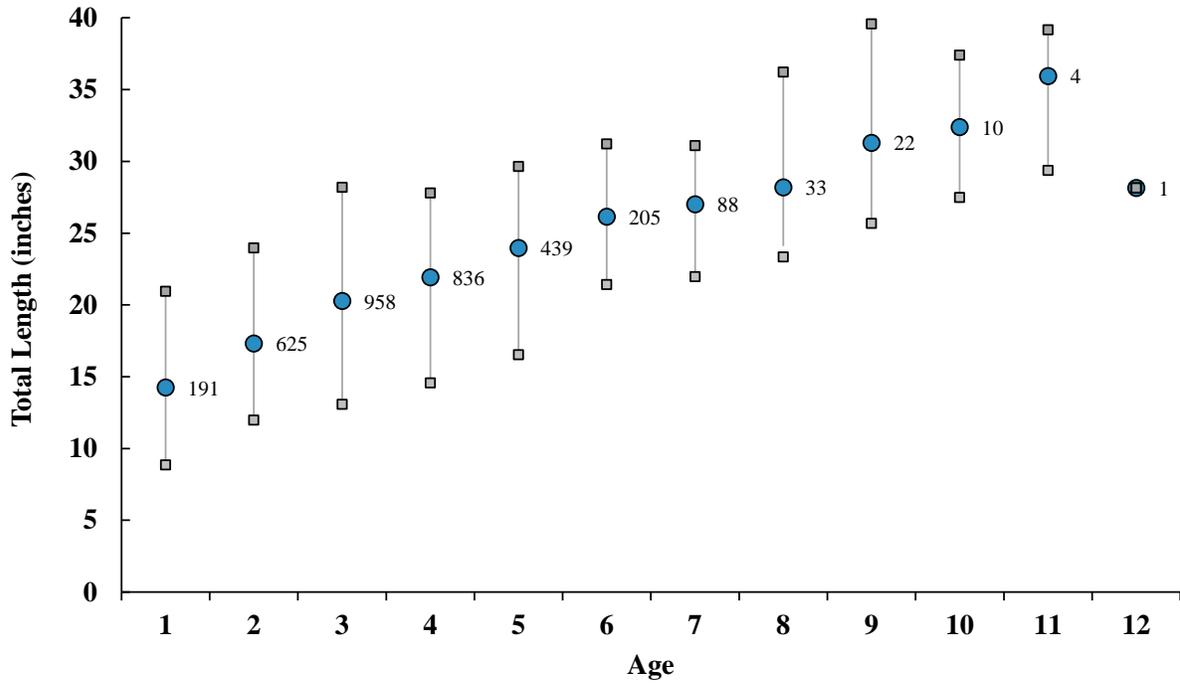


Figure 23. CSMA striped bass length at age based on otolith and genetic age samples collected, 2004–2021. Blue circles represent the mean size at a given age with the number of samples. The grey squares represent the minimum and maximum observed size for each age. Otolith age data from 2021 are considered preliminary, genetic ages from 2020 and 2021 are not currently available.