NC Marine Fisheries Commission

# Fishery Management Plans

November 2022 Business Meeting

ROY COOPER
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October 28, 2022

**MEMORANDUM**

**TO:** N.C. Marine Fisheries Commission

**FROM:** Corrin Flora, Fishery Management Plan Coordinator
Fisheries Management Section

**SUBJECT:** Fishery Management Plan Update and Schedule Review

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**Issue**

Update the N.C. Marine Fisheries Commission (MFC) on the status of North Carolina fishery management plans (FMPs).

**Action Needed**

For informational purposes only, **no action is needed at this time**.

**Overview**

This memo provides an overview on the status of four North Carolina FMPs for the November 2022 MFC business meeting.

**Eastern Oyster and Hard Clam FMPs**

The 2022 FMP Schedule includes review of the Eastern Oyster and Hard Clam FMPs. The Division has appointed a Plan Development Team who are currently identifying available data sources to assess the needs of the wild fisheries of North Carolina.

**Estuarine Striped Bass FMP**

Estuarine Striped Bass continues to be managed under Amendment 1 and associated Supplement and Revisions. The Division and Wildlife Resources Commission (WRC) staff jointly developed draft Amendment 2. At its May 2022 business meeting, the MFC selected preferred management for Amendment 2. As part of monitoring FMP development, the DEQ Secretary reported progress to the appropriate legislative bodies for review. At its August 2022 meeting, the MFC was updated on the progress of the plan and passed a motion to table the discussion until the November meeting.

Based on stock concerns identified during preparation of the Annual Review specifically continuing low juvenile abundance, where the Division is updating the 2020 Albemarle-Roanoke benchmark stock assessment. Data through 2022 is being included in the stock assessment update. Division and WRC staff continue to work together on the update.

**Striped Mullet FMP**

A peer reviewed, benchmark stock assessment for striped mullet was recently completed. The assessment indicated the stock was overfished and experiencing overfishing in the terminal year of 2019. The Division held public scoping September 26 – October 7. The scoping meetings are opportunities where the Division received stakeholder ideas and concerns prior to development of the FMP. Stakeholders participated in three in-person meetings, one of which was a hybrid format with participation in-person and via virtual meeting platform. At the November MFC business meeting, Division staff will present an overview of the stakeholder input received. In addition, the MFC will have the opportunity to provide additional management strategies and vote on approval of the Striped Mullet FMP Amendment 2 goal and objectives.

**Spotted Seatrout FMP**
A benchmark stock assessment for spotted seatrout was recently completed and underwent peer review. The peer review panel and the Division agreed that the spotted seatrout stock assessment is the best available science and is appropriate for management. The assessment contains data through 2019 and estimates the stock is not overfished, with biomass above the target, but is experiencing overfishing. A stock assessment overview will be presented to the MFC at its November meeting.

**Blue Crab FMP**
The Blue Crab FMP Amendment 3 adaptive management framework included an update to the stock assessment at least once between full reviews of the FMP. The 2018 stock assessment indicated the stock was overfished and overfishing was occurring in the terminal year of 2016. Amendment 3 implemented management to address the stock status. The stock assessment update will begin in 2023 and will include data through 2022.

# FISHERY MANAGEMENT PLAN UPDATE
# SPOTTED SEATROUT
# AUGUST 2022

## STATUS OF THE FISHERY MANAGEMENT PLAN

### Fishery Management Plan History

| | | |
|---|---|---|
| Original FMP Adoption: | February 2012 | |
| Amendments: | None | |
| Revisions: | None | |
| Supplements: | Supplement A to the FMP | February 2014 |
| Information Updates: | None | |
| Schedule Changes: | None | |
| Comprehensive Review: | 2019 — Ongoing | |

Spotted seatrout (*Cynoscion nebulosus*) is managed under the authority of two state and one interstate fishery management plans (FMP). The North Carolina Marine Fisheries Commission (NCMFC) currently manages spotted seatrout under the North Carolina Spotted Seatrout FMP (NCDMF 2012) and the North Carolina FMP for Interjurisdictional Fisheries (NCDMF 2022). Supplement A to the 2012 North Carolina Spotted Seatrout FMP (NCDMF 2014) maintains short–term measures in the spotted seatrout fishery (40% reduction at 14-inch total length minimum size) to address several sources of uncertainty in the 2009 stock assessment through acquisition and assessment of additional data. The supplement examined sources of uncertainty in the assessment, the rationale for not implementing on schedule the North Carolina Spotted Seatrout FMP February 2014 management measures and presented possible interim management measures. At the February 2014 NCMFC meeting the commission voted to maintain short-term management measures in the spotted seatrout fishery (Proclamation FF-38-2014: 14-inch minimum size, 75-fish commercial trip limit with weekend closures in joint waters except in Albemarle and Currituck sounds; Proclamation FF-39-2014: 14-inch minimum size, four-fish recreational bag limit). These measures will remain in effect until a new amendment is completed.

As required in the approved 2012 FMP, a stock assessment (NCDMF 2015a) was completed on schedule (2014-2015), peer reviewed, approved for management, and was presented to the NCMFC at its May 2015 business meeting. A new benchmark stock assessment began in late 2020. The North Carolina Division of Marine Fisheries (NCDMF) will review the state FMP for spotted seatrout to determine if changes to management are needed through the FMP amendment process, after the stock assessment is complete and accepted for management use.

The Atlantic States Marine Fisheries Commission (ASMFC) manages spotted seatrout in all Atlantic States who have a declared interest in the species. In addition to the state FMP, the

ASMFC manages spotted seatrout under the Omnibus Amendment to the Interstate Fishery Management Plans for Spanish Mackerel, Spot, and Spotted Seatrout (ASMFC 2011). The goals for the Omnibus Amendment are to bring the FMPs for the three species under the authority of the ASMFC Interstate Fishery Management Program Charter and bringing compliance requirements to each state. Because the intent of the Omnibus amendment was to bring the ASMFC spotted seatrout FMP into compliance with the new ASMFC charter, management measures were not adjusted and the identified objectives and compliance requirements to the states of the Omnibus Amendment are the same as Amendment 1 to the ASMFC spotted seatrout FMP (ASMFC 1990) and are as follows:

- Manage the spotted seatrout fishery restricting catch to mature individuals (12-inch minimum size limit).
- Manage the spotted seatrout stock to maintain appropriate spawning stock biomass (20% SPR).
- Develop research priorities that will further refine the spotted seatrout management program to maximize the biological, social, and economic benefits derived from the spotted seatrout population.

To ensure compliance with interstate requirements, North Carolina also manages this species under the North Carolina Fishery Management Plan for Interjurisdictional Fisheries (IJ FMP; NCDMF 2022). 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.

## Management Unit

The management unit for the North Carolina Spotted Seatrout FMP (NCDMF 2012) includes all spotted seatrout within the coastal and joint waters of North Carolina. The unit stock, or population unit, for North Carolina's assessment of spotted seatrout include all spotted seatrout caught in North Carolina and Virginia. Virginia landings were included in the stock assessment of spotted seatrout because of the high rate of mixing observed between North Carolina and Virginia.

## Goal and Objectives

The goal of the North Carolina Spotted Seatrout FMP (NCDMF 2012) is to determine the status of the stock and ensure long-term sustainability for the spotted seatrout stock in North Carolina. To achieve this goal, it is recommended that the following objectives be met:

- Develop an objective management program that provides conservation of the resource and sustainable harvest in the fishery.
- Ensure the spawning stock is of sufficient capacity to prevent recruitment-overfishing.
- Address socio-economic concerns of all user groups.

- Restore, improve, and protect important habitats that affect growth, survival, and reproduction of the North Carolina spotted seatrout stock.
- Evaluate, enhance, and initiate studies to increase understanding of spotted seatrout biology and population dynamics in North Carolina.
- Promote public awareness regarding the status and management of the North Carolina spotted seatrout stock.

## DESCRIPTION OF THE STOCK

### Biological Profile

Spotted seatrout range from Massachusetts to southern Florida and the Bahamas on the U.S. Atlantic Coast and continue through the Gulf of Mexico to the Yucatan Peninsula, Mexico (Murphy et al. 2006). Genetic data supports a single unit stock in Virginia and North Carolina (Ellis et al. 2019). In addition, based on genetic data, New River, North Carolina is an area of complex, seasonal mixing between two genetically distinct populations (Ellis et al. 2019): Georgia through Cape Fear River, North Carolina, and Bogue Sound, North Carolina and north (O'Donnell et al. 2014; Ellis et al. 2019). They inhabit shallow coastal and estuarine waters throughout their range and are considered a euryhaline species (Deaton et al. 2010). In North Carolina, the current state record was recorded at 12.3 pounds in 1961. The maximum reported age of spotted seatrout is 9 years in North Carolina for both male and female fish (NCDMF 2012). Most spotted seatrout in North Carolina are mature by age 1 and 7.9 inches for males and 9.9 inches for females. All males are mature at 12 inches and females at 15 inches. Spawning in North Carolina occurs from April to October with peak spawn around May (Burns 1996). Spawning occurs within the first few hours after sunset (Luczkovich et al. 1999) and a single fish is capable of spawning multiple times (batch spawners) throughout the season. In Florida, it has been observed that during peak spawning, spotted seatrout older than 3 years old may spawn every two days while younger fish may spawn as frequently as every four days (Roumillat and Brouwer 2004). Estimates of the number of eggs a female can produce in a year from the Southeast and Gulf Coasts vary, based on size and age and range, from 3 million to 20 million per year (Nieland et al. 2002; Roumillat and Brouwer 2004; Murphy et al. 2011).

### Stock Status

The 2014 North Carolina spotted seatrout stock assessment (NCDMF 2015b) indicated the spotted seatrout stock in North Carolina and Virginia is not overfished and overfishing is not occurring (Figures 1 and 2).

### Stock Assessment

The 2014 assessment of spotted seatrout in North Carolina and Virginia was conducted using a Stock Synthesis model that incorporated data collected from commercial and recreational fisheries, two fishery-independent surveys, and a tagging study (NCDMF 2015b). Data included 1991 through 2012 and relied on expanded fishery-independent data sources, including Virginia age, a juvenile abundance index, and North Carolina State University tag-return data (Ellis 2014). The fishing year was defined as the biological year, March 1 through February 28 or 29, to incorporate cold stun mortalities within a single model year.

The results of this assessment suggest the age structure of the spotted seatrout stock has been expanding during the last decade. However, an abrupt decline is evident in the model's estimate of recruitment after 2010, although this is not mirrored in the empirical survey data. Spawning stock biomass (SSB) has declined since 2007. In 2012, estimated SSB was 2,513,270 pounds (1,140 metric tons), which is greater than the threshold (SSB30%=868,621 pounds or 395 metric tons; Figure 1), indicating the stock is not overfished. There is no trend in fishing mortality (*F*), but periods of high *F* seem to coincide with spawning stock biomass declines and may be attributed to cold stun events. The 2012 estimate of fishing mortality was 0.40, which is less than the threshold (F20%=0.66), indicating the stock is not experiencing overfishing; however, the 2012 estimate of fishing mortality (0.40) is very near the target fishing mortality of F30%=0.42 (Figure 2).

A benchmark stock assessment for spotted seatrout began in 2020 coinciding with the scheduled FMP review and is scheduled to be completed in late 2022.

## DESCRIPTION OF THE FISHERY

### Current Regulations

The NCDMF currently allows the recreational harvest of spotted seatrout seven days per week with a minimum size limit of 14-inches total length (TL) and a daily bag limit of four fish. The commercial harvest is limited to a daily limit of 75 fish with a minimum size limit of 14-inches TL). It is unlawful for a commercial fishing operation to possess or sell spotted seatrout for commercial purposes taken from Joint Fishing Waters of the state from midnight on Friday to midnight on Sunday each week; the Albemarle and Currituck sounds are exempt from this weekend closure. In the event of a catastrophic cold stun, the NCDMF has the authority to close the fishery until the following spawning period. In 2018, the spotted seatrout commercial and recreational fishery was closed from January 5 through June 15 by proclamation due to a state-wide cold stun event.

### Commercial Fishery

Annual landings have been variable throughout the time series (Table 1; Figure 3). Commercial landings in 2021 (694,784 pounds) increased by 22% compared to the previous year (568,574 pounds; Table 1; Figure 3). Commercial landings in 2021 were the highest since 1991. This sharp increase in commercial landings is most likely due to several strong year classes of fish and mild winters in 2019, 2020 and 2021, resulting in high numbers of available fish. During the early to mid-1990s, landings in the ocean and estuarine areas were more similar than in the remainder of the time series (1995-2021) in which estuarine landings have dominated. The primary gear of harvest are estuarine gill nets (set, drift, and run around).

## Recreational Fishery

Recreational landings of spotted seatrout are estimated from the Marine Recreational Information Program (MRIP). Recreational estimates across all years have been updated and are now based on the MRIP's new Fishing Effort Survey-based calibrated estimates. For more information on MRIP see https://www.fisheries.noaa.gov/topic/recreational-fishing-data.

Recreational harvest of spotted seatrout estimated by MRIP (Type A + B1) in 2020 was 2,241,421 pounds, or 1,223,508 fish, much higher than the time series average of 1,535,506 pounds, or 976,689 but lower than the previous year (Table 1; Figure 3). Estimated recreational releases in 1(6,332,064 fish) were well above the time series average of 3,484,026 fish, and slightly higher than the previous year's releases of 6,215,778 fish (Table 1).

The North Carolina Saltwater Fishing Tournament recognizes anglers for landing and/or releasing fish of exceptional size or rarity by issuing citations that document the capture for the angler. Citations awarded through the North Carolina Saltwater Fishing Tournament for spotted seatrout have varied by year throughout the time series, averaging 338 citations (Table 2; Figure 4). The number of awarded citations in 2021 (655 citations) increased from the previous year (579 citations) and was the highest number of citations since 2007 (1,000 citations). The number of release citations (fish over 24 inches that are released) awarded (283 release citations) was the highest since release citations began in 2008. The percent of spotted seatrout release citations (43%) was the highest since 2018 and 2019 (both at 37%; Table 2).

# MONITORING PROGRAM DATA

## Fishery-Dependent Monitoring

Commercial fish houses are sampled monthly to provide length, weight, and age data. This information is used to characterize the commercial fishery for stock assessments and to monitor trends in the size and age of fish being removed from the stock. The average sizes of fish landed by the commercial fishery are typically larger than the recreational fishery and is primarily driven by the larger maximum size observed in the commercial landings; in addition, modal length for the commercial fishery was slightly higher (17 inches fork length) than the recreational fishery (15 inches fork length; Table 3; Figure 5). Undersized fish represent a small portion of the harvest in both sectors; 4.5% of commercial harvest and 1.3% of the recreational harvest was below the 14-inch size limit in 2021 (Figure 5).

The number of fish sampled by division staff at commercial fish houses has varied over time due to annual variability in landings of the fishery. The mean length of spotted seatrout in 2021 (17.5 inches fork length) was similar to the time series (1991-2020) average (16.6 inches fork length) and the mean and minimum lengths in 2021 (17.5 and 10.9-inches fork length, respectively) were all approximately equal to the previous two years (Table 3; Figure 6). In addition, for the past three years (2019-2021), minimum length has been consistently greater than the time series average (9.3 inches fork length). Maximum length in 2021 decreased to 29.9 inches fork length and was just above the time series average (29.3 inches fork length). The bulk of spotted seatrout landings by the commercial fishery in 2021 came from the ocean and estuarine gill net fishery (95%) with pound nets (2%), gigs (1%), and all other gears (mainly beach seines, swipe nets, and haul seines) accounting for the rest (2%).

Recreational catch is almost exclusively hook-and-line with few fish being landed by gigs. The mean (17.0 inches fork length), minimum (11.1 inches fork length), and maximum (26.5 inches fork length) lengths of fish measured in 2021 from the recreational fishery were similar to the previous year (17.0, 12.1, 26.8 inches fork length, respectively) and greater than the time series (1991-2020) average of each (16.0, 10.4, 25.8 inches fork length, respectively; Table 3; Figure 7). Ninety-two percent of the spotted seatrout sampled from the recreational fishery in 2021 were between 14 and 19 inches (Figure 5).

**Fishery-Independent Monitoring**

The NCDMF utilizes numerous independent monitoring programs to provide indices of juvenile (Program 120) and adult (Program 915) abundance to include in stock assessments. Program 120, the North Carolina Estuarine Trawl Survey, is a fishery independent multispecies monitoring program that has been ongoing since 1971 in the months of May and June. One of the key objectives of this program is to provide a long-term database of annual juvenile recruitment for economically important species. This survey samples a fixed set of 104 core stations with additional stations as needed. The core stations are sampled from western Albemarle Sound south to the South Carolina border each year without deviation two times in the months of May and June. An additional set of 27 spotted seatrout juvenile stations in Pamlico Sound and its major tributaries were added in 2004 and are sampled during the months of June and July. Data from the spotted seatrout specific stations are used to generate an index of relative abundance of age zero spotted seatrout, calculated as the average number of fish per tow. The resulting relative abundance index for the time series is variable with no significant trend overall, and peaks in 2006, 2008, 2012, 2013, and 2018 suggesting relatively higher recruitment in those years (Figure 8). The Program 120 relative abundance index in 2021 was 0.20, which was a 70% decrease from the previous year, and the lowest value since the beginning in 2004 (0.67 spotted seatrout per tow). The 2021 relative abundance index was a 90% decrease from the time series average (2004-2020; 2.08 spotted seatrout per tow).

The NCDMF started a fishery independent gill net survey (Program 915) in 2001 to generate a long-term database of age composition and to develop indices of abundance for numerous commercial and recreationally important finfish species, including spotted seatrout. The survey utilizes a stratified random sampling scheme of multi-mesh gill nets designed to characterize the size and age distribution for key estuarine species in Pamlico Sound and help managers assess the spotted seatrout stocks without relying solely on commercial and recreational fishery dependent data. Three regions encompassing most of the estuarine waters in North Carolina are sampled monthly from February to December. Pamlico Sound stations include waters on the backside of the barrier islands and the bays of Hyde and Dare counties. Relative abundance from Pamlico Sound has remained relatively steady from 2001 to 2015 (averaged 0.51 fish per set), increased to a time series high in 2019 (1.81 fish per set) and remained high in 2021 (1.46 fish per set; Figure 9). For the central river stations that include Pamlico, Pungo and Neuse rivers, abundance rose sharply in 2021 to the highest value in the time series (1.38 fish per set). Spotted seatrout abundance in the Cape Fear and New rivers has fluctuated without trend throughout the time series (Figure 11). Relative abundance in 2021 in the Cape Fear and New rivers was 0.91 fish per set, the second highest value in the time series. During 2020 no indices of abundance are available for spotted seatrout from the fishery-independent assessment (Program 915). Sampling in this program was suspended in February 2020 due to COVID-19 restrictions and protected species interactions but resumed July 2021.

Spotted seatrout age samples are collected from numerous NCDMF fishery independent and dependent sources. To date, a total of 20,668 otoliths from spotted seatrout have been aged since 1991 (Table 4). With the exception of 2003, the minimum age of sampled spotted seatrout has been age zero for every year the NCDMF has recorded this information. Maximum ages have varied every year, ranging from age five to age nine. Modal ages, which give an indication of the age of the largest cohort in the fishery, averages age one. Spotted seatrout length-at-age was summarized based on all available age data (1991-2020; Figure 12). Average growth of spotted seatrout slows down around age-4, but fish as large as 24.7 inches have the potential to be young of the year (age-0), demonstrating the species' fast growth. In 2021, the number of fish aged (1,006 fish) increased from the previous year (634 fish), which is to be expected with delays in sampling due to COVID-19 in 2020. Spotted seatrout sampled in 2021 had a modal age of 1 and maximum age of 6, an increase from the previous year (5).

## RESEARCH NEEDS

The following research needs were compiled from those listed in the 2012 North Carolina Spotted Seatrout FMP. Improved management of spotted seatrout is dependent upon research needs being met. Research needs are not listed in order of priority.

- Develop a juvenile abundance index to gain a better understanding of a stock recruitment relationship. — Ongoing, using program 120 since 2004; CRFL grant 2F40 is investigating an optimal sampling design for P120
- Research the feasibility of including measures of temperature or salinity into the stock recruitment relationship. — Not Completed
- Determine batch fecundity estimates for North Carolina spotted seatrout. — Not Conducted
- Size specific fecundity estimates for North Carolina spotted seatrout. — Not Conducted
- Area specific spawning surveys could help in the delineation of area specific closures to protect females in spawning condition. — Not Conducted
- Investigation of the relationship of temperature with both adult and juvenile mortality. — Ongoing: Ellis et al. 2017a, 2017b; CRFL project 2F40-F024 started in 2015, monitoring temperatures in overwintering habitat of spotted seatrout
- Incorporate cold stun event information into the modeling of the population. — Unsuccessfully attempted using stock synthesis model from the 2012 stock assessment, is being investigated in the 2019 benchmark stock assessment
- Estimate or develop a model to predict the impact of cold stun events on local and statewide spotted seatrout abundance. — Unsuccessfully attempted using stock synthesis model from the 2012 stock assessment, is being investigated further during 2019 benchmark stock assessment

- Obtain samples (length, age, weight, quantification) of the cold stun events as they occur. — Ongoing: obtained samples in 2001, 2010, 2014, 2015, 2018; length, weight, sex, age; unable to quantify extent of kills
- Define overwintering habitat requirements of spotted seatrout. — Preliminary work completed in Ellis et. al (2017a, 2017b)
- Determine factors that are most likely to influence the severity of cold stun events in North Carolina and separate into low and high salinity areas. — Preliminary work completed in Ellis et. al (2017a)
- Investigate the distribution of spotted seatrout in nursery and non-nursery areas. — Not Completed
- Further research on the possible influences of salinity on release mortality of spotted seatrout. — Not Completed
- Survey of fishing effort in creeks with conflict complaints. — Not Completed
- Determine targeted species in nursery areas and creeks with conflict complaints. — Not Completed
- Microchemistry, genetic, or tagging studies are needed to verify migration patterns, mixing rates, or origins of spotted seatrout between North Carolina and Virginia. — Genetic study completed: NCSU study CRFL grant 2F40-F022; tagging studies ongoing: Tim Ellis data (2008-2013); CRFL project 2F40-F017, NC Multi Species Tagging Study 2014 — Present
- Tagging studies to verify estimates of natural and fishing mortality. — Ongoing: Tim Ellis data (2008-2013); CRFL project 2F40-F017, NC Multi Species Tagging Study 2014 — Present
- Tagging studies to determine if there are localized populations within the state of North Carolina (e.g., a southern and northern stock). — Ongoing: Tim Ellis data (2008-2013); CRFL project 2F40-F017, NC Multi Species Tagging Study 2014 — Present
- A longer time series and additional sources of fishery-independent information. — Longer time series available for P915 as well as P915 surveys for rivers and southern portion of state
- Increased observer coverage in a variety of commercial fisheries over a wider area. — Ongoing
- Expand nursery sampling to include SAV bed sampling in high and low salinity areas during the months of July through September. — Not Completed
- Evaluate the role of shell hash and shell bottom in spotted seatrout recruitment and survival, particularly where SAV is absent. — Not Completed
- Evaluate the role of SAV in the spawning success of spotted seatrout. — Not Completed

## MANAGEMENT STRATEGY

Maintain a spawning potential ratio of 20% to increase the likelihood of sustainability through an expanded age structure and an increase in the spawning stock biomass. This strategy should provide a greater cushion for the population and likely lead to faster recovery of the population after cold stun events, which can lead to mass mortalities in the winter months potentially affecting the number of mature fish available to spawn the following spring. The Director maintains authority to intervene in the event of a catastrophic cold stun event and close the fishery in specific areas or statewide until June 15. This reduces fishing mortality on spotted seatrout until after the peak in their spawning season.

## FISHERY MANAGEMENT PLAN SCHEDULE RECOMMENDATIONS

The review of the plan is underway. A benchmark stock assessment is being conducted, incorporating data through February 2020.

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## TABLES

Table 1: Recreational harvest (number of fish landed and weight in pounds) and releases (number of fish) and commercial harvest (weight in pounds) of spotted seatrout from North Carolina for the period 1991–2021.

| Year | Recreational | | | Commercial | |
|---|---|---|---|---|---|
| | Numbers Landed | Numbers Released | Weight Landed (lb) | Weight Landed (lb) | Total Weight (lb) |
| 1991 | 988,049 | 719,372 | 1,360,530 | 660,662 | 2,021,192 |
| 1992 | 908,233 | 476,405 | 1,390,746 | 526,271 | 1,917,017 |
| 1993 | 569,327 | 542,137 | 857,720 | 449,886 | 1,307,606 |
| 1994 | 798,937 | 601,148 | 1,207,520 | 412,358 | 1,619,878 |
| 1995 | 863,057 | 764,503 | 1,221,065 | 574,296 | 1,795,361 |
| 1996 | 575,357 | 1,028,974 | 699,078 | 226,580 | 925,658 |
| 1997 | 779,611 | 480,093 | 1,025,110 | 232,497 | 1,257,607 |
| 1998 | 702,274 | 351,114 | 1,125,898 | 307,671 | 1,433,569 |
| 1999 | 1,080,411 | 1,168,909 | 1,878,913 | 546,675 | 2,425,588 |
| 2000 | 728,906 | 645,107 | 1,095,729 | 376,574 | 1,472,303 |
| 2001 | 499,556 | 1,210,336 | 659,893 | 105,714 | 765,607 |
| 2002 | 746,908 | 1,829,880 | 957,824 | 175,555 | 1,133,379 |
| 2003 | 388,715 | 903,292 | 515,678 | 181,462 | 697,140 |
| 2004 | 560,834 | 934,206 | 728,027 | 130,961 | 858,988 |
| 2005 | 1,517,647 | 3,744,921 | 1,695,036 | 129,855 | 1,824,891 |
| 2006 | 1,444,778 | 2,722,351 | 2,034,469 | 312,624 | 2,347,093 |
| 2007 | 1,241,296 | 3,558,110 | 1,998,275 | 374,722 | 2,372,997 |
| 2008 | 1,372,973 | 4,509,440 | 2,114,130 | 304,430 | 2,418,560 |
| 2009 | 1,857,890 | 5,369,092 | 2,878,160 | 320,247 | 3,198,407 |
| 2010 | 630,748 | 8,034,670 | 1,277,174 | 202,647 | 1,479,821 |
| 2011 | 723,502 | 7,486,377 | 1,353,388 | 75,239 | 1,428,627 |
| 2012 | 1,602,836 | 4,967,987 | 2,720,028 | 265,016 | 2,985,044 |
| 2013 | 1,107,957 | 4,312,436 | 1,881,881 | 367,648 | 2,249,529 |
| 2014 | 725,086 | 3,950,447 | 1,451,592 | 242,245 | 1,693,837 |
| 2015 | 249,260 | 4,883,109 | 430,579 | 128,762 | 559,341 |
| 2016 | 978,624 | 6,533,887 | 1,724,492 | 254,590 | 1,979,082 |
| 2017 | 1,217,834 | 5,151,510 | 2,157,198 | 299,911 | 2,457,109 |
| 2018 | 449,473 | 15,245,249 | 658,555 | 128,922 | 787,477 |
| 2019 | 1,937,250 | 7,185,562 | 3,334,163 | 378,491 | 3,712,654 |
| 2020 | 2,053,354 | 6,215,778 | 3,632,315 | 568,764 | 4,201,079 |
| 2021 | 1,223,508 | 6,332,064 | 2,241,421 | 694,784 | 2,936,205 |
| Mean | 976,689 | 3,484,026 | 1,535,506 | 308,709 | 1,844,215 |

Table 2: Total number of awarded citations for spotted seatrout (>24 inches total length for release or > five pounds landed) from the North Carolina Saltwater Fishing Tournament for the time period 1991–2021.

| Year | Total Citations | Release Citations[+] | % Release |
|---|---|---|---|
| 1991 | 185 | | 0 |
| 1992 | 203 | | 0 |
| 1993 | 12 | | 0 |
| 1994 | 237 | | 0 |
| 1995 | 483 | | 0 |
| 1996 | 132 | | 0 |
| 1997 | 125 | | 0 |
| 1998 | 332 | | 0 |
| 1999 | 695 | | 0 |
| 2000 | 511 | | 0 |
| 2001 | 518 | | 0 |
| 2002 | 353 | | 0 |
| 2003 | 328 | | 0 |
| 2004 | 378 | | 0 |
| 2005 | 290 | | 0 |
| 2006 | 686 | | 0 |
| 2007 | 1,000 | | 0 |
| 2008 | 428 | 5 | 1 |
| 2009 | 434 | 14 | 3 |
| 2010 | 168 | 16 | 10 |
| 2011 | 37 | 3 | 8 |
| 2012 | 143 | 5 | 3 |
| 2013 | 162 | 21 | 13 |
| 2014 | 197 | 18 | 9 |
| 2015 | 176 | 16 | 9 |
| 2016 | 214 | 44 | 21 |
| 2017 | 464 | 81 | 17 |
| 2018 | 198 | 73 | 37 |
| 2019 | 468 | 172 | 37 |
| 2020 | 579 | 193 | 33 |
| 2021 | 655 | 283 | 43 |

[+] Spotted seatrout release citations (fish released greater than 24 inches total length) began in 2008.

Table 3: Mean, minimum, and maximum lengths (fork length, inches) of spotted seatrout measured from the commercial and recreational fisheries, 1991–2021.

| Year | Commercial | | | | Recreational | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean Length | Minimum Length | Maximum Length | Total Number Measured | Mean Length | Minimum Length | Maximum Length | Total Number Measured |
| 1991 | 14.4 | 7.7 | 28.7 | 1,207 | 15.1 | 4.9 | 31.9 | 745 |
| 1992 | 16.0 | 8.4 | 27.9 | 1,791 | 15.6 | 5.1 | 24.2 | 543 |
| 1993 | 16.3 | 8.5 | 29.7 | 1,898 | 15.7 | 9.3 | 25.0 | 485 |
| 1994 | 15.6 | 7.0 | 29.1 | 1,224 | 16.0 | 10.6 | 24.0 | 1,076 |
| 1995 | 17.1 | 8.5 | 29.1 | 2,728 | 15.6 | 8.5 | 31.6 | 853 |
| 1996 | 16.0 | 7.0 | 27.6 | 748 | 14.6 | 8.9 | 24.3 | 307 |
| 1997 | 14.9 | 8.1 | 29.9 | 4,155 | 15.3 | 8.9 | 23.1 | 622 |
| 1998 | 14.5 | 8.0 | 29.9 | 4,698 | 16.4 | 11.0 | 36.5 | 551 |
| 1999 | 15.6 | 7.6 | 30.2 | 6,167 | 16.4 | 11.6 | 26.8 | 699 |
| 2000 | 17.5 | 6.0 | 30.7 | 2,901 | 15.6 | 11.3 | 25.2 | 330 |
| 2001 | 16.3 | 7.6 | 30.7 | 1,595 | 14.8 | 11.5 | 26.0 | 326 |
| 2002 | 16.1 | 8.0 | 28.9 | 3,897 | 14.9 | 11.8 | 24.8 | 283 |
| 2003 | 17.2 | 9.5 | 29.6 | 2,305 | 14.6 | 9.9 | 25.0 | 130 |
| 2004 | 16.6 | 9.0 | 27.9 | 2,676 | 15.3 | 8.9 | 22.5 | 294 |
| 2005 | 16.8 | 8.5 | 27.5 | 2,429 | 14.2 | 8.7 | 25.2 | 664 |
| 2006 | 16.3 | 8.9 | 29.3 | 6,493 | 15.5 | 10.1 | 25.9 | 706 |
| 2007 | 17.3 | 9.6 | 31.0 | 8,455 | 15.9 | 10.8 | 27.7 | 521 |
| 2008 | 17.0 | 7.3 | 30.3 | 5,877 | 15.6 | 11.5 | 26.5 | 790 |
| 2009 | 16.7 | 5.4 | 29.5 | 6,631 | 16.0 | 9.1 | 26.0 | 779 |
| 2010 | 17.5 | 11.4 | 30.9 | 4,060 | 17.5 | 12.4 | 24.8 | 336 |
| 2011 | 16.6 | 8.8 | 27.8 | 1,274 | 17.0 | 12.3 | 24.2 | 638 |
| 2012 | 16.5 | 7.4 | 31.1 | 4,822 | 16.5 | 13.0 | 24.1 | 939 |
| 2013 | 16.7 | 8.7 | 28.5 | 6,144 | 16.8 | 10.1 | 23.5 | 865 |
| 2014 | 17.3 | 5.5 | 28.3 | 3,321 | 17.6 | 13.1 | 26.0 | 381 |
| 2015 | 18.3 | 8.9 | 30.9 | 2,676 | 16.9 | 12.8 | 25.0 | 154 |
| 2016 | 17.3 | 9.4 | 31.7 | 3,025 | 16.8 | 13.0 | 25.2 | 647 |
| 2017 | 17.6 | 7.6 | 32.9 | 3,066 | 17.0 | 11.6 | 25.8 | 864 |
| 2018 | 17.2 | 10.5 | 28.0 | 1,180 | 15.7 | 9.3 | 23.3 | 274 |
| 2019 | 17.3 | 10.1 | 28.9 | 2,622 | 16.7 | 10.7 | 24.6 | 1,574 |
| 2020 | 17.5 | 10.9 | 33.4 | 2,851 | 17.0 | 12.1 | 26.8 | 1,119 |
| 2021 | 17.5 | 10.9 | 29.9 | 3,432 | 17.0 | 11.1 | 26.5 | 1,019 |

Table 4: Modal age, minimum age, maximum age, and number aged for spotted seatrout collected through NCDMF sampling programs, 1991–2021

| Year | Modal Age | Minimum Age | Maximum Age | Total Number Aged |
|---|---|---|---|---|
| 1991 | 1 | 0 | 7 | 679 |
| 1992 | 1 | 0 | 6 | 572 |
| 1993 | 1 | 0 | 6 | 645 |
| 1994 | 1 | 0 | 9 | 688 |
| 1995 | 1 | 0 | 5 | 623 |
| 1996 | 1 | 0 | 6 | 734 |
| 1997 | 1 | 0 | 6 | 710 |
| 1998 | 1 | 0 | 9 | 765 |
| 1999 | 1 | 0 | 6 | 869 |
| 2000 | 1 | 0 | 7 | 566 |
| 2001 | 1 | 0 | 5 | 425 |
| 2002 | 1 | 0 | 7 | 713 |
| 2003 | 1 | 1 | 7 | 405 |
| 2004 | 1 | 0 | 6 | 598 |
| 2005 | 1 | 0 | 5 | 727 |
| 2006 | 1 | 0 | 8 | 970 |
| 2007 | 2 | 0 | 8 | 702 |
| 2008 | 1 | 0 | 7 | 616 |
| 2009 | 2 | 0 | 6 | 660 |
| 2010 | 1 | 0 | 6 | 623 |
| 2011 | 1 | 0 | 6 | 421 |
| 2012 | 1 | 0 | 5 | 593 |
| 2013 | 2 | 0 | 5 | 635 |
| 2014 | 1 | 0 | 7 | 530 |
| 2015 | 2 | 0 | 5 | 448 |
| 2016 | 1 | 0 | 5 | 456 |
| 2017 | 1 | 0 | 7 | 881 |
| 2018 | 1 | 0 | 5 | 516 |
| 2019 | 1 | 0 | 8 | 1,167 |
| 2020 | 2 | 0 | 5 | 634 |
| 2021 | 1 | 0 | 6 | 1,006 |

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Table 5: Summary of the NCMFC management strategies and their implementation status for the 2012 N.C. Spotted Seatrout FMP.

| Management Strategy | Implementation Status |
|---|---|
| 50% reduction in harvest needed, six fish bag limit, 14-inch minimum size limit, and weekend closure for commercial gears year-round (no possession on weekends). | Accomplished; Proclamation authority |
| A maximum of two fish over 24 inches for recreational fishermen | Proclamation authority |
| The small mesh gill net attendance requirement is extended to include weekends, December through February | Accomplished |
| Development of a mutual aid agreement between NCDMF Marine Patrol and WRC Wildlife Enforcement Officers for Inland fishing waters | Accomplished |
| Move forward with the mediation policy process to resolve conflict between spotted seatrout fishermen | Conflict resolution process established under Rule 15A NCAC 03I .0122. |
| Remain status quo with the assumption that the Director will intervene in the event of a catastrophic event and do what is necessary in terms of temporary closures by water body | Repealed Rule 15A NCAC 03M .0504 and used proclamation authority in 15A NCAC 03M .0512; Beginning in May 2017 re-established spotted seatrout Rule 15A NCAC 03M .0522 due to ASMFC considering retiring Interstate Spotted Seatrout FMP |
| More extensive research on cold stun events by NCDMF, Universities, etc. | Preliminary research accomplished (Ellis et al. 2017a, 2017b), additional work ongoing. |

Table 6: Summary of the NCMFC management strategies and their implementation status for Supplement A to the 2012 N.C. Spotted Seatrout FMP adopted in 2014.

| Management Strategy | Implementation Status |
|---|---|
| 2014: 14-inch minimum size limit, four recreational bag limit, 75 fish commercial trip limit, no gill nets in joint waters on weekends, unlawful for a commercial operation to possess or sell spotted seatrout taken from joint waters on weekends. | Proclamation authority |
| 2014: 14-inch minimum size limit, three fish recreational bag limit with a December 15- January 31 closure, 25 fish commercial trip limit (no closure) | Delay in management strategy |
| If a cold stun occurs close spotted seatrout harvest through June 1 and retain four fish recreational bag limit and 75 fish commercial trip limit | Proclamation authority |
| Revisit the Spotted Seatrout FMP in three years to determine if sustainable harvest measures are working | On schedule to begin July 2017* |

* The NCMFC approved the 2017 FMP schedule in August 2017, which included a schedule change for spotted seatrout to begin in 2019, two years later than originally planned.

## FIGURES

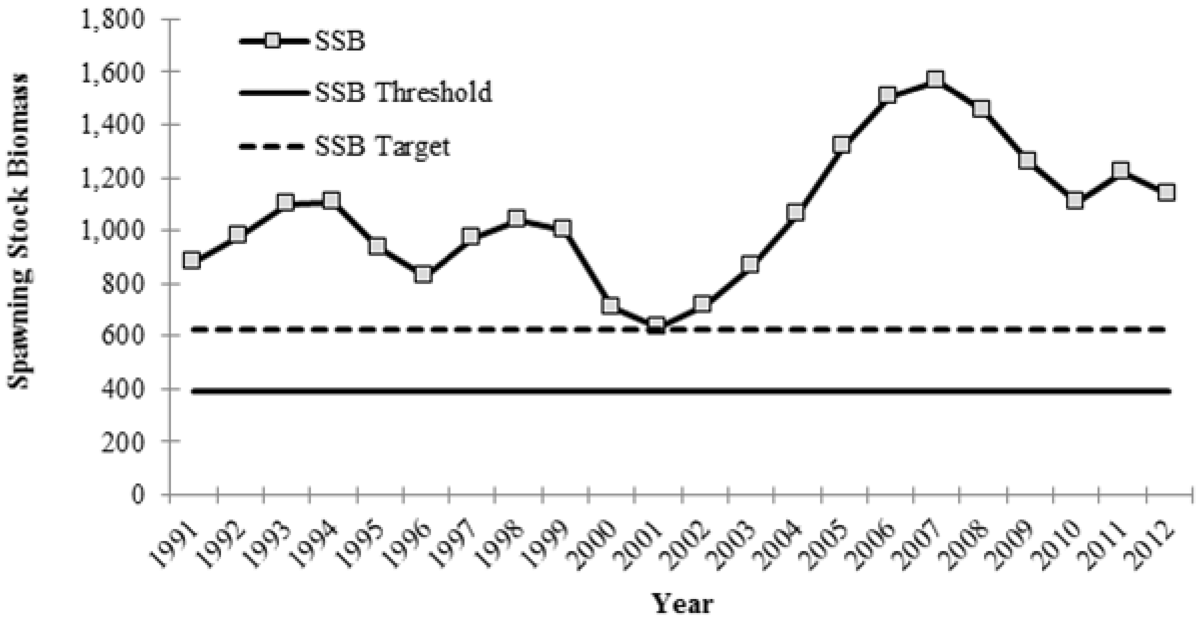


Figure 1. Annual predicted spawning stock biomass in metric tons, compared to estimated $SSB_{Threshold}$ ($SSB_{20\%}$) and $SSB_{Target}$ ($SSB_{30\%}$), 1991–2012. 2012 is the terminal year for the last spotted seatrout stock assessment (NCDMF 2015b).

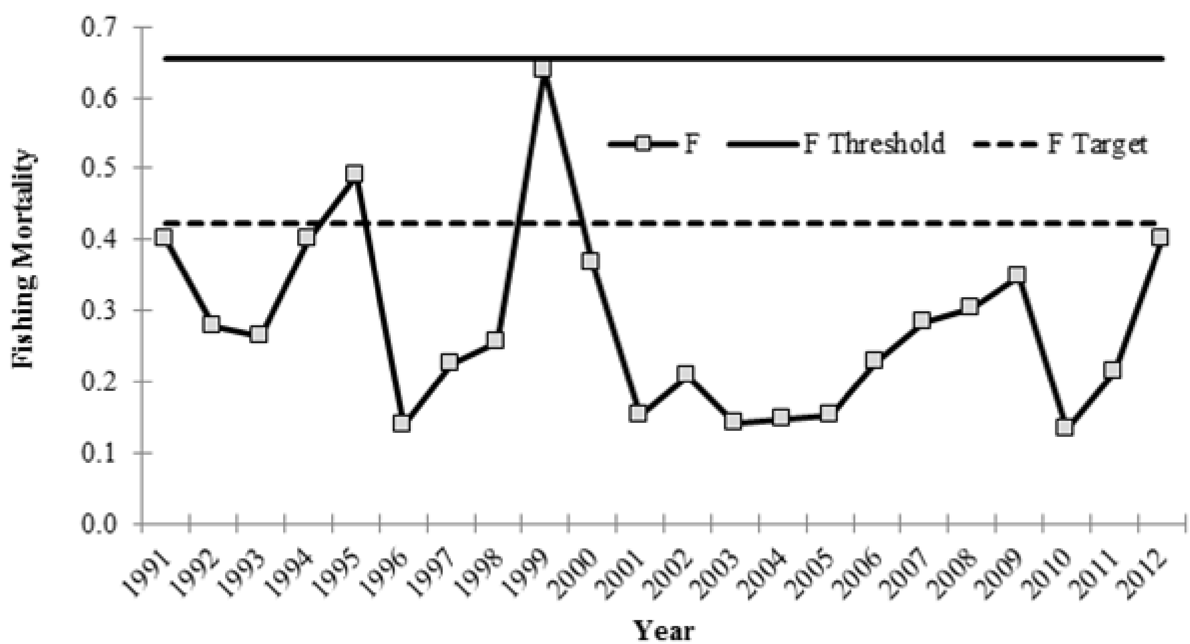


Figure 2. Annual predicted fishing mortality rates (numbers-weighted, ages 1–4) compared to estimated $F_{Threshold}$ ($F_{20\%}$) and $F_{Target}$ ($F_{30\%}$), 1991–2012. 2012 is the terminal year for the last spotted seatrout stock assessment (NCDMF 2015b).

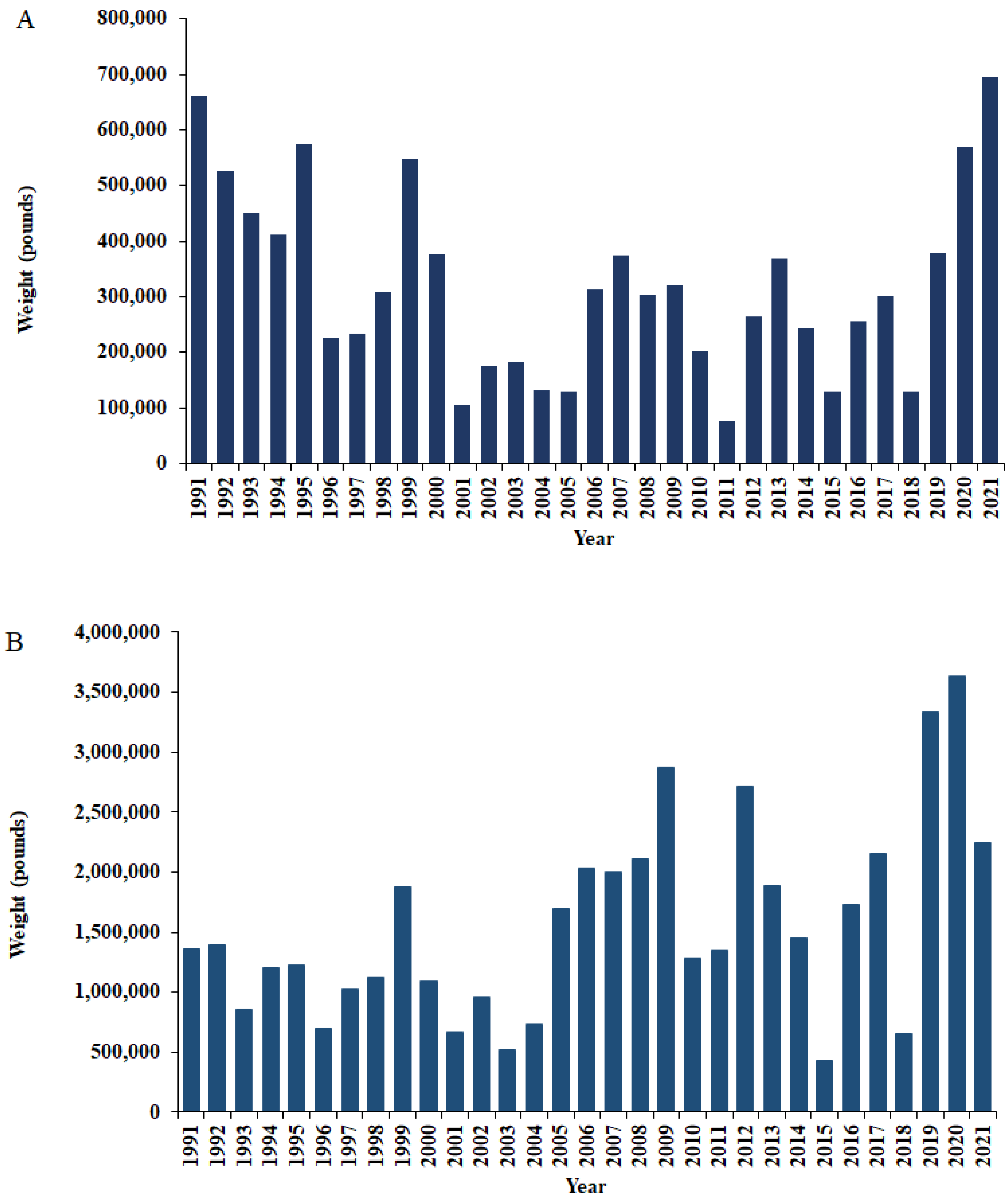


Figure 3. Commercial landings (pounds) reported through the North Carolina Trip Ticket Program (A) and recreational landings (Type A + B1; pounds) estimated from the Marine Recreational Information Program survey (B) for North Carolina, 1991–2021.

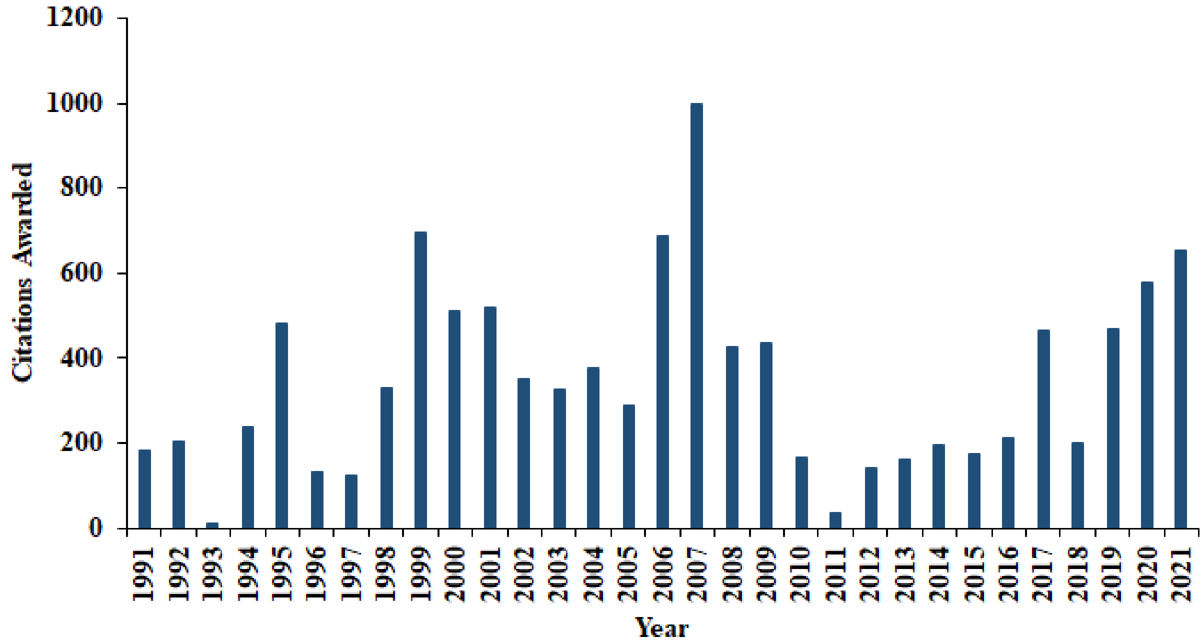


Figure 4. North Carolina Saltwater Fishing Tournament citations awarded for spotted seatrout, 1991–2021. Citations are awarded for spotted seatrout >24 inches total length for release or > five pounds landed.

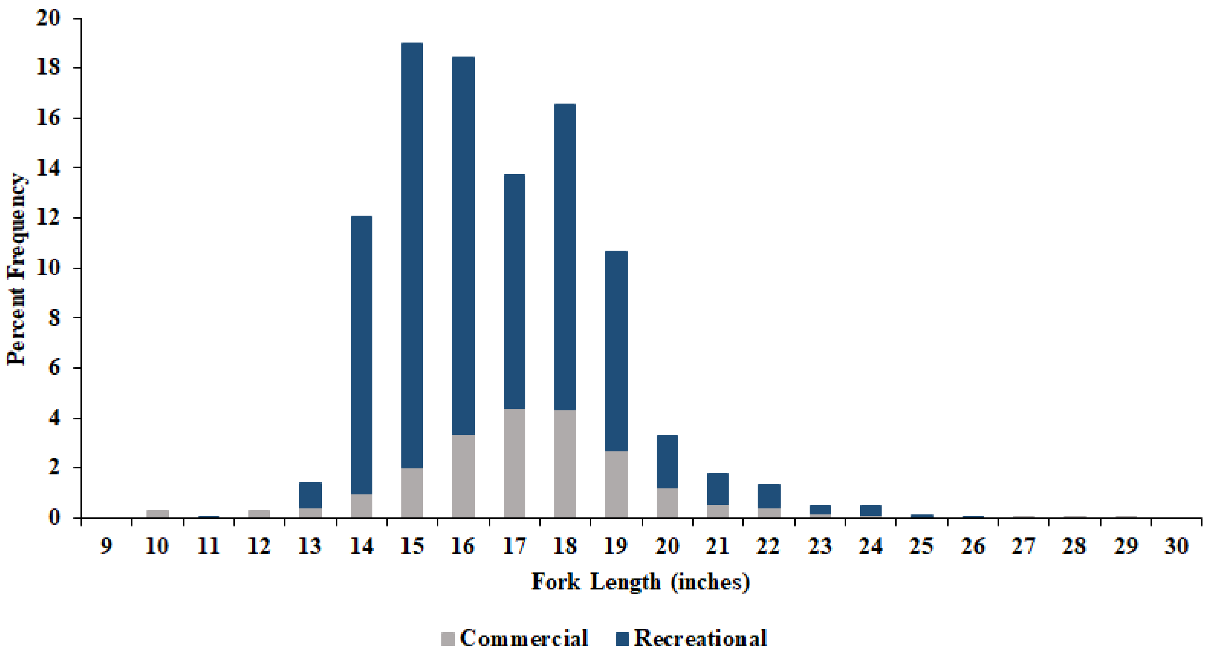


Figure 5. Commercial and recreational length frequency distribution from spotted seatrout harvested in 2021.

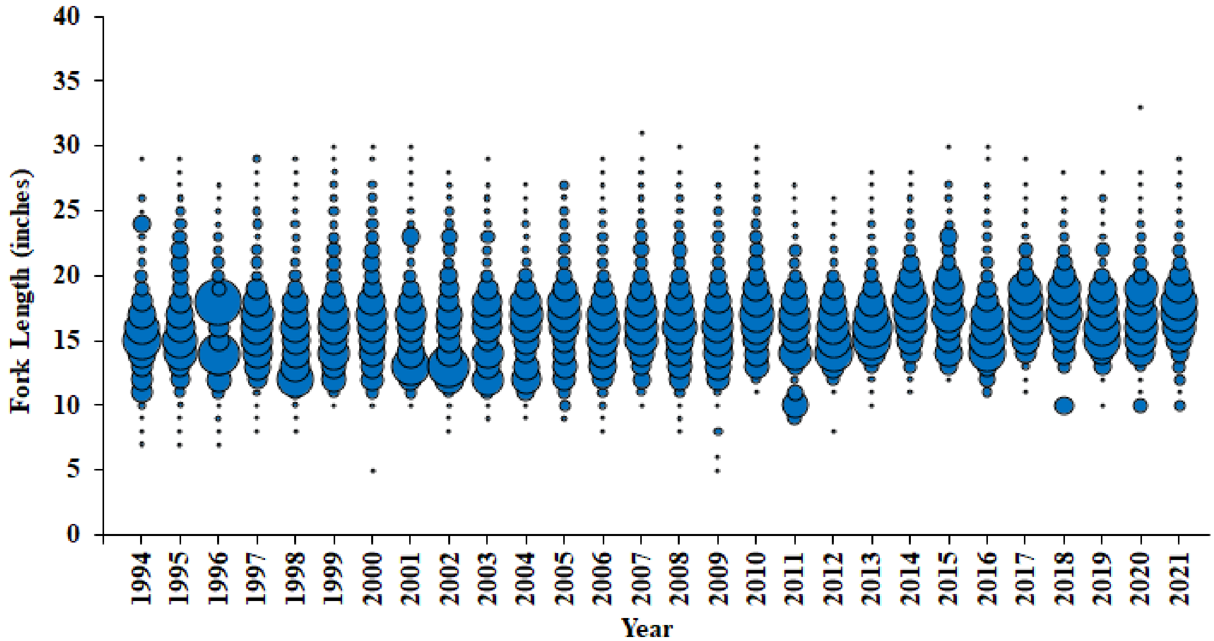


Figure 6. Commercial length frequency (fork length, inches) of spotted seatrout harvested, 1994–2021. Bubbles represent fish harvested at length and the size of the bubble is equal to the proportion of fish at that length.

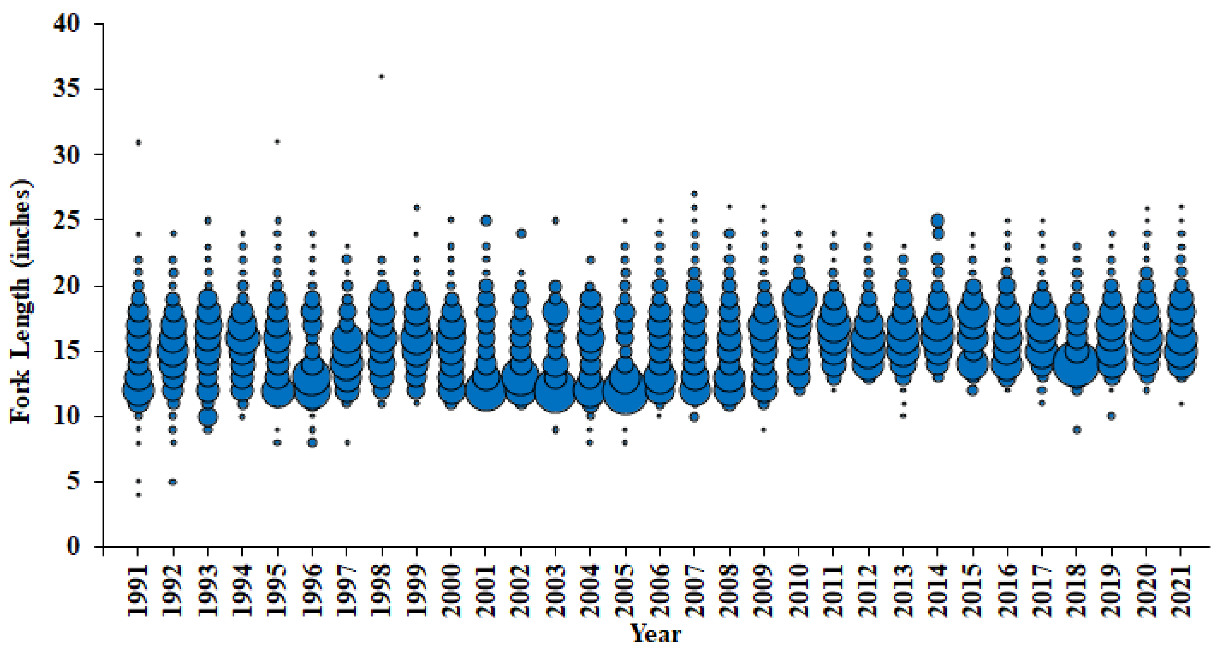


Figure 7. Recreational length frequency (fork length, inches) of spotted seatrout harvested, 1991–2021. Bubbles represent fish harvested at length and the size of the bubble is equal to the proportion of fish at that length.

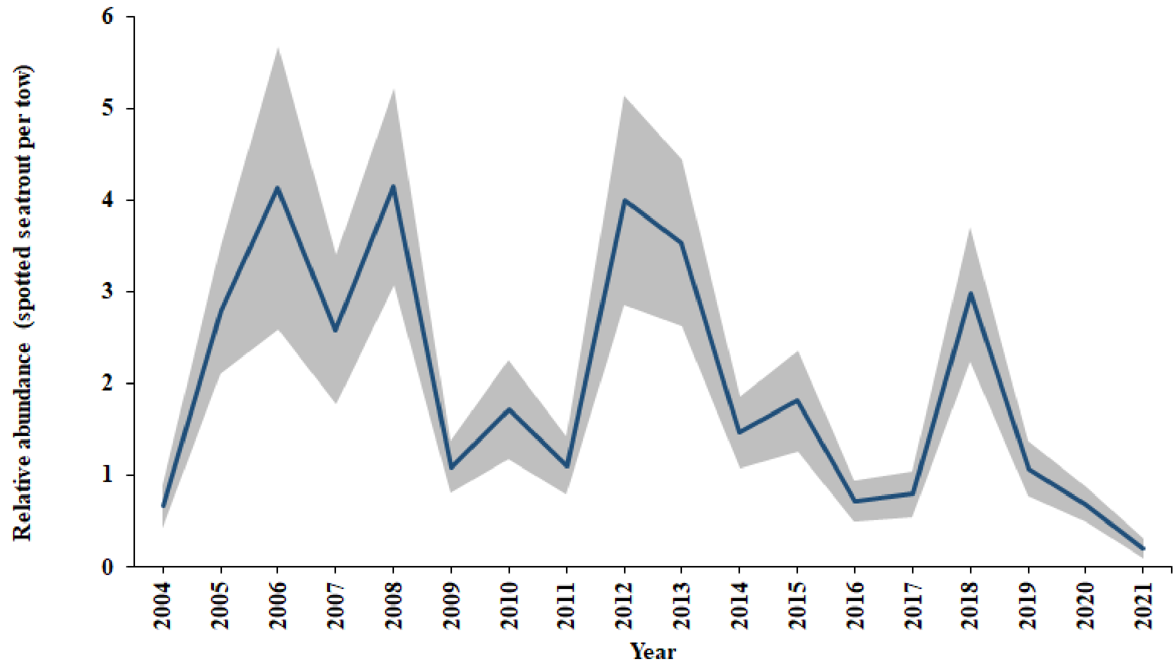


Figure 8. Relative abundance index (fish per tow) from the North Carolina Estuarine Trawl Survey (Program 120) during June and July, 2004–2021. Error bars represent ± 1 standard error.

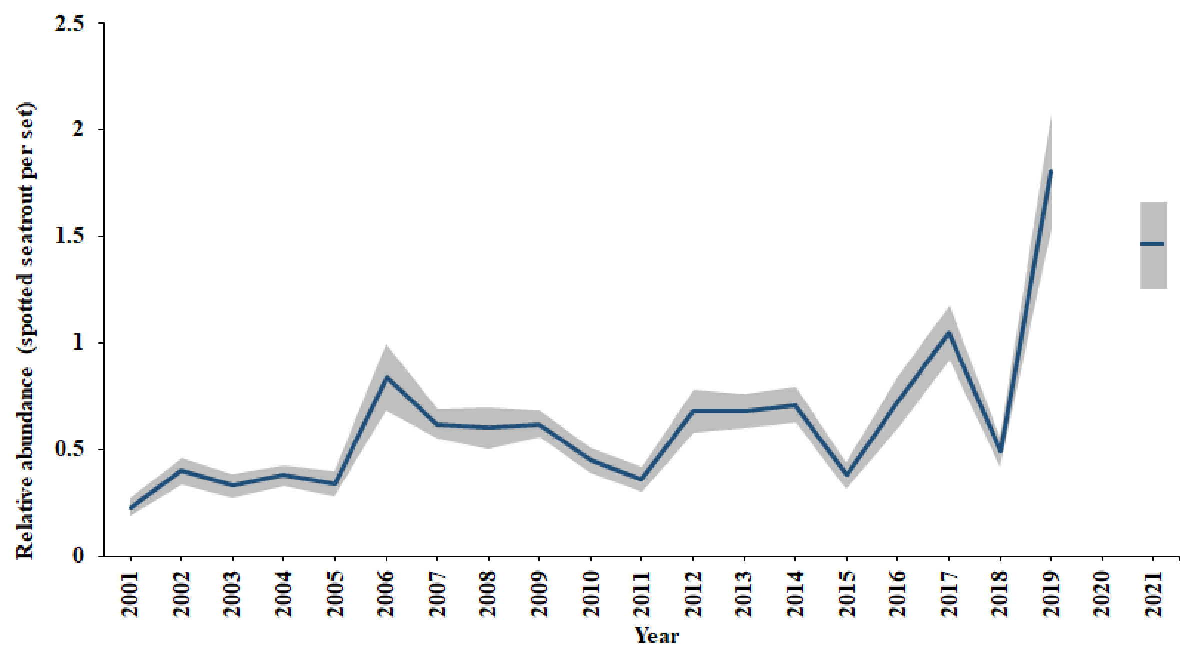


Figure 9. Relative abundance index (fish per set) of spotted seatrout collected from Program 915 in Pamlico Sound, 2001–2021. Error bars represent ± 1 standard error. Sampling not conducted in 2020.

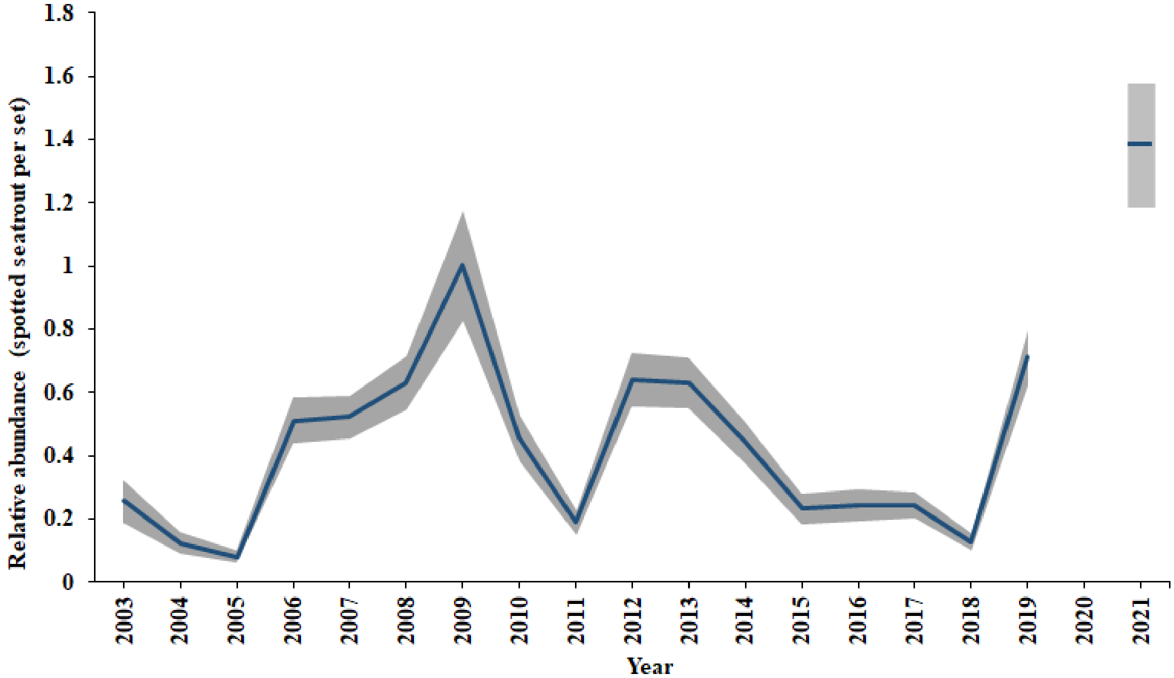


Figure 10. Relative abundance index (fish per set) of spotted seatrout collected from Program 915 in Pungo, Pamlico, and Neuse rivers, 2004–2021. Error bars represent ± 1 standard error. Sampling not conducted in 2020.

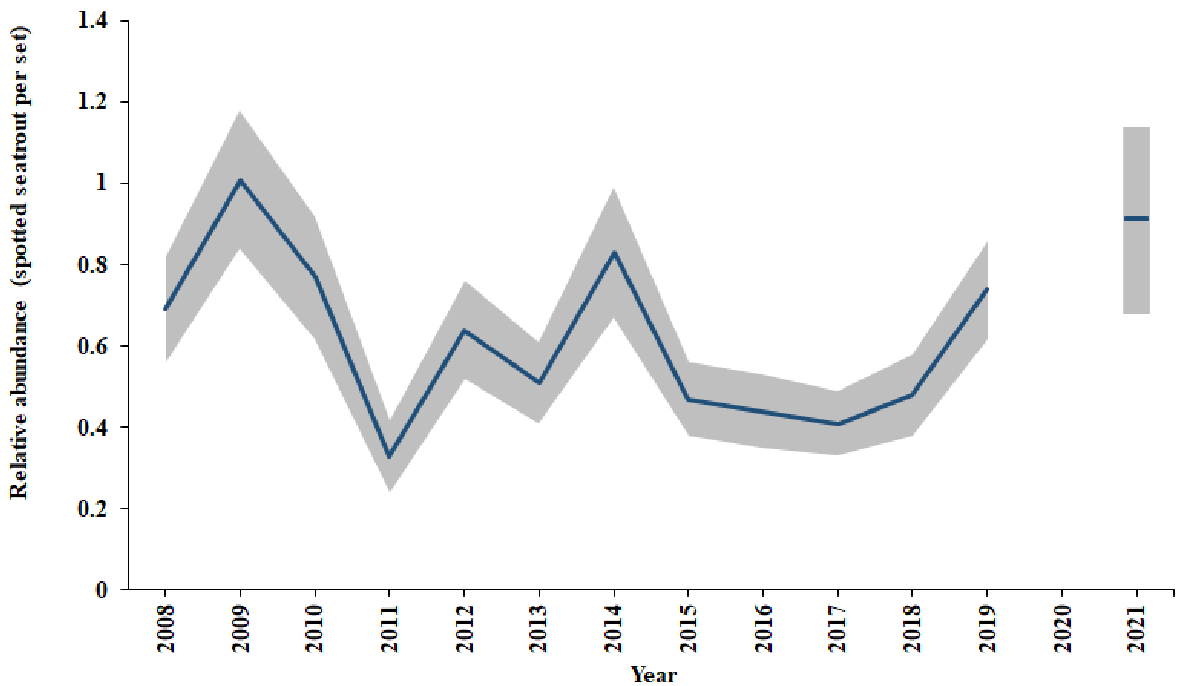


Figure 11. Relative abundance index (fish per set) of spotted seatrout collected from Program 915 in New and Cape Fear rivers, 2008–2021. Error bars represent ± 1 standard error. Sampling not conducted in 2020.

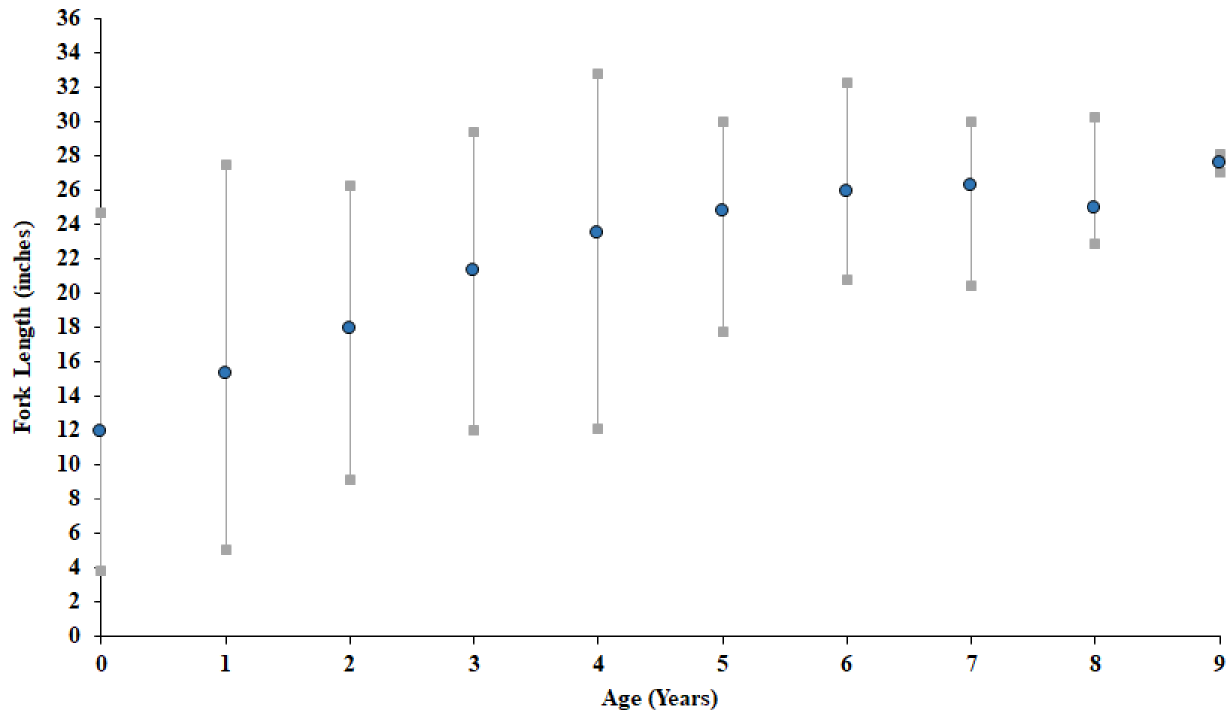


Figure 12. Spotted seatrout length at age based on all age samples collected from 1991 to 2020. Blue circles represent the mean size at a given age while the grey squares represent the minimum and maximum observed size for each age.

# Stock Assessment of Spotted Seatrout, *Cynoscion nebulosus*, in Virginia and North Carolina Waters, 1991–2019


*Prepared by*

North Carolina Division of Marine Fisheries
Spotted Seatrout Plan Development Team



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## ACKNOWLEDGMENTS

We would like to thank the Spotted Seatrout Plan Development Team (PDT) for their contributions to the development of the stock assessment. Members of the PDT for the current assessment are David Behringer (co-lead), Tracey Bauer (co-lead), Alan Bianchi, Andrew Cathey, Matt Damiano (NCSU), Tim Ellis (APNEP), Zach Harrison, Neil Kendrick, Yan Li (lead analyst), Brooke Lowman (VMRC), Edward Mann, Anne Markwith, Lee Paramore, Lucas Pensinger (co-lead), Jason Rock (mentor), Ami Staples, Amanda Tong, and Jason Walsh. Thanks also to Steve Poland, NCDMF Fisheries Management Section Chief, and Corrin Flora, NCDMF Fishery Management Plan Coordinator.

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# EXECUTIVE SUMMARY

The North Carolina Fisheries Reform Act requires that fishery management plans be developed for the state's commercially and recreationally significant species to achieve sustainable harvest. Stock assessments are the primary tools used by managers to assist in determining the status of stocks and developing appropriate management measures to ensure their long-term viability.

A seasonal size-structured assessment model was applied to data characterizing commercial and recreational landings and discards, fisheries-independent survey indices, and biological data collected from 1991 through 2019. A nonstationary process was assumed for natural mortality and growth in the model. The seasonal time step and nonstationary natural mortality assumption allows for capturing the cold-stun signals that have been observed for Spotted Seatrout. Both the observed data and the model predictions suggest a shift in population dynamics around the year of 2004 when the survey index data became available. Lower fishing mortality and higher spawning stock biomass and recruitment with greater variation were predicted for the time period after 2004. This trend was also observed in the recreational landing and discards data, with higher values in the time period after 2004.

Reference point thresholds for the Spotted Seatrout stock were based on 20% spawner potential ratio (SPR). The estimated $F$ threshold $F_{20\%}$ was 0.60 per year, and the estimated terminal year (2019) $F$ was 0.75 per year. Thus, the estimated $F/F_{20\%}$ for 2019 is greater than one (1.3), suggesting the stock is currently experiencing overfishing. The estimated SSB threshold ($SSB_{20\%}$) for 2019 was 1,143 metric tons, and the estimated 2019 SSB was 2,259 metric tons. Therefore, the estimated $SSB/SSB_{20\%}$ for 2019 is greater than one (2.0), suggesting the stock is not currently overfished.

An independent, external peer review of this stock assessment recommended the stock assessment for use in management for at least the next five years.

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# 1 INTRODUCTION

## 1.1 The Resource

Spotted Seatrout (*Cynoscion nebulosus*), also known as Speckled Trout, are a euryhaline species found from Massachusetts to Mexico (Manooch 1984), inhabiting shallow coastal and estuarine waters throughout their range. Spotted Seatrout is a member of the family Sciaenidae (drums), which includes Weakfish (*C. regalis*), Spot (*Leiostomus xanthurus*), kingfishes or sea mullet (*Menticirrhus* spp.), Atlantic Croaker (*Micropogonias undulatus*), Black Drum (*Pogonias cromis*), and Red Drum (*Sciaenops ocellatus*). This family of fishes is highly sought after in commercial and recreational fisheries. Spotted Seatrout has two other species within its genus found in Virginia and North Carolina waters—Weakfish (Gray Trout) and Silver Seatrout (*C. nothus*). Spotted Seatrout can be distinguished from the other two species by the circular specks or spots on its body, dorsal fin, and caudal fin.

## 1.2 Life History

### 1.2.1 Stock Definitions

The unit stock for this assessment consists of all Spotted Seatrout within North Carolina and Virginia waters. Tagging studies in North Carolina and Virginia indicate moderate mixing between the two states (between 6 and 10%; Ellis 2014; NCDMF, unpublished data; Susanna Musick, Virginia Game Fish Tagging Program—VGFTP, personal communication). In contrast, tagging studies in North Carolina and South Carolina suggest Spotted Seatrout rarely move between the two states (<1%; Davy 1994; Ellis 2014; NCDMF, unpublished data). Several genetics studies have been completed in recent years that further investigated Spotted Seatrout stock structure in Virginia, North Carolina, and South Carolina (O'Donnell et al. 2014; Ellis et al. 2019). Overall, genetic data support a single unit stock in Virginia and North Carolina coastal waters (Ellis et al. 2019); however, studies by Ellis et al. (2019) and O'Donnel et al. (2014) both suggest Spotted Seatrout in the Cape Fear, North Carolina region are genetically distinct from Spotted Seatrout found in Bogue Sound, North Carolina northward through Virginia and the New River, North Carolina serving as an area of complex, seasonal mixing and connectivity between these two populations.

In this stock assessment, Spotted Seatrout occurring in the waters between the Cape Fear River and South Carolina state line are included because it is a relatively small area with a low percentage of the total landings (0.5–11.5% of total North Carolina and Virginia landings from 1994 to 2019; NCDMF, unpublished data) and the available tagging data suggest extremely limited movement of Spotted Seatrout between North and South Carolina.

### 1.2.2 Movements & Migration

As with many estuarine and marine fish in North Carolina, Spotted Seatrout have distinct seasonal migrations. During the winter, Spotted Seatrout migrate to relatively shallow habitats of upper estuaries (Ellis 2014; Ellis et al. 2017b). As the waters warm in the summer, Spotted Seatrout return to oyster beds and shallow bays and flats (Daniel 1988). Movement rates and distance traveled is greatest in spring and fall (Ellis 2014; Moulton et al. 2017). Although Spotted Seatrout seasonally migrate, movements north in the spring and southern movements in the fall, Spotted Seatrout have considerable residency based on tag return studies, with most individuals usually traveling less than 50 km (Music 1981; Brown-Peterson et al. 2002; Ellis 2014; Moulton et al. 2017; Loeffler et al. 2019).

A coast-wide stock assessment of Spotted Seatrout has not been conducted given the largely non-migratory nature of the species (ASMFC 2008). Instead, a list of goals for coast-wide management exist to help guide states that have an interest in the Spotted Seatrout fishery so they can manage their stocks independently (ASMFC 1990).

South Carolina, Virginia, and North Carolina have long-term tagging studies of Spotted Seatrout. South Carolina tagged fish from 1978 to 2009 and less than 1% were recaptured in North Carolina or Virginia (Davy 1994; Wenner and Archambault 1996; Wiggers 2010). Virginia has an ongoing tagging program; from 1995 to 2020, a total of 6.4% of the Spotted Seatrout tagged in Virginia were recaptured outside of the state (mostly in North Carolina, but ranging from Ocean City, Maryland to Savannah, Georgia; Susanna Musick, VGFTP, personal communication). Ellis et al. (2018) collected North Carolina tagging data from 2008 to 2014. Overall, a total of 86% (i.e., 452 fish) of the tagged fish that a recapture location was recorded for were recaptured in North Carolina and 14% (i.e., 71 fish) were recaptured in the Chesapeake Bay. The remaining 0.4% (i.e., two fish) were recaptured in South Carolina. Ellis' (2014) analysis of tagged fish indicated Spotted Seatrout are capable of migrating more than 180 km; however, the majority (56%) of movement based on tag returns is local (<20 km). North Carolina Division of Marine Fisheries' tagging data (2014–2020) indicates a similar pattern (NCDMF, unpublished data). The majority of fish tagged in North Carolina were recaptured in North Carolina waters (91%) although some fish were recaptured in the Chesapeake Bay (Maryland and Virginia waters, 8%) and South Carolina (1%).

### 1.2.3 Age & Size

Spotted seatrout can reach a maximum size of 1,003 mm (39.5 inches) and 7.92 kg (17.4 lb; FWC 2022). North Carolina's state record was a 5.67-kg (12-lb 8-ounce) fish caught in 2022. The annual average size of Spotted Seatrout landed in the North Carolina recreational fishery between 1991 and 2019 ranged from 361 to 447 mm (14.2 to 17.6 inches); in the commercial fishery, annual average length ranged between 366 and 465 mm (14.4 to 18.3 inches). The maximum observed length in North Carolina's recreational fishery was 927 mm (36.5 inches) while the maximum observed length in the commercial fishery was 836 mm (32.9 inches). The maximum otolith-based age of Spotted Seatrout has been reported to be 10 years old in Virginia (Ihde and Chittenden 2003), 9 years old in North Carolina, 9 years old in South Carolina (Wenner and Archambault 1996), 8 years old in Georgia (GACRD 2003), and 10 years old in Florida (Addis et al. 2018). Although the oldest individual Spotted Seatrout observed in many studies was male (Moffett 1961; Maceina et al. 1987; Colura et al. 1994; Murphy and Taylor 1994; DeVries et al. 1997), both female and male Spotted Seatrout have been aged up to age 9 in North Carolina.

Virginia's state record was a 7.26-kg (16-lb) fish caught in 1977. The annual average size of Spotted Seatrout landed in the Virginia recreational fishery between 1991 and 2019 ranged from 384 to 610 mm (15.1 to 24.0 inches) total length (TL). In the commercial fishery, annual average length ranged between 397 and 537 mm (15.6 to 21.2 inches) TL. The maximum observed length in Virginia's recreational fishery was 770 mm (30.3 inches) TL while the maximum observed length in the commercial fishery was 870 mm (34.3 inches) TL.

### 1.2.4 Growth

Following the first winter, male Spotted Seatrout attain an average of 246 mm (9.70 inches) in length and females reach an average of 325 mm (12.8 inches) in length (NCDMF, unpublished data). Smith et al. (2008) calculated a growth rate of 1.44 mm/day for juveniles in Chesapeake Bay, which is two to three times higher than growth rates reported in Florida (McMichael and Peters 1989; Powell et al. 2004). Growth rate begins to decrease with age in North Carolina reaching an asymptote by age 4. The predicted average maximum size for Spotted Seatrout in North Carolina is 671 mm (26.4 inches) for males and 775 mm (30.5 inches) for females.

Several studies have examined environmental effects on Spotted Seatrout growth. There is evidence of reduced metabolism of Spotted Seatrout at high temperatures and salinities (temperature-dependent), which may be accompanied by reduced activity and growth (Wuenshel et al. 2004); however, greater Spotted Seatrout growth has also been observed in habitats with both higher salinities and greater seagrass densities (Bortone et al. 2006). Similarly, refuge, better feeding success, and/or habitat complexity were found to be potentially important for relative growth of hatchery-reared late juvenile Spotted Seatrout; Hendon and Rakocinski (2016) found that relative growth of hatchery-raised Spotted Seatrout was significantly greater in submerged aquatic vegetation and non-vegetated shoreline habitats as compared to open water habitats.

#### 1.2.4.1 Age-Length

Available otolith-based annual age data (raw data) from both fisheries-dependent and fisheries-independent data sources in Virginia and North Carolina were fit with a von Bertalanffy age-length model. Data were subset for females (n=14,664) including unknown sex (n=708), males (n=9,014) including unknown sex (n=708), and sex-aggregated (24,386) including unknown sex (n=708). Length at age was modeled using the von Bertalanffy (1938) growth model as:

$$L_{i,j} = L_{\infty,j}\left(1 - \exp\left(-K_j\left(t_{i,j} - t_{0,j}\right)\right)\right)\exp\left(\varepsilon_{L,i,j}\right)$$

$$\varepsilon_{L,i,j} \sim N(0, \sigma^2_{L,j})$$

where $j$ indexes the sex, $L_i$ and $t_i$ are the fork length (mm) and age (fractional age in years) of individual $i$, respectively, and the parameters to be estimated were the asymptotic length $L_\infty$, the growth coefficient $K$, and the theoretical age at which a fish has a length of zero $t_0$. The length $L_{i,j}$ of individual fish sampled was assumed to follow a lognormal distribution.

A Bayesian hierarchical approach was used to estimate parameters with a hierarchical structure for priors on the growth parameters. Growth parameters $L_{\infty,j}$, $K_j$, and $t_{0,j}$ were assumed to vary by sex and the logarithm of sex-specific parameters were assumed to be multivariate normally distributed (*MVN*), and $t_{0,j}$ was assumed to follow a normal distribution controlled by sex-average parameters:

$$\begin{bmatrix} lnL_{\infty,j} \\ lnK_j \end{bmatrix} \sim MVN\left(\begin{bmatrix} ln\bar{L}_\infty \\ ln\bar{K} \end{bmatrix}, \Sigma\right),$$

$$t_{0,j} \sim N\left(\bar{t_0}, \sigma^2_{t_0}\right),$$

where $\bar{L}_\infty$, $\bar{K}$, and $\bar{t_0}$ are sex-average parameters with uniform distributions and the standard deviation $\sigma_{t_0}$ was also assumed to be uniformly distributed. The variance-covariance matrix Σ was modeled with an inverse-Wishart distribution (Gelman and Hill 2007) as:

$$\Sigma = \begin{bmatrix} \sigma^2_{L\infty} & \varphi \\ \varphi & \sigma^2_K \end{bmatrix},$$

where $\sigma_{L_\infty}$ and $\sigma_K$ are standard deviations of $lnL_\infty$ and $lnK$ across sexes and represent variability in growth between sexes; $\varphi$ is the covariance of $lnL_\infty$ and $lnK$ across sexes. High negative correlation of $L_\infty$ and $K$ have previously been observed in the von Bertalanffy growth model (Kimura 2008; Midway et al. 2015); therefore, in order to improve model convergence, $L_\infty$ and $K$ parameters were modeled jointly with a negative correlation.

Posterior distributions were obtained using the Metropolis-Hasting algorithm using Markov Chain Monte Carlo simulation (Hilborn et al. 1994; Hoff 2009). Three concurrent chains were run with a total of 100,000 iterations for each chain. The first 70,000 iterations were discarded as burn-in and every 10th of the remaining samples from each chain were saved for analysis. The Just Another Gibbs Sampler software (JAGS; version 4.3.0; JAGS Community Team 2021) was used to run the Bayesian analysis.

Estimates of $L_\infty$, $K$, and $t_0$ were within the range of estimates from previous studies (Table 1.1). Plots of the observed and predicted values from this study are shown in Figure 1.1.

### 1.2.4.2 Length-Weight

Parameters of the length-weight relationship were also estimated in this study. The relation of fork length in millimeters to weight in grams (raw data) was modeled for each sex separately based on data collected from both fisheries-dependent and fisheries-independent sources in Virginia and North Carolina. Data were subset as female (n=13,264), male (n=9,249), and sex-aggregated (n=50,612) for the weight-at-length modeling. Sex-aggregated data included unknown sex (n=28,099). Modeling was performed using non-linear least squares. Weight at length was modeled as:

$$W_i \sim a * L_i{}^b$$

where $W_i$ and $L_i$ are the weight (g) and length (mm) of individual $i$, respectively, and $a$ and $b$ are estimated parameters.

The estimated parameters from this and previous studies are presented in Table 1.2. Plots of the observed and predicted values from this study are shown in Figures 1.2–1.4.

### 1.2.5 Reproduction

The spawning season for Spotted Seatrout varies depending on location (Texas: Brown-Peterson et al. 1988; Mississippi: Brown-Peterson et al. 2001; Gulf of Mexico estuaries: Brown-Peterson et al. 2002; South Carolina: Roumillat and Brouwer 2004; Florida: Lowerre-Barbieri et al. 2009) and peaks around the full moon (Tucker and Faulkner 1987; McMichael and Peters 1989). Virginia Spotted Seatrout spawn from May through August with peaks in the gonadosomatic index in May and July (Brown 1981). The spawning season in North Carolina is from April to October with a peak in May through June (Burns 1996). The spawning period is generally within the first few hours after sunset (Luczkovich et al. 1999). During this time Spotted Seatrout have been found to acoustically signal spawning using drums, grunts, and staccatos (Montie et al. 2017). During the peak of the season, older Spotted Seatrout (>3 years old) spawn approximately every two days while younger Spotted Seatrout (ages 0 and 1) spawn approximately every four days (Roumillat and Brouwer 2004), though spawning frequency can vary by location and time of year (Brown-Peterson et al. 2001, 2002).

Spawning takes place on or near seagrass beds, sandy banks, natural sand, shell reefs, near the mouths of inlets, and off the beach (Daniel 1988; Brown-Peterson et al. 2002). There is evidence that Spotted Seatrout individuals exhibit strong intra-seasonal and inter-annual spawning site fidelity (Lowerre-Barbieri et al. 2013; Zarada et al. 2019). Estimates of fecundity for Spotted Seatrout range from 3 to 20 million ova per year depending on age, length, and water temperature (Murphy et al. 1999; Nieland et al. 2002; Roumillat and Brouwer 2004; Lowerre-Barbieri et al. 2009); however, fecundity estimates specific to North Carolina and Virginia are not available at this time.

Temperature and salinity have an influence on the reproductive output of female Spotted Seatrout. Temperature and salinity in spawning areas can vary, with temperature ranging from 15 to 31°C and salinity ranging from 18 to 35 ppt (Brown-Peterson et al. 1988; McMichael and Peters 1989; Walters 2005). When water temperatures exceed 30°C, the spawning season can be reduced (Jannke 1971); however, more recent work determined salinity was the most probable factor for differences in spawning season, spawning frequency, and batch fecundity between Gulf of Mexico (GOM) estuaries, particularly low salinity may shorten spawning seasons and decrease spawning frequency and batch fecundity (Brown-Peterson et al. 2002).

The previous North Carolina Division of Marine Fisheries (NCDMF) stock assessment of Spotted Seatrout (NCDMF 2015) applied maturity parameters derived from macroscopic analysis of reproductive tissues. Because this approach relies on visual examination, it is considered subjective and can lead to inaccurate estimates of maturation, which, in turn, can lead to biased estimates of both spawning stock biomass and associated reference points as well as distorting the stock-recruitment relationship (Murawski et al. 2001; Morgan 2008). The NCDMF conducted a maturity study using three different maturity staging methods (macroscopic, whole mount, and histological) to estimate the maturity ogive for Spotted Seatrout and other species in order to improve the accuracy of NCDMF management targets and assessments of fishery stock viability (NCDMF 2021). The histological method is considered more objective, accurate, and reliable of the three approaches (e.g., Vitale et al. 2006; Midway and Scharf 2012). Logistic regression was applied to the maturity samples from female Spotted Seatrout to estimate the length at 50% maturity ($L_{50}$) and slope. Based on the histological data, the value of $L_{50}$ for females was estimated as 251 mm and the estimated slope was -0.192 (Figure 1.5).

### 1.2.6 Mortality

#### 1.2.6.1 Natural Mortality

Natural mortality rates are highly variable and are influenced by multiple factors including severe temperatures during the winter months when cold stun events are known to occur and have been documented throughout their range (de Silva, unpublished data; Perret et al. 1980; Johnson and Seaman 1986). Water temperatures below 5°C should trigger concern (Anweiler et al. 2014; Ellis et al. 2017a) as kill events have been found to have population-level impacts (Ellis et al. 2017a, 2018). Spotted seatrout lose equilibrium at ≤ 4°C with no survival after prolonged exposure to 3°C (Ellis at al. 2017a).

Ellis et al. (2018) conducted the first comprehensive Spotted Seatrout conventional tag-return study in North Carolina waters with the objective of quantifying mortality and movement. Estimates of bimonthly natural mortality ranged from 0.062 to 2.5 and varied by season, while annual estimates of natural mortality ranged from 1.1 to 3.8. Ellis et al. (2018) found natural mortality was responsible for 49%–97% of total mortality based on bimonthly estimates and 81% to 92% of total mortality based on annual estimates. The importance of natural mortality compared to fishing mortality was further supported by an acoustic telemetry study. Natural mortality was generally highest during periods of cold temperatures when water temperatures were below 5°C. Estimates of *M* from Ellis et al. (2017b) and Ellis et al. (2018) were particularly high during the winters of 2009/2010 and 2010/2011, periods which coincided with reports of cold-stunned Spotted Seatrout following rapid decreases in temperature throughout the state.

The tag-return model described by Ellis et al. (2018) was adapted to fit to data obtained from two-independent tagging experiments to estimate seasonal natural mortality (Myers and Hoenig 1997; Bacheler et al. 2010). The model was implemented using R statistical software (R Core Team 2021) and JAGS (JAGS Community Team 2021) and fit to tag/recapture data from experiments performed by North Carolina State University (NCSU) during 2008 through 2012 and by the NCDMF during 2014 through 2021. A three-month season time step was used, meaning each year was separated into four seasons: a spring season from March 1st to May 31st, a summer season from June 1st to August 31st, an autumn season from September 1st to November 30th, and a winter season from December 1st to February 28th/29th. Although there was only interest in estimates through February 2020, tag release data from March 2020 to February 2021 were included in the model to lower uncertainty in the final time steps of interest (i.e., the model structure allows for data input from tag-return matrices with more tag-recovery periods than tag-release periods).

Seasonal estimates of median natural mortality (*M*) with 95% lower and upper credibility intervals were obtained for autumn 2008 through winter 2019 (Table 1.3; Figure 1.6). Estimates from winter 2012 to summer 2014 (i.e., the greyed-out time steps in Table 1.3) were disregarded because no tags were released during these time steps. Median estimated *M* ranged from 0.0015 in summer 2017 to 2.4 in autumn 2010 and peaks generally occurred during the winter season, especially during years of known cold stuns (model years 1995, 1999, 2000, 2002, 2004, 2009, 2010, 2013, 2014, 2017). The overall pattern of season *M* was generally similar to the results of Ellis et al. (2018) and aligned with the working groups expectations based on knowledge of cold stun years; however, estimates of *M* in some non-winter seasons were larger than expected (autumn 2010, spring 2012, spring 2017, autumn 2018, and spring 2019). The working group suspects two potential causes: (1) if tag returns occur at a lag, the model becomes less certain as to what season mortality should be assigned and (2) mortality events unrelated to cold stuns can occur from other environmental impacts (e.g., hurricanes and associated poor water quality; Paerl et al. 1998). In one specific instance, the high natural mortality estimate in autumn 2010 is most likely reflective of confirmed high natural mortality in winter 2010 due to a severe cold stun event in December 2010 (Ellis et al. 2018). This error occurred because a large number of tags were released in November 2010 (the autumn time step in this model is September to November) and subsequently were never recaptured. This led the model to conclude there was high mortality in autumn 2010 instead of winter 2010. Overall, credibility intervals were also wider than expected. Sources of uncertainty in the model estimates include multiple time steps in which very few tags were released and allowing the model to assume similar tag loss rates and reporting rates among commercial and recreational sectors between NCSU and the NCDMF data when they most likely differ.

### 1.2.6.2 Discard Mortality

*Commercial*

A study in North Carolina (Price and Gearhart 2002) and one in Florida (Murphy et al. 1995) have examined Spotted Seatrout discard mortality associated with commercial small mesh gill nets. Spotted seatrout total discard mortality (at-net plus delayed mortality) in gill nets as reported by Price and Gearhart (2002) were between 66% and 90% depending on mesh size (Table 1.4), whereas Murphy et al. (1995) saw average discard mortalities between 10% and 69% depending on temperature and soak time. In addition, Price and Gearhart (2002), Murphy et al. (1995), and additional NCDMF data from the NCDMF Fisheries-Independent Gill-Net Survey (Program 915; NCDMF 2012a) show that time of year may be a significant factor affecting discard mortality of Spotted Seatrout (Tables 1.5 and 1.6). Mortalities appear higher during spring/summer when water temperatures are warmer and dissolved oxygen levels are lower compared to the fall/winter months. Price and Gearhart (2002) also found differences in delayed mortality between high salinity sites and low salinity sites (Table 1.7).

For the current stock assessment, a commercial discard mortality rate of 30% was assumed because a majority of the Spotted Seatrout commercial effort and landings occur in the late fall and winter when water temperatures are cooler and dissolved oxygen may be higher.

*Recreational*

Recreational release mortality is likely a significant source of mortality on Spotted Seatrout in North Carolina since Type B2 releases (unobserved or reported live releases) have accounted for an increasing percentage of the overall catch in recent years (between 74 and 97% in the past ten years; National Marine Fisheries Service Fisheries Statistics Division, personal communication). Several hook-and-line release mortality studies have been conducted on Spotted Seatrout throughout the Atlantic and Gulf coasts where estimates of mortality ranged from 4.6% up to 56% (Duffy 1999; Duffy 2002; Gearhart 2002; Hegen et al. 1983; Matlock and Dailey 1981; Matlock et al. 1993; Murphy et al. 1995; Stunz and McKee 2006; Brown 2007; Table 1.8).

Two of the studies were conducted by NCDMF in North Carolina waters: Gearhart (2002) found a hooking mortality rate of 15%, whereas Brown (2007) arrived at a rate of 25%. It was noted that Brown (2007) was limited geographically to the Neuse River and most likely had an inflated release mortality rate due to low dissolved oxygen in the holding pens resulting in deaths not associated with hooking. In comparison, Gearhart (2002) covered a wider geographic range in North Carolina at river (low salinity) and Outer Banks (high salinity) sites from Pamlico, Core, and Roanoke sounds between June 2000 and August 2001. Gearhart (2002) suggested applying separate release mortality rates to fish caught in low versus high salinity areas instead of using the overall release mortality rate, which potentially may overestimate release mortality.

For the current stock assessment, separate rates were applied to fish caught in low versus high salinity areas based on Marine Recreational Information Program (MRIP) data from 1991 through 2019 (see section 2.1.3.5). The MRIP estimates could not be directly separated into regions based on salinity; therefore, raw intercept data from the MRIP survey were used to calculate a ratio of observed catch based on county of landing in low salinity areas (Pamlico, Craven, Hyde, Beaufort, and Currituck counties) versus high salinity areas (Dare, Carteret, Onslow, Pender, New Hanover, and Brunswick counties). The total catch was weighted by the unadjusted mortality rates for low (19.4%) and high (7.3%) salinity sites as reported by Gearhart (2002) and divided by the combined total catch to obtain an overall release mortality rate of 10%. This rate is consistent with the rates used in the previous two Spotted Seatrout stock assessments in North Carolina (Jenson 2009; NCDMF 2015) and Spotted Seatrout stock assessments from South Carolina (Zhao and Wenner 1995), Georgia (Zhao et al. 1997), Florida (Addis et al. 2018), Alabama (Bohaboy et al. 2018), and Louisiana (West et al. 2014).

### 1.2.7 Food & Feeding Habits

Spotted seatrout have ontogenetic changes in their diet (Holt and Holt 2000). Spotted seatrout less than 38 mm consume copepods as the primary prey. Fish between 38 and 140 mm consume mysids, amphipods, polychaetes, and shrimp. These juvenile Spotted Seatrout have considerable dietary overlap with juvenile Red Drum and tend to inhabit similar areas (Powers 2012; Holt and Holt 2000). Spotted seatrout larger than 140 mm become one of the top predators in estuaries where they feed on a variety of fishes and shrimp (Daniel 1988; McMichael and Peters 1989; Binion-Rock 2018; Binion-Rock et al. 2019).

## 1.3 Habitat

### 1.3.1 Overview

Spotted seatrout make use of a variety of habitats during their life history with variations in habitat preference due to location, season, and ontogenetic stage. Although primarily estuarine, Spotted Seatrout use habitats throughout estuaries and occasionally the coastal ocean. Spotted seatrout are found in most habitats identified by the North Carolina Coastal Habitat Protection Plan (CHPP) including water column, wetlands, submerged aquatic vegetation (SAV), soft bottom, and shell bottom (NCDEQ 2016). Protection of each habitat type is therefore critical to the sustainability of the Spotted Seatrout stock.

### 1.3.2 Spawning Habitat

Spotted seatrout spawning is generally limited to estuarine waters in the late summer and early fall. Peak spawning activity occurs at temperatures between 21 and 29°C and at salinities typically greater than 15 ppt (ASMFC 1984; Mercer 1984; Saucier and Baltz 1992, 1993; Holt and Holt 2003; Kupschus 2004; Stewart and Scharf 2008). Spawning sites have been noted to include tidal passes, channels, river mouths, and waters in the vicinity of inlets with depths of spawning locations ranging from 2 to 10 m (Saucier and Baltz 1992, 1993; Roumillat et al. 1997; Luczkovich et al. 1999; Stewart and Scharf 2008; Lowerre-Barbieri et al. 2009; Boucek et al 2017). Spotted seatrout have been observed to move in the late afternoon or evening to the high intensity spawning sites in an inlet and low-intensity spawning sites within the estuary with larger, older fish being more abundant at the inlet site than the nearby estuary sites (Lowerre-Barbieri et al. 2009; Ricci et al 2017; Zarada et al. 2019). A strong intra-seasonal site fidelity at resident spawning aggregation sites has also been observed in Spotted Seatrout (Lowerre-Barbieri et al. 2013). During the spawning season, studies have found that Spotted Seatrout use SAV habitat as much, if not more, than other spawning sites (Ricci et al 2017; Boucek et al. 2017). Spawning aggregations of Spotted Seatrout have also been found to occur over shell bottom habitats including over subtidal shell bottom (2–5 m) in the lower Neuse River.

In North Carolina, Spotted Seatrout in spawning condition have been collected coast wide (Hettler and Chester 1990; Burns 1996). Spawning Spotted Seatrout were detected using hydrophone and sonobuoy surveys on both the western side of Pamlico Sound including Rose Bay, Jones Bay, Fisherman's Bay, Bay River, and the eastern side of Pamlico Sound near Ocracoke and Hatteras inlets from May through September with peak activity in July (Luczkovich et al. 1999). When Spotted Seatrout aggregations co-occurred with aggregations of Weakfish at Ocracoke Inlet, the habitat was partitioned and each species occupied different depth ranges. Additional hydrophone surveys noted large spawning aggregations of Spotted Seatrout in the Neuse River generally associated with moderate salinities (12–20 ppt), temperatures between 27 and 29°C, saturated dissolved oxygen levels (> 5 mg l-1 O2), and water depths less than 5 m over mud and subtidal shell bottoms (Barrios et al. 2006). Spawning was also reported to occur over both mud and subtidal shell bottoms in these areas. Spawning in Middle Marsh, Back Sound, and Beaufort Inlet has also been confirmed by passive acoustic monitoring.

Eggs of Spotted Seatrout are positively buoyant at spawning salinities allowing for wind- and tidally-driven distribution throughout the estuary (Churchill et al. 1999; Holt and Holt 2003); however, sudden salinity reductions cause Spotted Seatrout eggs to sink, thus reducing dispersal and survival (Holt and Holt 2003). Larval Spotted Seatrout have been collected in surface and bottom waters of estuaries in North Carolina, Florida, and Texas (McMichael and Peters 1989; Hettler and Chester 1990; Holt and Holt 2000). In North Carolina, larval transport studies in the vicinity of Beaufort Inlet indicated that ocean and inlet spawned larvae are dependent on appropriate wind and tidal conditions to pass through inlets and be retained in the estuary (Churchill et al. 1999; Hare et al. 1999; Luettich et al. 1999). Although Spotted Seatrout spawning generally occurs within the confines of the estuary (ASMFC 1984; Mercer 1984; Saucier and Baltz 1992, 1993), spawning aggregations have been located near inlets in North Carolina (Ricci et al. 2017). Therefore, these physical processes appear to directly limit the retention and recruitment success of Spotted Seatrout to high salinity nursery areas (McMichaels and Peters 1989). Behaviors such as directional swimming and movement throughout the water column also provide mechanisms for estuarine dispersal and retention of larvae within the estuary (Rowe and Epifanio 1994; Churchill et al. 1999; Hare et al. 1999).

### 1.3.3 Nursery & Juvenile Habitat

Wetlands are particularly valuable as nurseries and foraging habitat for Spotted Seatrout (Graff and Middleton 2003). The combination of shallow water, thick vegetation, and high primary productivity provides juvenile and small fishes with appropriate physicochemical conditions for growth, refuge from predation, and abundant prey resources (Boesch and Turner 1984; Mitsch and Gosselink 1993; Beck et al. 2001). Juvenile Spotted Seatrout appear to use estuarine wetlands, particularly the marsh edge habitat of salt/brackish marshes, as nurseries (Tabb 1966; ASMFC 1984; Mercer 1984; Hettler 1989; Rakocinski et al. 1992; Baltz et al. 1993; Peterson and Turner 1994). In North Carolina, juvenile Spotted Seatrout have been found to be abundant in tidal marshes and marsh creeks in eastern and western Pamlico, Bogue, and Core sounds (Epperly 1984; Ross and Epperly 1985; Hettler 1989; Noble and Monroe 1991; Ballie et al. 2015). Additionally, juvenile Spotted Seatrout have been found using salt marsh habitats in the Cape Fear River, although in less abundance than more northern estuaries (Weinstein 1979).

McMichaels and Peters (1989) found that seagrass was the primary habitat for juvenile Spotted Seatrout. In North Carolina, SAV is used extensively by Spotted Seatrout as important nurseries and foraging grounds. Historical data collected by the NCDMF through otter trawl and seine surveys have indicated that juveniles are abundant in high salinity SAV in both Pamlico and Core sounds (Purvis 1976; Wolff 1976; NCDMF, unpublished data). Additionally, meta-analyses indicated that juvenile Spotted Seatrout abundances were found to be greater in SAV than soft bottom and oyster reef and were greater than or equivalent to abundances in wetland habitats (Minello 1999; Minello et al. 2003).

Soft bottom habitats, generally adjacent to wetlands, also function as nursery areas for juvenile Spotted Seatrout (Ross and Epperly 1985; Noble and Monroe 1991; Powers 2012). The benthic microalgae and deposited detrital material provide a rich food base for invertebrates, which are important forage for juvenile Spotted Seatrout (Peterson and Peterson 1979). The primary prey of juvenile Spotted Seatrout (<30 mm in length) consists mainly of benthic invertebrates, including copepods and mysid shrimps; they grow (>30 mm in length), the dominant prey shifts to penaeid and palaemonid shrimps, which remain important in the diet of adults (Peterson and Peterson 1979; Daniel 1988; McMichael and Peters 1989).

Shell bottom habitats have been shown to provide an important forage base of invertebrates and small finfish for juvenile and adult Spotted Seatrout (Coen et al. 1999; ASMFC 2007).

### 1.3.4 Adult Habitat

Adult Spotted Seatrout use the water column as a migratory corridor and to forage on pelagic fishes and penaeid shrimps with increased importance with increasing size (Lorio and Schafer 1966; ASMFC 1984; Mercer 1984; Daniel 1988; Binion-Rock 2018; Binion-Rock et al. 2019). Adult Spotted Seatrout exhibit a high degree of estuarine fidelity with most movements less than 50 km; however, movements of a few individuals in upwards of 500 km have been noted (Moffett 1961; Iverson and Tabb 1962; Tabb 1966; Overstreet 1983; Callihan 2011; Ellis 2014; O'Donnell et al. 2014).

The Atlantic States Marine Fisheries Commission (ASMFC) lists SAV as a Habitat Area of Particular Concern (HAPC) for Spotted Seatrout (ASMFC 1984). All life stages of Spotted Seatrout have been documented in mesohaline and polyhaline seagrass beds (Tabb 1966; ASMFC 1984; Mercer 1984; Thayer et al. 1984; McMichael and Peters 1989; Rooker et al. 1998). The preferred habitat for Spotted Seatrout is low-flow areas with abundant seagrass and adults have been more commonly associated with soft bottom and SAV than oyster reefs (Tabb 1958; Moulton et al. 2017). SAV provides a safe habitat corridor for Spotted Seatrout and habitat suitability models have indicated that Spotted Seatrout abundance is linearly related to percent seagrass cover until a plateau is reached at 60% coverage (Irlandi and Crawford 1997; Micheli and Peterson 1999; Kupschus 2003).

Spotted seatrout can use shallow flats as migratory refuges from larger predators, which cannot access shallow waters (Peterson and Peterson 1979). Spotted seatrout exhibit conspicuous diel shifts from seagrass to bare substrate and greater rates of movement at night (Moulton et al. 2017). In North Carolina, it has been suggested that a portion of the population moves offshore to deeper marine soft bottom areas and beaches in response to falling temperatures in late autumn (ASMFC 1984; Mercer 1984).

Lenihan et al. (2001) found that adult Spotted Seatrout fed primarily on reef-associated fishes, such as Atlantic Croaker and Silver Perch (*Bairdiella chrysoura*) while inhabiting subtidal oyster reefs in North Carolina. Peterson et al. (2003) found that Spotted Seatrout were documented to use oyster reef habitats as adults; however, data were inconclusive on whether Spotted Seatrout populations were enhanced by the presence of oyster reefs.

### 1.3.5 Habitat Issues & Concerns

Human activities that alter the preferred environmental conditions of Spotted Seatrout, as well as introductions of excessive nutrients, toxins, and sediment loads can severely impact the habitat value for Spotted Seatrout, especially SAV (NCDEQ 2016; Lefcheck et al. 2018). Excessive nutrient loading in the environment can lead to nuisance algal blooms, increased biological oxygen demand, hypoxia or anoxia, fish kills, and eventually, loss of biodiversity (Paerl 2002, 2018). Much of the nutrient enrichment in North Carolina's estuaries is caused by cultural eutrophication, or the rapid accumulation of nutrients and sediments caused by human land and water use activities (NCDWQ 2000a). Wetland loss and decreasing vegetative buffers can hasten these impacts to the surrounding water (NCDWQ 2000b). The effect of anthropogenic threats on SAV, wetlands, shell bottom, soft bottom, and water quality are summarized in the North Carolina Coastal Habitat Protection Plan (NCDEQ 2016).

Increased loss of wetlands and hydrological modifications due to climate change may cause degraded water quality, fish kills from hypoxia, salinity regime changes, and shoreline erosion resulting in increased sediment and nutrient loading (Meeder and Meeder 1989; Paerl et al. 2001; Mallin et al. 2002; Paerl 2018; Mallin et al. 2019) and higher costs for storm repair (Costanza et al. 2008). Declines in SAV, globally and in North Carolina, due to increased coastal development and decreased water quality, are also altering these ecosystems and their community structure.

Tabb et al. (1962) reported that excessively turbid waters in Everglades National Park following Hurricane Donna resulted in mass mortalities of Spotted Seatrout when their gill chambers became packed with suspended sediments. In 1999, the Pamlico Sound was reported to have salinities reduced by three-fourths, vertical stratification of the water column, bottom water hypoxia, increased algal biomass, displacement of marine organisms, and an increase in the presence of fish disease following hurricanes Dennis, Floyd, and Irene (Paerl et al. 2001). Similar events were observed after hurricanes Matthew (2016) and Florence (2018; Osburn et al. 2019); however, there is no conclusive evidence that hurricanes have a measurable impact on the Spotted Seatrout population in North Carolina (Burgess et al. 2007).

Some simplistic climate change scenario models of Florida Bay have shown that increasing water temperatures may improve habitat suitability for Spotted Seatrout; however, under the same climate change scenarios their prey species show significant decreases which could result in a prey-limited population (Kearney et al. 2015). It has been predicted that hundreds of finfish and invertebrate species will be forced to move northward due to increasing temperatures caused by climate change (Morley et al. 2018).

Generally, Spotted Seatrout overwinter in estuaries, only moving to deeper channels or to nearshore ocean habitats in response to water temperatures below 10°C (Tabb 1966; ASMFC 1984); however, extreme cold waves accompanied by strong winds mix and chill the water column, causing sudden drops in water temperature. The abrupt temperature declines numb Spotted Seatrout and can result in mass mortality. Many estuarine temperature refuges, such as deep holes and channels, are often far from inlets and become death traps as Spotted Seatrout are cold stunned before they can escape (Tabb 1966; Ellis et al. 2017a; McGrath and Hilton 2017). This suggests that the severity and duration of cold weather events can have profound effects on the Spotted Seatrout population in North Carolina's estuaries (Ellis et al. 2017b).

## 1.4 Description of Fisheries

### 1.4.1 Commercial Fishery

Virginia

Predominant gears in Virginia's commercial Spotted Seatrout fishery since 1994 have been haul seines (~67%) and gill nets (23.7%). A small amount is also harvested using hook and line and pound net. During more recent years, the commercial haul seine fishery has been targeting Spotted Seatrout during the months of September and October. Virginia currently has between eight and ten haul seine fishermen who target Spotted Seatrout during these months. Gill-net fishermen also target sotted seatrout during this time period. The 2021/2022 commercial season is the first season under the new incidental catch provision and preliminary results show that most incidental catch was harvested by gill nets.

North Carolina

Spotted seatrout have been commercially harvested in North Carolina using a variety of gears, but four gear types are most common: estuarine gill net, long haul seine, beach seine, and ocean gill net. Estuarine gill nets are the predominant gear. Historically, long haul seines (swipe nets) used in estuarine waters were the dominant gear, but effort and landings by this gear have diminished in recent years.

Monthly landings of Spotted Seatrout by estuarine anchored gill nets occur year round but mostly occur during the late fall and winter (October–February) with slight increases in the spring (April–May).

There has been a shift from anchored gill nets to actively fished runaround and strike netting techniques that may have been prompted by expanded fishery rules requiring gill-net attendance for small mesh (<5 inches stretch mesh) beginning in 1998. The importance of runaround gill nets (inclusive of strike netting) in North Carolina has steadily increased since 1972 and a continued surge in the mid-1990s may have been caused by the 1995 gill-net closure in Florida state waters (NCDMF 2006) as some Florida commercial fishermen moved their operations to North Carolina. More jet drive boats, spotting towers, night fishing, and runaround gillnetting were reported by the mid-1990s.

Monthly landings of Spotted Seatrout by estuarine runaround gill nets are highest in November and December. A large spike in the number of positive trips occurs during October without a corresponding spike in catch. This could be indicative of Spotted Seatrout bycatch in other fisheries that are active during October such as the striped mullet (*Mugil cephalus*) fishery.

The long haul season starts in the spring and continues through the fall. The majority of trips occur in July; however, the best catches occur in November and December.

The small mesh beach seine fishery operates predominantly during the spring (April–May) and fall (September–October). Beach seine landings of Spotted Seatrout typically occur during the spring (April–May) and fall (October–November) months. If conditions are favorable, fishermen along the northern Outer Banks particularly target Spotted Seatrout during the full moon in May.

Landings of Spotted Seatrout by ocean set gill nets are most active from October through February, but good catches occur in April and May.

### 1.4.2 Recreational Fishery

Spotted seatrout are taken by a variety of methods throughout the coastal zone. Depending on the time of year, anglers fish for Spotted Seatrout from the surf, inlets, piers and jetties, bays and rivers, and inland creeks. The fall season produces the largest portion of the catch and offers the most widespread fishing opportunities. Anglers catch Spotted Seatrout using an array of artificial and natural baits. Preferred artificial baits include soft and hard bodied lures of various colors and shapes fished on the bottom, mid-water, and top water. Bottom fishing using natural baits (including peeler/soft crabs, live shrimp, and various finfish) is also a popular and productive method of fishing for Spotted Seatrout.

Spotted seatrout are often selective feeders requiring anglers to use a variety of baits (natural and artificial) and different fishing techniques. While baits and fishing techniques are constantly evolving, the past twenty years have seen significant changes and improvements in artificial baits and other tackle available to anglers that target and catch Spotted Seatrout. There is anecdotal evidence that these improvements have had a positive impact on catch rate and overall fishing success. In the early 2000s, manufacturers introduced scented soft-bodied artificial baits that have become very popular and lead to increased success of anglers targeting Spotted Seatrout. Hard-bodied artificial baits have also undergone design and color pattern changes increasing their effectiveness. Many anglers also attest to better catch rates due to the widespread use of braided fishing lines. Braided lines along with new graphite rod building technology provide increased sensitivity improving strike detections resulting in more fish caught.

In addition to hook-and-line catches, some Spotted Seatrout are taken by gig and recreational commercial gear (gill nets) in North Carolina where permitted (ASMFC 1984; Watterson 2003). In Virginia, gigging is generally impractical, and regulations prohibit recreational use of commercial gear (gill nets) for species that have a commercial quota (including Spotted Seatrout).

## 1.5 Fisheries Management

### 1.5.1 Management Authority

The NCDMF is responsible for the management of estuarine and marine resources occurring in all state coastal fishing waters extending to three miles offshore. The Virginia Marine Resources Commission (VMRC) is responsible for tidal waters of Virginia and the ocean waters extending to three miles offshore.

Spotted seatrout have been managed along the Atlantic Coast through an Interjurisdictional Fishery Management Plan (FMP) developed by the Atlantic States Marine Fisheries Commission (ASMFC). The ASMFC Spotted Seatrout FMP was initially approved in 1984 (ASMFC 1984) and has been reviewed annually since 2001. Amendment 1, approved by the ASMFC Policy Board in November 1990, developed a list of goals for coast-wide management but allowed each state that had an interest in the Spotted Seatrout fishery (Florida through Maryland) to manage their stocks independently (ASMFC 1990). The adoption of the Omnibus Amendment 2 (ASMFC 2011) to the Interstate Fishery Management Plan for Spotted Seatrout requires states to comply with Atlantic Coastal Fisheries Cooperative Management Act (1993) and the ASMFC Interstate Fishery Management Program Charter. North Carolina and Virginia are currently in compliance with the minimum size limit for both recreational and commercial sectors and have adopted the recommended 20% spawning potential ratio (SPR) threshold.

### 1.5.2 Management Unit Definition

The management unit includes Spotted Seatrout and its fisheries in all of Virginia and North Carolina's fishing waters.

### 1.5.3 Regulatory History

Virginia

Effective July 1, 1992, the VMRC established a 14-inch TL minimum size limit for both the commercial and recreational fisheries, as well as a ten-fish possession limit for the recreational fishery and commercial hook-and-line fishery. In 1995, at a Virginia Finfish Advisory Committee (FMAC) meeting, recreational anglers asked for the commercial fishery of Spotted Seatrout to be regulated by a quota since recreational anglers were held to a ten-fish possession limit. FMAC and staff agreed to a commercial quota of 51,104 pounds. This quota was established using the average landings of Spotted Seatrout from 1993 and 1994 plus 25%. The quota has remained at this level since August 1, 1995, after the VMRC held a public hearing in July 1995 and it was approved and put into regulation. The season runs from September 1 through August 31 of the following year. Effective April 1, 2011, the VMRC lowered the commercial hook-and-line and the recreational possession limit to five fish from December 1 through March 31 and only allowed one fish 24 inches or greater. Effective April 1, 2014, the VMRC established a five fish commercial hook-and-line and recreational possession limit and allowed only one fish 24 inches TL or greater as a year-round regulation. Also, effective April 1, 2014, an 80% trigger was also added to regulation. Once this trigger was hit, then the fishery would move into a bycatch fishery of 100 pounds per vessel (with an equal amount of other species on board) until the quota was landed. Due to directed harvest using large haul seines during the beginning of the season, the 80% trigger has been met by mid-October most years, causing the fishery to switch over to the 100 pounds per vessel per day regulations early in the season. Additionally, language was added to regulation in 2014 to require mandatory buyer reporting from August 1 through November 30 of each year. Effective September 1, 2018, the VMRC established an exemption in the Spotted Seatrout minimum size limit for pound net or haul seine fishermen where the catch of Spotted Seatrout may consist of up to 5.0%, by weight, of Spotted Seatrout less than 14 inches TL.

Because the fishery was getting shut down so quickly after it was opened, harvesters asked staff to consider changes to the regulation in 2021 to cut down on dead discards in the gill-net fishery. Without scientific stock evidence, staff was hesitant to change the overall commercial quota but did change regulation to remove the trigger and bycatch provision and institute an incidental catch provision.

North Carolina

The size limit rule (15A NCAC 03M .0504) for Spotted Seatrout in North Carolina became effective September 1989 (12 inches TL). The first harvest restriction (ten fish recreational bag limit or taken by hook and line) was established through proclamation authority of hook-and-line regulated species (1994). This was put into rule in 1997 by amending 15A NCAC 03M .0504. The rules remained the same until 2009 when the size limit was increased by proclamation (14 inches TL). Rules for Spotted Seatrout management from 1991 to 2009 were that:

(a) it is unlawful to possess Spotted Seatrout less than 12 inches total length.

(b) it is unlawful to possess more than ten Spotted Seatrout per person per day taken by hook and line or for recreational purposes. In 2010, the daily bag limit was reduced to six fish and of those six fish, only two could be greater than 24 inches TL. In 2011, the bag limit was reduced to four fish with a 14-inch TL size limit for recreational fishermen and commercial fishermen using hook and line gear.

The trout rule was repealed in 2012, and Spotted Seatrout was managed under the proclamation authority granted in 15A NCAC 03M. 0512 (Compliance with Fishery Management Plans) until 2017 when the NCDMF re-established the Spotted Seatrout rule 15A NCAC 03M. 0522 due to ASMFC considering retiring the Interstate Spotted Seatrout FMP.

### 1.5.4 Current Regulations

Virginia

The current regulations in Virginia are a 14-inch TL minimum size limit and five fish commercial hook-and-line and recreational possession limit and allows only one fish 24 inches TL or greater. In addition, the catch of Spotted Seatrout by pound net or haul seine may consist of up to 5.0%, by weight, of Spotted Seatrout less than 14 inches TL. A commercial landings quota of 51,104 pounds is set for each 12-month period of September 1 through August 31 of the following year. As of 2021, when the fishery is predicted to hit 100% of the quota (51,104 pounds) staff will announce a switch over to an incidental catch fishery. When the commission announces that the directed commercial landings quota has been reached, it shall be unlawful for any commercial fisherman to take, harvest, land, or possess more than the daily incidental catch limit for the remainder of the fishing year. The daily incidental catch limit shall be 50 pounds of Spotted Seatrout per licensee aboard the vessel, not to exceed 100 pounds per vessel. In addition, seafood buyers are now required to report daily Spotted Seatrout purchases from August 1 through November 30 until the directed commercial landings quota has been reached.

North Carolina

The NCDMF currently allows the recreational harvest of Spotted Seatrout seven days per week with a minimum size limit of 14-inches TL and a daily bag limit of four fish. Since 2011, the commercial harvest is limited to a daily limit of 75 fish and a minimum size limit of 14-inches TL except for when using hook and line gear. When using hook and line gear, the commercial harvest limit is four fish per day. It is unlawful for a commercial fishing operation to possess or sell Spotted Seatrout for commercial purposes taken from Joint Fishing Waters of the state from midnight on Friday to midnight on Sunday each week; the Albemarle and Currituck sounds are exempt from this weekend closure. In the event of a cold stun, the NCDMF has the authority to close the fishery until the following spawning period. The Spotted Seatrout fishery has been closed three times due to cold stun events. It was closed from January 14 through June 15, 2011, from February 5 through June 14, 2014, and from January 5 through June 14, 2018.

## 1.6 Assessment History

### 1.6.1 Review of Previous Methods & Results

The 2015 NCDMF Spotted Seatrout assessment applied a forward-projecting length-based, age-structured model (Stock Synthesis text version 3.24f) and data collected from 1991 through 2012, including tag-recapture data (NCDMF 2015). A two-sex model that accounted for sex specific differences in mortality and growth was assumed. The results of that assessment suggested an expansion of the age structure but also predicted an abrupt decline in estimated recruitment after 2010. Estimates of spawning stock biomass also showed a decline in the final years of the time series. Based on the results of that assessment, the stock was not overfished and overfishing was not occurring in 2015.

### 1.6.2 Progress on Research Recommendations

Research recommendations put forward in the 2015 NCDMF stock assessment of Spotted Seatrout (NCDMF 2015) are listed below and progress, if any, is discussed.

*High*

- Histological maturity; fecundity evaluation/batch fecundity

  The NCDMF completed an analysis of histological maturity for Spotted Seatrout in North Carolina (NCDMF 2021). To date, there has been no research into fecundity evaluation or batch fecundity in North Carolina or Virginia.

- Validate juvenile abundance survey; improve juvenile abundance survey through expansion and addition of random stations (or replace fixed design with random or random stratified)

  A Coastal Recreational Fishing License (CRFL) project is currently in progress that is quantitatively analyzing the Estuarine Trawl Survey (Program 120) to identify redundancies, highlight underrepresented habitats, and suggest feasible modifications to their use in identifying fish nursery habitat. Another CRFL project in progress has similar objectives including evaluation of the performance of the current Program 120 survey design in terms of its accuracy, precision, and ability to capture annual variability of juvenile abundance for producing annual recruitment indices and to determine if Program 120 could be optimized using alternative sampling schemes that are more cost-effective and robust to environmental changes.

- Continue and expand tagging studies for estimating natural and fishing mortality, understanding stock structure, and examining migration (e.g., ocean vs. creeks)

  The NCDMF Multispecies Tagging Program (Program 366) is an ongoing tagging program that was started in 2014. Over 9,000 Spotted Seatrout have been tagged between October 2014 and February 2020 throughout coastal North Carolina. Fishing and natural mortality were estimated for a five-year CRFL completion report (Loeffler et al. 2019) and the current stock assessment.

- Collect data to characterize the length distribution of recreational releases

  During August of 2021, NCDMF implemented a new citizen science initiative called “Catch U Later” to collect recreational fisheries-dependent discard data. “Catch U later” is a smartphone and tablet application that allows recreational anglers to report trip and biological data (length frequencies) for flounder species. To date, over 350 flounder records have been submitted. During 2022, “Catch U Later” will be expanded to include additional species including Kingfish, Red Drum, Weakfish, and Spotted Seatrout.

- Conduct further studies to identify appropriate unit stock

  Ellis et al. (2019) conducted a genetic analysis of Spotted Seatrout from Virginia to Florida and identified two separate stocks—one from Virginia to Bogue Sound, North Carolina and a second from the Cape Fear River and southward to Florida. The New River was identified as a mixing area between these two stocks.

- Develop a custom model that allows for incorporation of variable natural mortality rates

  A customized, seasonal, size-structured model was developed in the current assessment. In this model, nonstationary natural mortality and growth were assumed to incorporate the inter-annual variability in natural mortality rates and growth.

- Develop a fishery-independent survey for Virginia waters

  No progress to date.

*Medium*

- Initiate surveys that assess Spotted Seatrout winter and spawning habitats

  Ellis (2014) and the NCDMF Multispecies Tagging Program (Program 366) both have information on conventionally tagged Spotted Seatrout recaptured from November through March, which would provide information on overwintering areas; however, an analysis has not yet been completed. Ellis et al. (2017b) used telemetry tags to track fish during three consecutive winters while overwintering in North Carolina estuaries.

- Compare maturity ogives between North Carolina and Virginia

  No progress to date.

- Improve discard estimates

  No progress to date.

- Conduct further studies to estimate discard mortality by gear and sector

  No progress to date.

- Investigate relationship between environmental variables and adult and juvenile mortality

  Ellis et al. (2017a) investigated how low temperature and variable salinity impact mortality of adult Spotted Seatrout. Laboratory experiments in this study suggest the temperatures in which Spotted Seatrout become stunned, or experience a complete loss of equilibrium, range from 2 to 4°C; however, Spotted Seatrout begin showing signs of stress at temperatures as low as 7°C. An adult Spotted Seatrout's critical thermal minimum, or the lowest temperature Spotted Seatrout can be exposed to for a short time and still survive, was found to be approximately between 2–3°C. When adult Spotted Seatrout were acclimated and exposed to low water temperatures for an extended period of time, a water temperature of 3°C was found to be 100% lethal to Spotted Seatrout after less than two days. At 5°C, a total of 93% of Spotted Seatrout were still alive after five days, but only 15% survived after ten days. There was high, but not complete, survival (83%) after ten days at 7°C. Ellis et al. (2017a) also observed that Spotted Seatrout subjected to rapid temperature declines in higher salinity were able to withstand lower temperatures before becoming completely stunned compared to fish in lower salinity; the critical thermal minimum was lower by about 1°C in high salinity. In addition, under long term exposure to 7°C water temperatures, several Spotted Seatrout mortalities were observed in lower salinity compared to no mortalities in high salinity at 7°C. Neither effect was statistically significant though, so further research is needed to determine if salinity does influence Spotted Seatrout survival of cold stuns.

- Selectivity of program 915 indices—gear/availability

  In progress. Details not yet available.

*Low*

- Collect more age and sex samples from the recreational fishery

  The NCDMF Carcass Collection Program, in which fishermen can donate their carcasses to freezers located in select locations throughout coastal North Carolina, has allowed us to collect more age and sex samples from the recreational fishery; however, more age and sex samples from this sector are still needed.

- Evaluate influences of salinity on release mortality

  Gearhart (2002) found differences in delayed mortality in hooking mortality study between high salinity sites and low salinity sites. Price and Gearhart (2002) also found differences in delayed mortality for gill-net caught fish between high salinity and low salinity sites.

- Conduct marginal increment analysis

  No progress to date.

- Conduct an age validation study

  No progress to date.

## 2 DATA

Note that all data were summarized by fishing year (March to February) to correspond with the life history of the species (a March 1 birth date was assumed). Data were summarized for fishing years 1991 (March 1991) to 2019 (February 2020), where available, to coincide with the time series used in the stock assessment model.

### 2.1 Fisheries-Dependent

### 2.1.1 Commercial Landings

#### 2.1.1.1 Survey Design and Methods

Virginia

The VMRC's commercial fisheries records include information on both commercial harvest (fish caught and kept from an area) and landings (fish offloaded at a dock) in Virginia. Records of fish harvested from federal waters and landed in Virginia have been provided by the NMFS and its predecessors since 1929 (NMFS, pers. comm.). The VMRC began collecting voluntary reports of commercial landings from seafood buyers in 1973. A mandatory harvester reporting system was initiated in 1993 and collects trip-level data on harvest and landings within Virginia waters. Data collected from the mandatory reporting program are considered reliable starting in 1994, the year after the pilot year of program. The Potomac River Fisheries Commission has provided information on fish caught in their jurisdiction and landed in Virginia since 1973.

North Carolina

Prior to 1978, North Carolina's commercial landings data were collected by the National Marine Fisheries Service (NMFS). In 1978, the NCDMF entered into a cooperative program with the NMFS to maintain and expand the monthly surveys of North Carolina's major commercial seafood dealers. Beginning in 1994, the NCDMF instituted a mandatory trip-ticket system to track commercial landings.

On January 1, 1994, the NCDMF initiated a Trip Ticket Program (TTP) to obtain more complete and accurate trip-level commercial landings statistics (Lupton and Phalen 1996). Trip ticket forms are used by state-licensed fish dealers to document all transfers of fish sold from coastal waters from the fishermen to the dealer. The data reported on these forms include transaction date, area fished, gear used, and landed species as well as fishermen and dealer information.

The majority of trips reported to the NCDMF TTP only record one gear per trip; however, as many as three gears can be reported on a trip ticket and are entered by the program's data clerks in no particular order. When multiple gears are listed on a trip ticket, the first gear may not be the gear used to catch a specific species if multiple species were listed on the same ticket but caught with different gears. In 2004, electronic reporting of trip tickets became available to commercial dealers and made it possible to associate a specific gear for each species reported. This increased the accuracy of reporting by documenting the correct relationship between gear and species.

#### 2.1.1.2 Sampling Intensity

Virginia

All registered licensees are required to report daily harvest from Virginia tidal and federal waters to the VMRC on a monthly basis.

North Carolina

North Carolina dealers are required to record each transaction with a fisherman and report trip-level data to the NCDMF on a monthly basis.

#### 2.1.1.3 Biological Sampling

Virginia

Field sampling at fish processing houses or dealers involves multi-stage random sampling. Targets are set based on mandatory reporting of harvest data by harvesters from the previous years. A three-year moving average of landings by gear and by month (or other temporal segment) provides a preliminary goal for the amount of length and weight samples to be collected. Real time landings are used to adjust the preliminary targets. Targets for ageing samples (see below for criteria) are tracked and collection updates are done weekly. Sampling data are recorded on electronic measuring boards. Weights of individual fish are recorded on electronic scales and downloaded directly to the electronic boards. A fish identification number unique to each specimen is created as well as a batch number for a subsample from a specific trip.

Subsamples of a catch or batch are processed for sex information (gender and gonadal maturity or spawning condition index). Such subsamples are indexed by visual inspection (macroscopic) of the gonads. Females are indexed as gonadal stage I–V and males I–IV, with stage I representing an immature or resting stage of gonadal development and stages IV (males) and V (females) representing spent fish. Fish that cannot be accurately categorized in terms of spawning condition are not assigned a gonadal maturity stage.

Ancillary data for fish sampled at dealers are collected and include date harvested, harvest area, gear type used, and total catch (recorded if only a subsample was measured). This information would allow for expansion of the sample size to the total harvest reported for a species. Estimates of effort are not typically recorded by this program but can be extrapolated from mandatory harvest reports sent to the VMRC on a monthly basis by harvesters, sometime after a sampling event.

The numbers of Spotted Seatrout lengths sampled from commercial landings by the VMRC are summarized in Table 2.1.

<u>North Carolina</u>

Commercial length-frequency data were obtained by the NCDMF commercial fisheries-dependent sampling program. Spotted seatrout lengths are collected at local fish houses by gear, market grade, and area fished. Random samples of culled catches are taken to ensure adequate coverage of all species in the catches. Length frequencies obtained from a sample were expanded to the total catch using the total weights from the trip ticket. All expanded catches were then combined to describe a given commercial gear for a specified time period.

In cases where the weight of particular species' market grades was included on the trip ticket but were not sampled, an estimate of the number of fish landed for the grade was made by using the mean weight per individual from samples of that species and grade from the same year. Species numerical abundance was calculated by determining the number of individuals/market grade and then summing all the market grades for each species. Catches were analyzed by gear type (i.e., gill nets, seines, and other), month, year, and season (i.e., March–November and December–February).

The numbers of Spotted Seatrout lengths sampled from commercial landings by the NCDMF are summarized in Table 2.2.

#### 2.1.1.4 Potential Biases & Uncertainty

Because trip tickets are only submitted when fish are transferred from fishermen to dealers, records of unsuccessful fishing trips are not available for both the VMRC and the NCDMF. As such, there is no direct information regarding trips where a species was targeted but not caught. Information on these unsuccessful trips is necessary for calculating a reliable index of relative abundance for use in stock assessments.

Another potential bias for NCDMF data relates to the reporting of multiple gears on a single trip ticket. It is not always possible to identify the gear used to catch a particular species on a trip ticket that lists multiple gears and species.

#### 2.1.1.5 Development of Estimates

Annual commercial landings statistics were calculated by year and season (season 1: March 1–November 30, season 2: December 1–February 28/29) for both states combined and separately by state.

Length data were summarized in 40-mm length bins by year and season. Length data were pooled over states and summarized for the commercial fisheries.

#### 2.1.1.6 Estimates of Commercial Landings Statistics

Between 1991 and 2019, total commercial landings for Virginia and North Carolina combined have ranged from 24 to 245.1 mt in season 1 and ranged from 11 to 145.1 mt in season 2 (Table 2.3; Figure 2.1). Annually (March through February), total commercial landings for both states combined have ranged from 38 to 335 mt. Commercial landings of Spotted Seatrout have been consistently higher for season 1 than season 2.

Commercial length-frequency data are summarized in Figures 2.2 and 2.3.

### 2.1.2 Commercial Discards

#### 2.1.2.1 Survey Design and Methods

The Sea Turtle Bycatch Monitoring Program (Program 466) was designed to monitor bycatch in the North Carolina estuarine gill-net fishery, providing onboard observations to characterize effort, catch, and finfish bycatch by area and season. Additionally, this program monitors fisheries for protected species interactions. The onboard observer program requires the observer to ride onboard the commercial fishermen's vessel and record detailed gill-net catch and discard information for all species encountered. Observers contact licensed commercial gill-net fishermen throughout the state in order to coordinate observed fishing trips.

#### 2.1.2.2 Sampling Intensity

Trips are observed per management unit based on the average number of trips per month and management unit reported to the trip ticket program for the previous five-year period. Per the sea turtle incidental take permit (ITP; NMFS 2013, 2014), the division is required to observe a minimum of 7% (goal of 10%) of anchored large mesh gill-net trips and a minimum of 1% (goal of 2%) of anchored small mesh gill-net trips by management unit by season. The mesh size categories in the sea turtle ITP (large mesh >= 4-inch inside stretched mesh (ISM), small mesh <= 4-inch ISM) are different than the categories in the trip ticket program (large mesh >= 5-inch ISM, small mesh <= 5-inch ISM).

#### 2.1.2.3 Biological Sampling

Data collected from each species include length, weight, and fate (landed, live discard, dead discard).

#### 2.1.2.4 Potential Biases & Uncertainty

Program 466 began sampling statewide in May 2010. To provide optimal coverage throughout the state, management units were created to maintain proper coverage of the fisheries. Management units were delineated on the basis of four primary factors: similarity of fisheries and management; extent of known protected species interactions in commercial gill net fisheries; unit size; and the ability of the NCDMF to monitor fishing effort. Total effort for each management unit can vary annually based on fishery closures due to protected species interactions or other regulatory actions. Therefore, the number of trips and effort sampled each year by management unit varies both spatially and temporally.

Program 466 data do not span the entire time series for the assessment (no data are available for 1991–2000 and spatially limited data are available 2000–2003). Since 2004, observed trips were sparse for some seasons and management areas for several years despite widespread fishing effort. However, observations were likely adequate to determine whether discards in this fishery were a significant source of removals from the population. Observer data have been collected throughout the Pamlico Sound since 2000 and outside the Pamlico Sound since 2004. Data from 2000 to 2003 were not included due to spatial limitations.

Lastly, observed trips ideally would be random across fishery participants within each sampling stratum; however, participants avoid and occasionally refuse to take an observer. Although anecdotally small, the number of participants who are not observed has not been quantified.

**2.1.2.5 Development of Estimates**

A generalized linear model (GLM) framework was used to predict Spotted Seatrout discards in North Carolina's estuarine gill-net fishery based on data collected during 2004 through 2019. Only those variables available in all data sources were considered as potential covariates in the model. Available variables were fishing year, season, mesh category (large: ≥5 inches and small: <5 inches), and management unit, all of which were treated as categorical variables in the model. Effort was measured as soak time (days) multiplied by net length (yards). Live and dead discards were modeled separately.

All available covariates were included in the initial model and assessed for significance using the appropriate statistical test. Non-significant covariates were removed using backwards selection to find the best-fitting predictive model. The offset term was included in the model to account for differences in fishing effort among observations (Crawley 2007; Zuur et al. 2009, 2012). Using effort as an offset term in the model assumes the number of Spotted Seatrout discards is proportional to fishing effort (A. Zuur, Highland Statistics Ltd., personal communication).

The best-fitting model for live discards and for dead discards was applied to available effort data from the NCTTP to estimate the total number of live discards and dead discards for the estuarine gill-net fishery. A discard mortality rate of 60% (see section 1.2.6) was applied to the estimates of live discards to estimate those live discards that were not expected to survive. This number was added to the number of dead discards to estimate the total number of dead discards.

Length data were summarized by 2-cm length bins and year.

**2.1.2.6 Estimates of Commercial Discard Statistics**

The best-fitting GLM for the commercial gill-net live discards assumed a zero-inflated Poisson distribution (dispersion=3.1). The significant covariates for the count part of the model were year mesh and area while the significant covariates for the binomial part of the model were mesh and area. The best-fitting GLM for the dead discards assumed a zero-inflated Poisson distribution (dispersion = 1.4). The significant covariates for the count part of the model were year, season, and area while the significant covariates for the binomial part of the model were season, mesh, and area.

Estimates of dead commercial discards for North Carolina were variable for the gill-net estuarine fishery during 2004 through 2019 (Figure 2.4). Estimates were minimal compared to the magnitude of all fisheries overall. Though estimates of discards from Virginia were not available, they were assumed minimal as well.

Annual length-frequency distributions of commercial gill-net estuarine fishery discards are shown in Figures 2.5.

### 2.1.3 Recreational Fishery Monitoring

#### 2.1.3.1 Survey Design and Methods

The Marine Recreational Information Program (MRIP) is designed to provide annual and bi-monthly estimates of marine recreational fisheries catch and effort data. Information on commercial fisheries has long been collected by the NMFS; however, data on marine recreational fisheries were not collected in a systematic manner by the NMFS until implementation of the Marine Recreational Fishery Statistics Survey (MRFSS) in 1979. The purpose of the MRFSS was to provide regional estimates of effort and catch from the recreational sector. Importantly, the National Research Council (NRC) identified under-coverage, inefficiency, and bias issues within the MRFSS survey and estimation methodologies (NRC 2006). These deficiencies spurred the development of the MRIP as an alternative data collection program to the MRFSS. The MRIP is a national program that uses several component surveys to obtain timely and accurate estimates of marine recreational fisheries catch and effort and provide reliable data to support stock assessment and fisheries management decisions. The program is reviewed periodically and undergoes modifications as needed to address changing management needs. A detailed overview of the program can be found online at https://www.fisheries.noaa.gov/topic/recreational-fishing-data.

The MRIP uses three complementary surveys: (1) the Fishing Effort Survey (FES), a mail survey of households to obtain trip information from private boat and shore-based anglers; (2) the For-Hire Telephone Effort Survey (FHTES) to obtain trip information from charter boat operators; and (3) the Access Point Angler Intercept Survey (APAIS), a survey of anglers at fishing access sites to obtain catch rates and species composition from all modes of fishing. The data from these surveys are combined to provide estimates of the total number of fish caught, released, and harvested; the weight of the harvest; the total number of trips; and the number of people participating in marine recreational fishing. In 2005, the MRIP began at-sea sampling of headboat (party boat) fishing trips.

The APAIS component was improved in 2013 to sample throughout the day (24-hour coverage) and remove any potential bias by controlling the movement of field staff to alternative sampling sites. The MRFSS allowed samplers to move from their assigned site to more active fishing locations but could not statistically account for this movement when calculating estimates. The MRIP implemented the FES in 2018 to replace the Coastal Household Telephone Survey (CHTS) due to concerns of under-coverage of the angling public, declining number of households using landline telephones, reduced response rates, and memory recall issues.

#### 2.1.3.2 Sampling Intensity

Creel clerks collect intercept data year-round (in two-month waves) by interviewing anglers completing fishing trips in one of four fishing modes (man-made structures, beaches, private boats, and for-hire vessels). Intercept sampling is separated by wave, mode, and area fished. Sites are chosen for interviewing by randomly selecting from access sites that are weighted by estimates of expected fishing activity. The intent of the weighting procedure is to sample in a manner such that each angler trip has a representative probability of inclusion in the sample. Sampling is distributed among weekdays, weekends, and holidays. In North Carolina, strategies have been developed to distribute angler interviews in a manner to increase the likelihood of intercepting anglers landing species of management concern.

The FES mail survey employs a dual-frame design with non-overlapping frames (1) state residents are sampled from the United States Postal Service computerized delivery sequence file (CDS) and (2) non-residents are individuals who are licensed to fish in one of the target states but live in a different state and are sampled from state-specific lists of licensed saltwater anglers. Sampling from the CDS uses a stratified design in which households with licensed anglers are identified prior to data collection. The address frame for each state is stratified into coastal and non-coastal strata defined by geographic proximity to the coast. For each wave and stratum, a simple random sample of addresses is selected from the CDS and matched to addresses of anglers who are licensed to fish within their state of residence. Non-resident anglers are sampled directly from state license databases. The sample frame for each of the targeted states consists of unique household addresses that are not in the targeted state but have at least one person with a license to fish in the targeted state during the wave.

The FES mail survey collects fishing effort data for all household residents, including the number of saltwater fishing trips by fishing mode (shore and private boat). The FES is a self-administered mail survey, administered for six two-month reference waves annually. The initial survey mailing is sent one week prior to the end of the reference wave so that materials are received right at the end of that wave. This initial mailing is delivered by regular, first-class mail and includes a cover letter stating the purpose of the survey, a survey questionnaire, a post-paid return envelope, and a $2 cash incentive. One week after the initial mailing, a follow-up thank you and reminder postcard is mailed via regular first-class mail to all sampled addresses. For addresses that could be matched to a landline telephone number, an automated voice message is also delivered as a reminder to complete and return the questionnaire. Three weeks after the initial survey mailing, a final mailing is delivered to all addresses that have not yet responded to the survey.

#### 2.1.3.3 Biological Sampling

Fish that are available during APAIS interviews for identification, enumeration, weighing, and measuring by the interviewers are called landings or Type A catch. Fish not brought ashore in whole form but used as bait, filleted, discarded dead, or are otherwise unavailable for inspection are called Type B1 catch. Finally, fish released alive are called Type B2 catch. Type A and Type B1 together comprise harvest, while all three types (A, B1, and B2) represent total catch. The APAIS interviewers routinely sample fish of Type A catch that are encountered. Fish discarded during the at-sea headboat survey are also sampled. The headboat survey is the only source of biological data characterizing discarded catch that are collected by the MRIP; however, this number has been negligible (0 Spotted Seatrout headboat discards between 2005 and 2019). The sampled fish are weighed to the nearest five one-hundredth (0.05) of a kilogram or the nearest tenth (0.10) of a kilogram (depending on scale used) and measured to the nearest millimeter for the centerline length. The numbers of Spotted Seatrout measured in Virginia and North Carolina by the MRIP are summarized in Table 2.4.

#### 2.1.3.4 Potential Biases & Uncertainty

The MRIP was formerly known as the MRFSS. Past concerns regarding the timeliness and accuracy of the MRFSS program prompted the NMFS to request a thorough review of the methods used to collect and analyze marine recreational fisheries data. The NRC convened a committee to perform the review, which was completed in 2006 (NRC 2006). The review resulted in several recommendations for improving the effectiveness and use of sampling and estimation methods. In response to the recommendations, the NMFS initiated the MRIP, a program designed to improve the quality and accuracy of marine recreational fisheries data. The MRIP estimation method and sampling design for the APAIS were implemented in 2013, replacing MRFSS. In 2016, the NMFS requested that the NRC, now referred to as the National Academies of Sciences, perform a second review to evaluate how well and to what extent the NMFS has addressed the NRC's original recommendations (NASEM 2017). The review noted the impressive progress made since the earlier review and complimented the major improvements to the survey designs. The review also noted some remaining challenges and offered several recommendations to continue to improve the MRIP surveys. MRIP implemented the FES in 2018 to address the concerns of under-coverage of the angling public, declining number of households using landline telephones, reduced response rates, and memory recall issues of the CHTS.

#### 2.1.3.5 Development of Estimates

The intercept and at-sea headboat data are used to estimate catch per trip for each species encountered. The estimated number of angler trips is multiplied by the estimated average catch per trip to calculate an estimate of total catch for each survey stratum.

Releases of seatrout genus (Spotted Seatrout and Weakfish) are sometimes recorded to the genus (*Cynoscion*) level in the MRIP. Releases are not observed by interviewers and some recreational fishermen are not able to report seatrout to the species level. To estimate the number of Spotted Seatrout released, the proportion of Spotted Seatrout estimated by MRIP as harvested (relative to other *Cynoscion* species) is applied to numbers of reported released *Cynoscion* spp. from the same wave (1–6), mode (type of fishing), and area (inshore vs. ocean). The number of recreational live releases was multiplied by a discard mortality of 10% (see section 1.2.6.2) to estimate the number of dead recreational discards.

The length data from the MRIP sampling of the Type A catch were expanded to total recreational harvest by wave/mode/area strata for each of the states by year and season. The length frequencies were then summed over the states by wave/mode/area strata to provide length frequencies by year and season for the recreational harvest.

#### 2.1.3.6 Estimates of Recreational Fishery Statistics

Recreational harvest (Type A + B1) in terms of weight ranged from 164 to 1,769 mt in season 1 (Table 2.5; Figure 2.6) and from 1 to 716 mt in season 2 (Table 2.6; Figure 2.6) between 1991 and 2019. In terms of numbers, recreational harvest (Type A + B1) in season 1 (Table 2.5; Figure 2.7) has exceeded the recreational harvest in season 2 throughout the time series (Table 2.6; Figure 2.7). Estimates of live releases (Type B2) have increased in recent decades, especially in season 1 (Tables 2.5 and 2.6; Figure 2.8).

Annual length-frequency data for the recreational fishery are presented in Figures 2.9 and 2.10.

### 2.2 Fisheries-Independent

All the available fisheries-independent data come from North Carolina as there are currently no fisheries-independent sampling programs in Virginia that catch sufficient numbers of Spotted Seatrout to develop a reliable index.

### 2.2.1 Fisheries-Independent Gill-Net Survey (Program 915)

#### 2.2.1.1 Survey Design and Methods

The Fisheries-Independent Gill-Net Survey, also known as Program 915 (P915), began on May 1, 2001 and originally included Hyde and Dare counties (Figure 2.11). In July 2003, sampling was expanded to include the Neuse, Pamlico, and Pungo rivers (Figure 2.12). Additional areas in the Southern District were added in April 2008 (New and Cape Fear rivers; Figure 2.13) and in the Central District in May 2018 (the White Oak River to Back Sound).

Floating gill nets are used to sample shallow strata while sink gill nets are fished in deep strata. Each net gang consists of 30-yard segments of 3-, 3.5-, 4-, 4.5-, 5-, 5.5-, 6-, and 6.5-inch stretched mesh, for a total of 240 yards of nets combined. Catches from an array of gill nets comprise a single sample; two samples (one shallow, one deep)—totaling 480 yards of gill net—are completed each trip. Gill nets are typically deployed within an hour of sunset and fished the following morning. Efforts are made to keep all soak times within 12 hours. All gill nets are constructed with a hanging ratio of 2:1. Nets constructed for shallow strata have a vertical height between 6 and 7 feet. Prior to 2005, nets constructed for deep and shallow strata were made with the same configurations. Beginning in 2005, all deepwater nets were constructed with a vertical height of approximately 10 feet. With this configuration, all gill nets were floating and fished the entire water column.

A stratified random sampling design is used, based on area and water depth. Each region is overlaid with a one-minute by one-minute grid system (equivalent to one square nautical mile) and delineated into shallow (<6 feet) and deep (>6 feet) strata using bathymetric data from NOAA navigational charts and field observations. Beginning in 2005, deep sets have been made along the 6-ft contour. Sampling in Pamlico Sound is divided into two regions: Region 1, which includes areas of eastern Pamlico Sound adjacent to the Outer Banks from southern Roanoke Island to the northern end of Portsmouth Island; and Region 2, which includes Hyde County bays from Stumpy Point Bay to Abel's Bay and adjacent areas of western Pamlico Sound. Each of the two regions is further segregated into four similar sized areas to ensure that samples are evenly distributed throughout each region. These are denoted by either Hyde or Dare and numbers 1 through 4. The Hyde areas are numbered south to north, while the Dare areas are numbered north to south. The rivers are divided into four areas in the Neuse River (Upper, Upper-Middle, Lower-Middle, and Lower), three areas in the Pamlico River (Upper, Middle, and Lower), and only one area for the Pungo River. The upper Neuse area was reduced to avoid damage to gear from obstructions, and the lower Neuse was expanded to increase coverage in the downstream area. The Pungo area was expanded to include a greater number of upstream sites where a more representative catch of Striped Bass (*Morone saxatilis*) may be acquired.

#### 2.2.1.2 Sampling Intensity

Initially, sampling occurred during all 12 months of the year. In 2002, sampling from December 15 through February 14 was eliminated due to extremely low catches and unsafe working conditions. Sampling in the Pamlico, Pungo, and Neuse rivers did not begin until July 2003. Each of the sampling areas within each region is sampled twice a month. Within a month, a total of 32 samples are completed (eight areas × twice a month × two samples) in both the Pamlico Sound and the river systems.

#### 2.2.1.3 Biological Sampling

All Spotted Seatrout are enumerated and an aggregate weight (nearest 0.01 kilogram (kg)) is obtained for each net (mesh size) fished. All individuals are measured to the nearest millimeter fork length (FL). Specimens are also retained and taken to the lab where age structures (otoliths) are removed, sex, and maturity stage of gonads are determined. The numbers of biological samples collected in Program 915 is summarized in Table 2.7.

#### 2.2.1.4 Potential Biases & Uncertainty

Spotted seatrout are a target species in Program 915. The survey is designed to collect data of fish using estuarine habitats but nearshore ocean areas, which may be used by Spotted Seatrout, are not sampled. In addition, shallow creeks, which are often used by Spotted Seatrout as overwintering habitat and many deepwater areas of Pamlico Sound, potentially used for spawning, are not sampled in Program 915. Despite being used by Spotted Seatrout and being areas of high fishery activity, Albemarle Sound is not sampled. Ellis (2014) noted acoustic tagged Spotted Seatrout seemed to avoid anchored gill nets, indicating catchability of this species using Program 915 gear may be an issue.

While sample design has been largely consistent some adjustments have been made with the goal of reducing sea turtle interactions. In 2005, some deep water grids were dropped in Pamlico Sound, which may have some influence on deep relative abundance prior to this time period. Beginning in 2011, one area strata in eastern Pamlico Sound was not sampled for a three-month period from June through August to reduce sea turtle interactions. This change eliminated 16 samples per year. Excluding these samples from prior analysis had minimal impact on Spotted Seatrout relative abundance and variance.

#### 2.2.1.5 Development of Estimates

Two indices of relative abundance, spring and fall, were developed from the Program 915 data from Pamlico Sound and the Neuse, Pamlico and Pungo rivers. The spring index was based on data from April through June. The fall index was based on data collected from September through November.

The indices were developed using a GLM approach to attempt to remove the impact of factors other than changes in abundance that may be affecting the indices (Maunder and Punt 2004). Because there was some variability in effort (soak time in hours) among hauls, effort was included as an offset variable in the GLM.

Length data were summarized by 40-mm length bins and year. Length data were summarized for each index; that is, they are based on collections from the same months of the associated index.

#### 2.2.1.6 Estimates of Program 915 Survey Statistics

The spring standardized index was modeled using a zero-inflated negative binomial GLM (dispersion=1.0). Significant variables for the presence/absence (binomial) sub-model included depth, temperature, salinity, and distance from shore and the significant variables for the count sub-model included year, depth, temperature, salinity, dissolved oxygen, distance from shore, sediment size, and strata. The fall standardized index was modeled using a negative binomial GLM (dispersion=1.2). Significant variables included year, dissolved oxygen, sediment size, and strata.

The spring and fall standardized indices derived from Program 915 survey data for the northern region indicate a stable or increasing trend in relative abundance from 2003 to 2019 and the standardized indices do not differ dramatically from the nominal indices (Figure 2.14).

Annual length-frequency distributions for the Program 915 survey indices are shown in Figures 2.15 and 2.16.

# 3 ASSESSMENT

## 3.1 Overview

### 3.1.1 Scope

The unit stock for the current assessment is considered all Spotted Seatrout occurring within Virginia and North Carolina waters. The time period covered in this assessment is 1991–2019.

### 3.1.2 Summary of Methods

The current assessment is based on a seasonal, size-structured model. The model has a seasonal time step to account for seasonal biological processes and fishing patterns. The seasonal time-step may help capture the impact of cold stuns for Spotted Seatrout during cold winters. A size-structured model is used because: (1) size-based data are usually easier to obtain than age-based data and thus are associated with higher accuracy and less uncertainty; (2) management of most fisheries is based on size; and (3) use of a size-based model reduces the uncertainty introduced by age-size conversion during analysis (Quinn and Deriso 1999; Cao et al. 2017).

### 3.1.3 Current vs. Previous Method

The 2015 NCDMF Spotted Seatrout assessment (NCDMF 2015) used the Stock Synthesis (SS3) model and data collected from 1991 through 2012. The SS model is a length-based, age-structured model that accounts for sex-specific differences in mortality and growth. The model's inability to capture cold stun mortality was one of the major concerns from external peer reviewers in the previous assessment and thus, developing a customized model to account for variable natural mortalities was listed as a research recommendation with high priority. The seasonal, size-structured model was developed for the current assessment. Both the SS3 model and the seasonal size-structured model can incorporate information from multiple sources including fisheries, surveys, and a variety of biological datasets. Both assessments used only fisheries-independent surveys to derive relative abundance indices and used the maximum likelihood estimator through the Automatic Differentiation Model Builder (ADMB) to estimate parameters; however, unlike the previous assessment, this assessment model (1) used a seasonal time step instead of an annual time step to account for cold stun mortality of Spotted Seatrout during winter months; (2) the population dynamics were modeled by size structure instead of age structure; (3) the available data extended through 2019; (4) sexes were combined; (5) natural mortality and growth were assumed nonstationary; (6) the newly calibrated MRIP data were used for the recreational fishery, which are approximately three times the landings and discards used in the 2015 assessment.

## 3.2 Data Sources

This assessment included data from commercial and recreational fishing fleets that caught Spotted Seatrout in North Carolina and Virginia waters (Table 3.1). The model was fit to data on seasonal landings (in number), discards (in number), and length compositions. Two fisheries-independent indices of abundance and their associated length compositions were included, namely the Program 915 northern spring index (P915NorthSring, April–June, Pamlico Sound and rivers) and the Program 915 northern fall index (P915NorthFall, September–November, Pamlico Sound and rivers).

### 3.3 Seasonal, Size-Structured Model Configuration

The model developed in this stock assessment was adapted from a seasonal, size-structured model for northern shrimps (*Pandalus* spp.) developed by Cao et al. (2017). The model was coded in the ADMB (Fournier et al. 2012; http://admb-foundation.org).

#### 3.3.1 Population Dynamics

In a size-structured model, the population dynamics of a stock are described in terms of the number of individuals at each size class over time (Sullivan et al. 1990; Cao et al. 2017). With a seasonal time step, the number of fish in size class $k$ at the beginning of the season $t$ in year $y$ is calculated as:

$N_{k,t+1,y} = \sum_{k'} \left( G_{k',k} N_{k',t,y} exp\left(-M_{k',t,y} - \sum_f F_{f,k',t,y}\right)\right) + R_{k,t+1,y}$ for $t < T$ (growing to next season of the same year)

$N_{k,t'=1,y+1} = \sum_{k'} \left( G_{k',k} N_{k',t=T,y} exp\left(-M_{k',t=T,y} - \sum_f F_{f,k',t=T,y}\right)\right) + R_{k,t'=1,y+1}$ for $t = T$ (growing to next year)

where $t$ and $t'$ index the season, $y$ indexes the year, $k$ and $k'$ index the size class, $f$ indexes the fishing fleet, $N$ is the population size, $T$ is the maximum number of seasons, $G$ is a growth transition matrix, $G_{k',k}$ represents the probability of surviving individuals in size class $k'$ that grow to size class $k$ during one time step (i.e., one season in a seasonal model), $M$ and $F$ are instantaneous mortalities, and $R$ is the recruitment.

In this assessment, a model year began on March 1st and ended on February 28/29th of the following year. For example, the model year 1991 spanned from March 1st, 1991 to February 29th, 1992. Spawning of Spotted Seatrout in North Carolina and Virginia occurs in May–September and peaks in June–July. In the model, spawning was assumed to occur on June 1st. Each year was separated into two seasons, the non-winter season ($t$ = 1) from March 1st to November 30th and the winter season ($t$ = 2) from December 1st to February 28th/29th. The available length composition data used in this assessment contained lengths from 120 mm to 880 mm. Also, a von Bertalanffy growth model was fit externally using length-age data (section 1.2.4.1) and estimated a mean length of approximately 169 mm for recruits (age 0). Thus, in the model, 19 size classes were used ranging from 120 to 879.9 mm with a 40 mm size bin (i.e., 120–159.9 mm, 160–199.9 mm). The size bins covered in this assessment started at 120 mm to ensure the recruits were included and the length composition data were available for most of the size bins.

#### 3.3.2 Growth

In the assessment model, individuals in a size class grew into the following size classes through a growth transition matrix. The growth transition matrix ($G$) can be determined by assuming growth follows the von Bertalanffy growth curve and the size increment for size class $k$ (mm, $\Delta L_k$) follows a normal distribution with mean $E(\Delta L_k)$ and variance $Var(\Delta L_k)$ (Chen et al. 2003; Cao et al. 2017):

$$E(\Delta L_k) = (L_\infty - L_k)\left(1 - exp(-a_t K)\right)$$

$$Var(\Delta L_k) = \sigma_{L\infty}^2\left(1 - exp(-a_t K)\right)^2 + a_t{}^2(L_\infty - L_k)^2\sigma_K^2 exp(-2a_t K)$$
$$+ 2\rho a_t \sigma_{L\infty}\sigma_K\left(1 - exp(-a_t K)\right)(L_\infty - L_k)exp(-a_t K)$$

where $L_\infty$ is the asymptotic length (mm), $K$ is the annual growth coefficient ($yr^{-1}$), $\rho$ is the correlation coefficient between $L_\infty$ and $K$, $L_k$ is the mid-length of size class $k$, $\sigma_{L\infty}$ and $\sigma_K$ are standard deviations of $L_\infty$ and $K$ respectively, and $a_t$ is a scalar for partitioning the growth for season $t$ within a year, where $0 \leq a_t \leq 1$. The probability of an individual growing from size class $k$ to size class $k'$ within one time step can be calculated as:

$$G_{k,k'} = \int_{k'_{low}}^{k'_{up}} f(x|E(\Delta L_k), Var(\Delta L_k))dx$$

where $k'_{up}$ and $k'_{low}$ are the upper and lower ends of size class $k'$ and $f(.)$ denotes the probability density function of a normal distribution. Negative growth is not permitted and thus, $k' \geq k$ and $\sum_{k'} G_{k,k'} = 1$. The last size class is a plus group with all the individuals staying in the same size class and only subject to mortality.

In this assessment, the growth parameters $L_\infty$ and $K$ were assumed to vary over time and modeled using a random walk process:

$$L_{\infty,y+1} = L_{\infty,y} exp\left(LDev_{y+1}\right)$$
$$K_{y+1} = K_y exp\left(KDev_{y+1}\right)$$

where the growth parameters in year $y$+1 were determined by the parameters in the previous year $y$ and a multiplicative deviation term in log space (*LDev* and *KDev*). We set $a_1 = 0.75$ and $a_2 = 0.25$ for non-winter season and winter season respectively.

### 3.3.3 Natural Mortality

Ellis (2014) and Ellis et al. (2018) have demonstrated increasingly high inter-annual variability in natural mortality during periods of cold stuns. Additionally, Ellis et al. (2017) showed high winter natural mortality associated with cold temperature. Thus, to account for the impact of cold stuns in this assessment, the natural mortality was assumed to be constant in the non-winter season but vary by year during the winter season. The natural mortality also varied by size during each season:

$$M_{k,t,y} = M_{t,y} w_k w_y$$

where $w_k$ and $w_y$ are size year scalars respectively and can be pre-specified. In the base model, we set $w_y = 1$ to allow the model to estimate the annual variability in the natural mortality. The size scalar can be determined based on the Lorenzen method (Lorenzen 1996). In this assessment, the Lorenzen $M$ ($M_k'$, in per year) was calculated based on weight ($W$, in g) with the parameters $M_u = 3.69$ and $d = -0.305$, which are values that were estimated for a wide range of ocean fishes (Lorenzen 1996):

$$M'_k = M_u W_k^d.$$

Then the calculated Lorenzen $M$ values were divided by their average (Avg($M_k'$)) to generate the size scalar:

$$w_k = \frac{M'_k}{Avg(M'_k)}$$

Such a size scalar would scale the Lorenzen $M$ values to have an average that equals to the size-constant target natural mortality $M_{t,y}$. The seasonal natural mortality for a given year ($M_{t,y}$) was modeled with a mean ($\bar{M}$) and a deviation term ($MDev_y$):

$$M_{t,y} = \overline{M_t} exp\left(MDev_y\right)$$

where $MDev$ is a multiplicative deviation term in log space. In this assessment, the natural mortality for the non-winter season was assumed a fixed constant input, whereas the natural mortality for the winter season was assumed to vary over time and estimated with a deviation. An annual natural mortality of 0.6 was used derived from a meta-analysis (Then et al. 2015; section 1.2.6.1) and then was split into the winter and non-winter seasons based on a ratio of 2:1. As a result, $M_{t=1,y} = \overline{M_{t=1}}$ = 0.2 and $\overline{M_{t=2}}$ = 0.4. Information on how to split the annual natural mortality into seasons were limited, and thus, we tested a series of splitting ratios ranging from 0.2 to 5 (the ratio of winter season relative to non-winter season). The ratio of 2:1 was selected because it produced the lowest total negative log-likelihood. Additionally, a tagging model that was fit externally using tag-recapture data (section 1.2.6.1) estimated a similar ratio (1.78:1).

### 3.3.4 Female Maturity, Sex Ratio, Fecundity, and Spawning Stock

Female maturity was modeled with a logistic function and the estimated maturity by size was treated as a fixed input to the model. The model was sex combined. The sex ratio was also treated as a fixed input to the model and assumed a 50% female proportion for the first eight size classes (120 mm–440 mm), 70% for the next four size classes (440 mm–600 mm), and 95% for the remaining size classes (600 mm–880 mm). Both female maturity and sex ratio were constant over time. In this assessment, the spawning stock biomass (SSB) was modeled as the population fecundity (number of eggs) and assumed to be equivalent to mature female biomass. Reproduction was assumed to occur once a year on June 1st.

### 3.3.5 Recruitment

Assuming the age-0 fish represent recruitment, the size-specific seasonal recruitment $R_{k,t,y}$ was modeled as the product of annual recruitment ($R_y$) and the proportion of $R_y$ that recruits to each season ($\pi_t$) and each size ($\pi'_k$):

$$R_{k,t,y} = R_y \pi_t \pi'_k.$$

In the base model, $\pi_{t=1}$ = 1 and $\pi_{t=2}$ = 0 because spawning was assumed to only occur in the non-winter season. It was also assumed the fish would recruit to the first seven size classes with the proportion $\pi_{k=1}$ =0.06, $\pi_{k=2}$ =0.11, $\pi_{k=3}$ =0.17, $\pi_{k=4}$ =0.21, $\pi_{k=5}$ =0.20, $\pi_{k=6}$ =0.16, and $\pi_{k=7}$ =0.09, according to the estimates from the von Bertalanffy growth model that was fit externally using length-age data (section 1.2.4.1). These proportions were fixed inputs and assumed constant over time. Recruitment is often driven by environmental factors and spawner abundance often only explains a small amount of the high variation in recruitment. Thus, in the model, the annual recruitment $R_y$ was directly estimated with a deviation term to avoid assuming a fixed spawner-recruitment relationship:

$$R_y = \bar{R} exp\left(RDev_y\right)$$

where $RDev$ is a multiplicative deviation term in log space, and its standard deviation was fixed at a value of 0.38 from a meta-analysis (R package FishLife; Thorson et al. 2017).

### 3.3.6 Landings

Time series (by season) of landings from two fleets were modeled, including the commercial landing fleet and the recreational harvest fleet. Landings were fit in number and were modeled with the Baranov catch equation (Baranov 1918):

$$C_{f,k,t,y} = \frac{F_{f,k,t,y}}{M_{k,t,y} + \sum_f F_{f,k,t,y}} \left(1 - exp\left(-M_{k,t,y} - \sum\nolimits_f F_{f,k,t,y}\right)\right) N_{k,t,y}$$

$$C_{f,t,y}^{pred} = \sum\nolimits_k C_{f,k,t,y}$$

where $C$ is landings. The landings from North Carolina and Virginia were combined for each fleet.

### 3.3.7 Discards

In this assessment, discards from the commercial and recreational fisheries were modeled as separate fleets, and thus, a total of two discard fleets were included, namely the commercial discard fleet and the recreational discard fleet. The discard fleets accounted for only the dead discards. Commercial discard data were available starting in 2004 for North Carolina (section 2.1.2); commercial discard data were unavailable for Virginia. The recreational fishery data only report those fish that were released, and thus a 10% post-release mortality rate was applied to calculate the dead discards from the recreational discard fleet for North Carolina and Virginia (section 2.1.3). As with landings, the discards were fit in number to the time series (by season) of discards and were modeled with the Baranov catch equation, and the data from North Carolina and Virginia were combined for each fleet.

### 3.3.8 Fishing Mortality

For each time series of removals (landings and discards), a separate full seasonal fishing mortality ($F_{f,t,y}$) was estimated. The size-specific fishing mortality ($F_{f,k,t,y}$) was then calculated by multiplying the full seasonal fishing mortality with the corresponding fishery selectivity ($S_{f,b,k}$) for each fleet $f$, time block $b$ (if applicable), and size class $k$:

$$F_{f,k,t,y} = F_{f,t,y} S_{f,b,k} \ .$$

In this assessment, the annual fishing mortality was represented by the sum of the fishing mortalities across fleets and seasons.

### 3.3.9 Abundance Index

The model was fit to two NCDMF indices of relative abundance from the Program 915 fisheries-independent survey, the P915NorthSpring and P915NorthFall indices. Both abundance indices were standardized using a generalized linear model (GLM) approach before being input to the model (Maunder and Punt 2004; section 2.2.1.6). The standardization attempts to reduce the impact of other factors, especially environmental factors on the trend of the index timeseries. Predicted indices ($I$) were conditional on the selectivity of the surveys ($S^{survey}$) and were computed from abundance (number of fish) at the midpoint of the survey time period ($N_{i,k,y}^{survey}$):

$$I_{i,y}^{pred} = q_i \sum\nolimits_k \left(N_{i,k,y}^{survey} S_{i,k}^{survey}\right)$$

$$N_{i,k,y}^{survey} = N_{k,y} exp\left(\frac{month_i}{12}\left(\sum_t\left(-M_{k,t,y} - \sum_f F_{f,k,t,y}\right)\right)\right)$$

where $q$ is the survey catchability and $i$ indexes the $i$th abundance index.

### 3.3.10 Catchability

In the model, the catchability scales the abundance index to the estimated population abundance, conditional on the survey selectivity. In this assessment, catchability ($q$) was assumed to be time-invariant for each survey and all abundance indices were assumed to have a linear relationship to the population abundance. The survey catchability was calculated internally as follows:

$$ln(q_i) = \frac{1}{n_y}\sum_y ln\left(\frac{I_{i,y}^{obs}}{\sum_k N_{i,k,y}^{survey} S_{i,k}^{survey}}\right)$$

where $n_y$ is the total number of years in assessment time period and $I_{i,y}^{obs}$ is the observed abundance index in year $y$ for survey $i$.

### 3.3.11 Selectivity

An asymptotic shaped selectivity was assumed for landing fleets and a dome-shaped selectivity was assumed for discard fleets. The asymptotic-shaped selectivity was modeled using a two-parameter logistic curve and the dome-shaped selectivity was modeled using a six-parameter double-normal curve (Methot and Wetzel 2013).

The minimum size limit for Spotted Seatrout in Virginia has been 14 inches since 1992. The minimum size limit in North Carolina was changed from 12 inches (304.8 mm) to 14 inches (355.6 mm) starting in 2009; however, the length compositions show minimal shift associated with the increase of size limit in 2009. Thus, in the base model, the selectivities of commercial and recreational landing fleets were assumed time-invariant. A model with two time blocks (1991–2008; 2009–2019) for fleet selectivities was included in a sensitivity analysis.

The selectivities of commercial and recreational discard fleets could not be freely estimated because no length composition data were input to the model. Therefore, the selectivities for the two discard fleets were estimated externally and treated as fixed inputs in the model. The selectivity of the commercial discard fleet was estimated based on a length composition from the NCDMF observer data, and the selectivity of the recreational discard fleet was estimated based on a NCDMF tagging study and expert opinions. The selectivities for the winter season mirrored those for the non-winter season, except for the parameter of the first peak in the double normal curve. The value of this parameter for the winter season selectivities was set at a length 15 mm larger than the value for the non-winter season selectivities based on the length information from the observer data.

The selectivity of P915NorthSpring and P915NorthFall surveys were assumed to be asymptotic shaped and time-invariant. Both selectivities were modeled using a logistic function.

### 3.3.12 Length Composition

The model was fit to four length composition time series (by season), including the length compositions from commercial and recreational landings, and the length compositions from

P915NorthSpring and P915NorthFall surveys. There were no length composition data input for discards fleets.

### 3.3.13 Initialization

Initial (1991) numbers at size ($N_{k,t=1,y=1}$) were estimated in the model assuming the proportions at size ($Pas_k$) follows a mixture distribution with three normal distributions ($f_1$, $f_2$ and $f_3$) to account for multiple peaks:

$$N_{k,t=1,y=1} = N_{y=1} Pas_k$$

$$Pas_k = \emptyset_1 f_1(L_k) + \emptyset_2 f_2(L_k) + \emptyset_3 f_3(L_k)$$

where $\emptyset_1 + \emptyset_2 + \emptyset_3 = 1$, and the three normal distributions have different means and variances.

### 3.3.14 Optimization

Model parameters were estimated using a penalized likelihood approach. In the penalized likelihood approach, each data component is assumed to have an error distribution and each observation is assigned a variance so that the observed removals (landings and discards) are fit closely and the observed compositions and abundance indices are fit to a compatible degree. The objective function is the sum of individual log-likelihood components. In this assessment, removals and abundance indices were fit assuming lognormal likelihood. Landings were assumed precise and assigned a minimal observation error with coefficient of variation (CV) = 0.05 for commercial landings and CV = 0.10 for recreational landings. The discards were assigned a larger observation error, with CV = 0.25 for both commercial and recreational discards. The CVs for abundance indices were estimated from the GLM standardization. Length compositions were fit assuming multinomial likelihood with variance described by the effective sample size. For length compositions, the effective sample size for each fleet and survey was the number of sampled trips and a maximum of 200 was imposed to prevent overfitting to composition data.

The deviations (log-scale) for natural mortality of winter season, recruitment, and growth ($L_\infty$ and $K$) were modeled assuming normal likelihood with a mean of zero. Normal priors with a CV of 0.15 were applied for growth parameters ($L_\infty$, $K$, $\sigma_{L\infty}$ and $\sigma_K$) to prevent the gradient-based parameter search routine from drifting into parameter space that yields negligible changes in the likelihood. The means of these normal priors were from the von Bertalanffy growth model that was fit externally using length-age data (section 1.2.4.1).

In the objective function, weight can be assigned to each likelihood component to account for data quality. All likelihood components were initially assigned a weight equivalent to one.

## 3.4 Diagnostics

Multiple measures were applied to assess the model convergence. The Hessian matrix (i.e., matrix of second derivatives of the likelihood with respect to the parameters) was checked to ensure it inverted. The model convergence level was checked to ensure it was less than the convergence criteria (0.0001, common default value). Parameters with estimated values hitting bounds or with excessively high variance (PSE > 50%) were identified. The correlation matrix was evaluated to detect high correlations between parameter estimates. A jitter analysis was performed to evaluate whether the model converged on a global solution (Cass-Calay et al. 2014). In the jitter analysis, initial values for all estimated parameters were randomly jittered by 10% for 100 runs. The total likelihood value, annual estimates of spawning stock biomass and fishing mortality, and stock status (see section 4) from the jitter runs were compared to the base run results.

The model fits were evaluated by comparing the estimates of landings, discards, abundance indices, and length compositions to the observed values via visual inspection. For the fits to the abundance indices, the residuals were calculated and then tested for randomness and normality. The runs test was applied to evaluate whether the residuals are randomly distributed (runs.test function; R Core Team 2021), and the Shapiro-Wilk test was applied to determine whether the residuals are normally distributed (shapiro.test function; R Core Team 2021). A significance level of 0.05 was used for both tests.

A retrospective analysis was also performed to evaluate the consistency of estimates over time, and how recent data changed the perspective of the past (Mohn 1999; Harley and Maunder 2003). Specifically, it evaluates systematic changes in the annual estimates as additional years of data were added (Mohn 1999). The analysis is run by peeling back (removing) one year of data from the end of the time series. The retrospective patterns would not be considered concerning if they are random and do not show a clear bias in any direction. The retrospective error (Mohn's $\rho$) is used to describe the degree of retrospectivity and is calculated as follows (Mohn 1999; Hurtado-Ferro et al. 2015):

$$\text{Mohn's } \rho = \frac{1}{n_{peel}} \sum_{t=terminal\ year-n_{peel}}^{terminal\ year} \frac{X_t|data\ to\ year\ t - X_t|data\ to\ terminal\ year}{X_t|data\ to\ terminal\ year}$$

where $X$ is the variable of interest and $n_{\text{peel}}$ is the total number of years that are "peeled off". Hurtado-Ferro et al. (2015) suggested a range between -0.22 and 0.3 for short-lived species; any values falling outside this range would indicate a concerning retrospective pattern. A positive value of Mohn's $\rho$ for biomass and a negative value for fishing mortality may imply consistent overestimation of biomass and high risk of overfishing. Retrospective patterns may either result from inconsistent or insufficient data or result from natural variation in population dynamics. In this assessment, the base model was run with one year of data removed at a time starting from 2019 until the terminal year reached 2014 ($n_{\text{peel}} = 5$). The estimates of annual fishing mortality and spawning stock biomass ($X$) were evaluated from each retrospective run. Additionally, a series of sensitivity runs were also developed to explore the robustness of the model to some key model inputs and assumptions (See section 3.6).

### 3.5 Base Run Configuration

The base run was configured as described above. Uncertainties in point estimates were investigated through sensitivity analyses.

### 3.6 Sensitivity Analyses

Sensitivity of model outcomes to some key model inputs and assumptions were explored through sensitivity analyses (Table 3.2). Annual estimates of spawning stock biomass, fishing mortality, and recruits were compared to those from the base run.

#### 3.6.1 Data Sources

The contributions of different fisheries-independent surveys were explored by removing the data from each survey one at a time. In each of these runs, the abundance index and length composition data (if applicable) from the survey under evaluation were removed by assigning a lambda weight of 0.0 to their likelihood components.

### 3.6.2 Initial Year

In the base model, the initial year was set to 1991 when the landing data started; however, the abundance index data were not available until 2003. With no abundance index data extending back to the initial year, the estimates for the early time period, especially the initial year, could become highly dynamic and uncertain. To examine the impact of the initial year on model outcomes, a sensitivity run with 2003 as the initial year was conducted.

### 3.6.3 Natural Mortality

In the base model, the annual average natural mortality was set to 0.6 based on a meta-analysis. Additionally, two sensitivity runs were performed to explore the impact of the annual average natural mortality on model outcomes, one run with a lower value of 0.4 and the other with a higher value of 0.8. A ratio of 2:1, the same as in the base model, was used to split this annual average natural mortality to the seasonal average natural mortalities for the winter and non-winter seasons in these two sensitivity runs.

### 3.6.4 Recreational Discards for Non-Winter Season 2018

In the base model, the input value for recreational discards in Season 1 (non-winter season) of 2018 was 1,863.527 thousands of fish. This input value was the highest across the whole assessment time period and approximately three times higher than the average (521.951 thousands of fish) discards within the previous five years (2013–2017). Removal from the recreational fishery dominates the total removal from the Spotted Seatrout stock. The input for 2018 may have affected the estimates for the terminal year 2019 and therefore its stock status determination. Thus, this extremely high input value for 2018 raised concerns over its impacts on model outcomes. A sensitivity run with a lower input value that equaled to 521.951 thousands of fish was conducted.

### 3.6.5 Time Block Fleet Selectivity

In the base model, no time blocks were set up for fleet selectivity due to no substantial shift in observed size distribution after the minimum size limit was changed in North Carolina in 2009. A sensitivity run with two time blocks was conducted to explore the impacts of time blocks on model outcomes. In the sensitivity run, for each fleet in a given season, its selectivity had two time blocks, i.e., the time block 1991–2008 during which the minimum size limit in North Carolina was 12 inches (304.8 mm) and the time block 2009–2019 during which the minimum size limit in North Carolina increased to 14 inches (355.6 mm). The same as in the base model, all selectivity parameters for landing fleets were free parameters to estimate, and all those for discard fleets were fixed input. The parameter setup for the first time block was the same as in the base model for the fleet in a given season. The parameter setup for the second time block was the same as the first time block except that the parameter controlling the location of the selectivity curve was increased by 50 mm to reflect the increase in minimum size limit. These parameters included the parameter for the length at 50% selection of a logistic curve for landing fleets and the parameter for the first peak of a double-normal curve for discard fleets.

## 3.7 Results

### 3.7.1 Base Model—Diagnostics

The base model was considered converged given an inverted Hessian matrix, no parameters hitting bounds or with excessively high variance, no high correlation between parameters, and a reasonably small convergence level of 0.0094. Although this convergence level was higher than the commonly used criteria (0.0001), a value less than one is typically deemed acceptable for such complex models with hundreds of parameters to estimate. Eighty-eight of the 100 jitter runs successfully converged. None of the converged jitter runs resulted in a total negative log-likelihood value that was significantly lower than the base model (Figure 3.1). Although 14 of the 100 jitter runs produced a slightly lower total negative log-likelihood value than the base model, the difference was less than three and thus was not considered statistically significant. This difference in the total negative log-likelihood values was contributed by a slightly better fit to the length compositions of the commercial and recreational landing fleets from these 14 runs. Most of the converged jitter runs predicted similar trends in SSB and $F$ to the base model (Figure 3.2). Overall, the jitter analysis provides evidence that the base model converged to the global solution.

The base model fit the landings and discards well (Figures 3.3–3.6). The fits to the fisheries-independent survey indices were reasonable (Figures 3.7 and 3.8). The predicted indices captured the overall trends in the observed data. The runs test and the Shapiro-Wilk test on the residuals (log-scale) produced non-significant $P$-values for both P915NorthSpring and P915NorthFall indices at a significance level of 0.05 (Table 3.3). These results suggested the residuals were randomly distributed with no statistically significant temporal patterns or departures from a normal distribution.

The fits to the length compositions were reasonable for most of the fleets and surveys except for RecLanding Season 2 (Figures 3.9–3.14). The fits to the length compositions in individual years appeared reasonable for most of the years. The poor fits to the length compositions for RecLanding Season 2 and for some years in other fleets and surveys were likely due, in part, to the small effective sample size.

### 3.7.2 Base Model—Predicted Population Dynamics

The predicted selectivities for the landing fleets and the surveys were considered reasonable (Figures 3.15 and 3.16, 3.19 and 3.20). The selectivities for the discard fleets were fixed inputs (Figures 3.17 and 3.18). Overall, fish of the same size were more likely to be selected in Season 1 than Season 2 for most fleets except the recreational landing fleet. The fish smaller than 360 mm were more likely to be caught in Season 2 than Season 1.

Model predictions of annual fishing mortality showed a declining trend over time (Figure 3.21). The predicted fishing mortality was higher and more variable from 1991 through 2004. During this time period, a sharp decrease in fishing mortality estimates occurred in 1998. After 2004, the fishing mortality estimates decreased to a lower level with less variability compared to the earlier time period. An increase in fishing mortality was predicted for the terminal year 2019 with large uncertainty.

The size-averaged natural mortality estimates for the winter season showed great inter-annual variability (Figure 3.22). The model predicted high or rising winter natural mortality in years 1991, 1995, 1999–2000, 2002, 2006–2007, 2009–2010, 2013–2014, 2017, and 2019. This annual trend captured most of the identified cold-stun years except one year (2004). The size-specific natural mortality for individual years showed the winter season had higher natural mortality than the non-winter season and this seasonal difference became more evident for smaller fish (Figure 3.23).

The annual predicted recruitment varied among years and showed a general increasing trend over the assessment time period (Figure 3.24). The predicted recruitment was higher and more variable during the time period after 2004 (2005–2019). The annual predicted spawning stock biomass showed a general increasing trend over the assessment time period (Figure 3.25). Similar to recruitment, higher spawning stock biomass with greater variation was predicted for the time period after 2004. The predicted abundance also demonstrated strong year classes and high abundances through the years after 2004 (Figure 3.26).

The model predicted growth parameters varied moderately among years (Figures 3.27 and 3.28). The predicted $L_\infty$ remained around 1,000 mm. The predicted $K$ averaged around 0.2 with a slow decrease over time. Seasonal growth for individual years showed growth mostly occurred in the non-winter season and the difference in growth between seasons became more evident for smaller fish (Figure 3.29).

### 3.7.3 Retrospective Analysis

Retrospective analysis showed terminal year fishing mortality was consistently overestimated and terminal year spawning stock biomass was consistently underestimated (Table 3.4; Figure 3.30). The relative bias in terminal year fishing mortality and spawning stock biomass was low when peeling back to 2014, substantially increased when peeling back to 2015– 2017, and became larger when peeling back to 2018. Adding 2019 data seemed to have an essential impact on the predicted fishing mortality and spawning stock biomass, especially during the most recent five years (2015–2019). With 2019 data added, the fishing mortality estimates during 2015–2019 were substantially lowered and the spawning stock biomass estimates during this time period were greatly elevated. The Mohn's $\rho$ values for fishing mortality and spawning stock biomass were 0.762 and -0.284, respectively. Both values are outside the recommended range of -0.22 to 0.3 for short-lived species and suggest a strong retrospective pattern.

### 3.7.4 Sensitivity Analyses

Removal of either P915NorthFall or P915NorthSpring survey data had minimal impact on predicted fishing mortality, spawning stock biomass, and recruitment (Figure 3.31). Initializing the base model from year 2003 when the survey data become available yielded higher fishing mortality estimates and lower spawning stock biomass estimates during 2004–2010 compared to the base model (Figure 3.32). Otherwise, the predicted fishing mortality and spawning stock biomass after 2010 and the predicted recruitment during the assessment period from this scenario were quite similar to those from the base model.

Changes in natural mortality led to similar trends in outcomes to the base model (Figure 3.33). Increased natural mortality led to lower fishing mortality estimates and higher spawning stock biomass and recruitment estimates.

Overall, a low input value of 2018 Season 1 recreational discards produced almost identical trends in outcomes compared to the base model (Figure 3.34). The predicted fishing mortality during 1999–2002 declined in this scenario compared to an increased trend in the base model.

This discrepancy was likely contributed by the difference in the trends of growth estimates during this time period between this scenario and the base model.

When two time blocks were set up for fleet selectivity, similar trends in outcomes were produced compared to the base model (Figure 3.35). The time block selectivity assumption led to lower fishing mortality estimates than the base model for the time period before 2009 and for the terminal year of 2019. The predicted fishing mortality during 2009–2018 from this scenario was almost identical to that from the base model. The time block selectivity assumption also resulted in higher spawning stock biomass estimates and slightly higher recruitment estimates during the entire assessment period.

### 3.8 Discussion of Results

Performance of the stock assessment model was considered reasonable in terms of predicting the observed data. The quality of the fits strongly depends on data quality that is reflected by the input variance and effective sample size. The fits to the observed landing and discard data were better than the fits to the survey indices, which was expected given the lower variance assumed for these data sources. The P915NorthFall index was fit better than the P915NorthSpring index due to its 33% smaller variance input on average. The model outcomes were insensitive to the removal of either survey's data, suggesting these two data sources share consistent information. The stock status determination for the terminal year was insensitive to the removal of either survey's data.

The stock assessment model was able to capture the signal from cold-stun events, which was a major concern from both the 2009 and 2015 NCDMF stock assessments and has been one of the major interests for this assessment. Without specifying cold-stun years as inputs in the model, the predicted natural mortality for the winter season was able to track the cold-stun signals for most years. The assumptions regarding the seasonal time step and nonstationary biological processes were essential to allow for the estimation of variation in winter natural mortality in this assessment. This type of modeling practice has not been successfully attempted in the previous assessments of this species or other state-managed species. This model can be easily applied to other species that experience strong seasonal dynamics in fishing and biological processes.

Developing an assessment model that can capture the cold-stun signal was a major interest in this assessment and thus, an extensive effort was attempted to explore alternative approaches. One of the approaches was to directly input the natural mortality estimates from a tagging model. The tagging model was fit externally to the tag-recapture data collected by North Carolina State University (NCSU) and NCDMF from 2008 to 2019. The tagging model was fit using a Bayesian approach and a three-month time step. Several attempts were made to incorporate the tagging model estimates including having tagging estimates as fixed input, incorporating tagging estimates as an environmental factor to guide the estimation of natural mortality deviation, and using tagging estimates to inform the seasonal average natural mortality; however, these attempts were unsuccessful. In these attempts, the assessment model yielded either unrealistic population estimates (e.g., extremely high $L_\infty$ or $K$) or a collapsed population, which indicated there was conflicting information in the input or the assumptions. Natural mortality estimates for the winter season from the tagging model were extremely variable interannually and had large uncertainty, ranging from 0.002 to 2.346 with an average of 0.9 and a standard deviation of 0.9. These three-month estimates were also extremely high when compared to an annual scale estimate of 0.6 from a meta-analysis for this species. Given such high values of natural mortality and high variability, the population in the model would be difficult to sustain.

The tagging model and this assessment model have different assumptions and use different data sources. For example, the tagging data for Spotted Seatrout covered less than half of the whole assessment time period and only involved fish of certain sizes (280 mm–760 mm). Therefore, the estimated trends from these two types of models may be more comparable than their absolute values. The trends in the winter natural mortality from these two models were consistent. Given that tagging data could provide valuable auxiliary information in stock assessments, future effort may focus on integrating the tagging model as a sub-model into the stock assessment model so that both tagging data and assessment data can inform the population dynamics at the same scale in a coherent system.

Other approaches explored with an attempt to model cold-stun events was to use winter water temperature (cumulative degree days below 5ºC, CDD). One approach was to directly use the CDD as an environmental factor to guide the estimation of natural mortality deviation. Another approach was to predict the natural mortality value for a given winter water temperature based on a linear regression relationship developed by Ellis et al. (2017a) and then use these predicted values as fixed input in the model. These approaches predicted extremely variable and high values of natural mortality and suffered the same problem as with the tagging estimates. Predicting natural mortality solely based on water temperature may not be appropriate because the natural mortality in the model is often a result of a combination of multiple factors, among which cold winter temperature is only one single factor. Other factors may include predation, intra- and inter-species competition, resource availability, habitat quality, and environmental stochasticity such as hurricanes and salinity change. Also, the severity of cold-stun events is variable with some affecting large geographic range and others being more localized and acute (within 24 hours), and thus its impact at population level and annual time scale is still largely unknown and likely variable.

Due to different model structure, assumptions, and data input, it is not possible to compare results from this assessment with the 2015 assessment. The recreational harvest and discards input in this assessment were three times higher than those in the 2015 assessment due to the new MRIP calibration process. Regardless of the differences between these two assessments, the stock status determination for 2012—the terminal year in 2015 assessment—was consistent. The 2012 stock was not overfished, and overfishing was not occurring, but was approaching the threshold.

Trends in predicted fishing mortality, recruitment, spawning stock biomass, and abundance showed a shift in population dynamics around the year of 2004 when the index survey data became available. For example, the fishing mortality shifted from a high level during a time period around 1991–2004 to a low level during a time period around 2005–2019. In this assessment, the model was informed by both fishery and survey data after 2003, before which the model was probably heavily informed by the fishery data only. The fishery data in this assessment, especially the discard data and the recreational landing data, showed such a shift corresponding to the shift in these model results.

Among numerous sensitivity runs, including those in this report, stock status for the terminal year consistently indicates that overfishing is occurring. Although the stock status of being not overfished was determined in most of sensitivity runs, there were a few scenarios suggesting the opposite. For example, in the scenario with initial year of 2003 (Ini2003), the terminal year stock was determined overfished, although the 2019 spawning stock biomass estimate (2,475.647 metric tons) was fairly close to the threshold (2,701.429 metric tons). In the base model, a longer time series of landing and discard data were used, and these data showed a shift around 2004 as discussed above. Excluding these fishery data during the early time period in the Ini2003 scenario led to the data time series being lack of contrast and the model being incapable of capturing the potential shift in population dynamics, and further resulted in different outcomes (e.g., difference in estimated growth, fishing mortality, spawning stock biomass, and stock status).

Although the retrospective analysis in this assessment showed strong retrospective patterns in the predicted fishing mortality and spawning stock biomass, it is less concerning in terms of management risk in this assessment. Based on the results, this assessment model was consistently overestimating fishing mortality and underestimating spawning stock biomass. Thus, theoretically, a lower estimate of fishing mortality and a higher estimate of spawning stock biomass would be expected for 2019 after adding future data, and the management based on this assessment would be more conservative. Management risk caused by strong retrospective patterns has often been more of a concern in cases where the assessment model is consistently underestimating fishing mortality and overestimating spawning stock biomass. In these cases, the stock is most likely to collapse and least likely to meet the management goals if management practices are made based on the results without adjustment for the retrospective patterns (Huynh et al. 2022). Various approaches have been proposed to inform management decisions when strong retrospective patterns emerge in stock assessment, such as the model averaging (Stewart and Hicks 2018) and the adjustment for Mohn's ρ (Miller and Legault 2017); however, the performances of these approaches are mixed on a case-by-case basis (Huynh et al. 2022). Identifying causes of retrospective patterns is challenging due to multiple confounding factors (e.g., nonstationary processes and selectivity assumptions) and insufficient data (Legault 2020; Huynh et al. 2022). The strong retrospective patterns in this assessment were likely partially caused by 2019 data. Before adding 2019 data, the relative biases in the predicted fishing mortality and spawning stock biomass from the other retrospective runs were quite small. The input data showed the recreational harvest for 2019 were historically the highest, and the abundance index values for 2019 were also among the highest values. Given that this fishery is heavily dominated by recreational fishing, such high input values for the 2019 recreational fishery may have led to the high estimate of spawning stock biomass in 2019 even though the stock is undergoing overfishing.

In this type of seasonal, size-structured model, the model behaviors might be complicated by the interaction among the nonstationary natural mortality, the nonstationary growth, size-based selectivity, and the interaction in the dynamics between seasons. Exploratory runs indicate the model could become more robust and predictable with the estimation of growth parameters stabilized and less variable. In this assessment, a small value of 0.04 was selected for the standard deviation of the annual deviation of the time-varying growth parameters through a likelihood profiling, in which a series of values ranging from 0.01 to 0.2 were tested. With such a small value, the estimated growth patterns were able to vary over time while still remaining within a biological meaningful range and make scenarios more comparable.

## 4 STATUS DETERMINATION CRITERIA

The General Statutes of North Carolina define overfished as "the condition of a fishery that occurs when the spawning stock biomass of the fishery is below the level that is adequate for the recruitment class of a fishery to replace the spawning class of the fishery" (NCGS § 113-129). The General Statues define overfishing as "fishing that causes a level of mortality that prevents a fishery from producing a sustainable harvest."

The North Carolina Spotted Seatrout FMP defines the stock's thresholds in terms of 20% spawning potential ratio (SPR; NCDMF 2012b). Targets for the stock are based on 30% SPR. These reference points were adopted in this assessment. The base model was used to estimate reference points and to determine the stock status for the stock. The stock is overfished if $SSB/SSB_{20\%}$ is less than one, and overfishing is occurring if $F/F_{20\%}$ is greater than one. In this assessment, the benchmarks are conditional on the estimated selectivity patterns and biological parameters. The selectivity pattern used here was the average selectivity at size across fleets.

Due to the large uncertainty in the terminal year (2019) estimates in this assessment, a weighted average of the estimates over the most recent three years (2017–2019) was used to best represent the terminal year estimate for determination of stock status. The estimates of 2017–2019 from the base model were weighted by the inverse of their CV values before calculating the average. The threshold and target values for the terminal year were also averaged over 2017–2019. The resulting estimated $F$ threshold, $F_{20\%}$, and the $F$ target, $F_{30\%}$, were 0.60 and 0.38 respectively, and the estimated terminal year $F$ was 0.75 (all based on 2017–2019 averages). Thus, the estimated $F/F_{20\%}$ for the terminal year is greater than one (1.3), suggesting the stock is currently experiencing overfishing (Figures 4.1 and 4.2). The stock has been centering around the overfishing threshold from 2007 through 2019. In the base model, the estimated SSB threshold ($SSB_{20\%}$) and the SSB target ($SSB_{30\%}$) for the terminal year (based on 2017–2019 averages) were 1,143 and 1,714 metric tons respectively, and the estimated terminal year SSB was 2,259 metric tons (based on 2017–2019 average). Therefore, the estimated $SSB/SSB_{20\%}$ for the terminal year is greater than one (2.0), suggesting the stock is not currently overfished. The stock has not been overfished since 2007. Overall, results showed the stock had consistently been overfished and overfishing had been occurring until 2007 and has greatly improved since then.

## 5 SUITABILITY FOR MANAGEMENT

Stocks assessments performed by the NCDMF in support of management plans are subject to an extensive review process. External reviews are designed to provide an independent peer review and are conducted by experts in stock assessment science and experts in the biology and ecology of the species. The goal of the external review is to ensure the results are based on sound science and provide a valid basis for management.

The review workshop allows for discussion between the working group and review panel, enabling the reviewers to ask for and receive timely updates to the models as they evaluate the sensitivity of the results to different model assumptions. The workshop also allows the public to observe the peer review process and better understand the development of stock assessments.

The external peer review panel met with the working group in person August 30–September 1, 2022. The external peer review panel recommended the base model (i.e., the seasonal size-structured model) as the best scientific information available and suitable for management advice for the next five years. The reviewers agreed the determination of the spotted seatrout stock status concurs with professional opinion and observations and suggested using an average of the most recent three years as the best representation of the terminal-year estimates for fishing mortality and spawning stock biomass. The reviewers also agreed that: (1) the justification of inclusion and exclusion of data sources are appropriate; (2) the data sources used in this assessment are appropriate; (3) the base model is a step forward for incorporating nonstationary natural mortality and seasonal variability to capture the cold-stun signal; (4) determination of stock status is overall robust to model assumptions and configurations that have been explored in sensitivity analyses and during the peer-review workshop. The reviewers expressed concerns over the potential overparameterization of the nonstationary growth assumption, the constant live-release mortality assumption for the recreational fishery, and the fixed constant CV input for recreational landings and discards fleets, and the reviewers recommended further investigation in the future. The reviewers also recommended: (1) integration of tagging data in the assessment model being given high priority; (2) exploration of potentially incorporating the P120 juvenile survey data and age composition data in the assessment model; (3) conducting a continuity run with the age-structured model (Stock Synthesis) to compare with this new size-structured base model; (4) improving understanding of live-release mortality and size structure of discards; (5) validating model with existing data. Detailed comments from the external peer reviewers are provided in Appendix.

# 6 RESEARCH RECOMMENDATIONS

The following research recommendations are offered (ranked by priority) to improve the next assessment of the North Carolina and Virginia Spotted Seatrout stock:

*High*

- Test and validate the newly developed size-structured model with known data sets and a simulation study that compares this size-structured model with an age-structured model
- Collect data to characterize annual length distributions of commercial discards and recreational releases to inform selectivity parameterization
- Develop a fishery-independent survey for Virginia waters
- Develop a winter-season survey to capture population dynamics in that period, including collection of length composition data
- Integrate tagging data into stock assessment model so both tagging data and other data sources can work together to give a better picture of the population
- Implement a year-round, fisheries-independent juvenile survey
- Improve estimates of recreational discard mortality

*Medium*

- Conduct a detailed analysis of the existing Program 915 data to determine the extent to which late fall and spring provide insights into overwinter changes in abundance; this analysis could also provide insights into the magnitude of cold-stun events, which could explain differences in the effects observed in tagging and telemetry studies versus survey and fishery monitoring

- Incorporate empirically estimated errors for the recreational landings and live releases, if possible
- Compare maturity ogives between North Carolina and Virginia
- Develop estimates of commercial discards for runaround nets

*Low*

- Conduct additional work to evaluate more fully the utility of the Program 120 survey; including the recruitment index data may require a higher variance to accommodate the large fluctuations observed in the survey
- Improve estimates of commercial discard mortality
- Conduct an age validation study

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# 8 TABLES

**Table 1.1.** Estimated parameter values of the von Bertalanffy age-length model fit to Spotted Seatrout data from this and previous studies, where length is measured in millimeters.

| Location | Collection Dates | Gear | Structure | Sex | n | $L_\infty$ | $K$ | $t_0$ | Reference |
|---|---|---|---|---|---|---|---|---|---|
| Galveston Bay, Texas | October 1981–September 1982 | exp gill nets (most) and hook and line | sectioned otoliths | Female | | 687 | 0.512 | -0.260 | Maceina et al. 1987 |
| Galveston Bay, Texas | October 1981–September 1982 | exp gill nets (most) and hook and line | sectioned otoliths | Male | | 664 | 0.179 | 1.939 | Maceina et al. 1987 |
| Charlotte Harbor, Florida | February 1986–January 1988 | hook and line, seine, gill and trammel nets | sectioned otoliths | Female | 1,102 | 698 | 0.363 | 0.39 | Murphy and Taylor 1994 |
| Indian River Lagoon, Florida | February 1986–January 1988 | hook and line, seine, gill and trammel nets | sectioned otoliths | Female | 1,195 | 839 | 0.362 | 0.74 | Murphy and Taylor 1994 |
| Apalachicola Bay, Florida | March 1986–January 1988 | hook and line, seine, gill and trammel nets | sectioned otoliths | Female | 797 | 818 | 0.350 | 0.68 | Murphy and Taylor 1994 |
| Virginia/North Carolina | 1991–2013 | various | sectioned otoliths | Female | 10,914 | 794 | 0.341 | -0.588 | NCDMF 2015 |
| Virginia/North Carolina | 1991–2013 | various | sectioned otoliths | Male | 6,764 | 669 | 0.314 | -0.938 | NCDMF 2015 |
| Virginia/North Carolina | 1991–2019 | various | sectioned otoliths | Female + unknown | 14,664 | 868 | 0.263 | -0.856 | This study |
| Virginia/North Carolina | 1991–2019 | various | sectioned otoliths | Male + unknown | 9,014 | 677 | 0.293 | -1.11 | This study |
| Virginia/North Carolina | 1991–2019 | various | sectioned otoliths | Pooled | 24,386 | 885 | 0.217 | -0.975 | This study |

**Table 1.2.** Estimated parameter values of the length-weight function fit to Spotted Seatrout data from this and previous studies, where length is measured in millimeters and weight is measured in grams.

| Location | Collection Dates | Gear | Sex | n | Length Type | *a* | *b* | Reference |
|---|---|---|---|---|---|---|---|---|
| Indian River Lagoon, Florida | February 1986–January 1988 | hook and line, seine, gill and trammel nets | Female | 1,194 | TL | 5.75E-06 | 3.12 | Murphy and Taylor 1994 |
| Indian River Lagoon, Florida | February 1986–January 1988 | hook and line, seine, gill and trammel nets | Male | 605 | TL | 4.76E-06 | 3.17 | Murphy and Taylor 1994 |
| Apalachicola Bay, Florida | March 1986–January 1988 | hook and line, seine, gill and trammel nets | Female | 1,229 | TL | 1.47E-05 | 2.86 | Murphy and Taylor 1994 |
| Apalachicola Bay, Florida | March 1986–January 1988 | hook and line, seine, gill and trammel nets | Male | 608 | TL | 1.68E-05 | 2.81 | Murphy and Taylor 1994 |
| southeastern Louisiana coastal areas | January 1975–December 1978 | trawl, cast net, hook and line, hoop net, gill net, seine, and trammel net | All | 1,208 | TL | 5.40E-06 | 3.15 | Hein et al. 1980 |
| Virginia/North Carolina | 1991–2013 | various | Female | 10,242 | FL | 1.07E-05 | 3.00 | NCDMF 2015 |
| Virginia/North Carolina | 1991–2013 | various | Male | 6,909 | FL | 8.59E-06 | 3.05 | NCDMF 2015 |
| Virginia/North Carolina | 1991–2019 | various | Female | 13,264 | FL | 1.18E-05 | 2.98 | This study |
| Virginia/North Carolina | 1991–2019 | various | Male | 9,249 | FL | 7.79E-06 | 3.04 | This study |
| Virginia/North Carolina | 1991–2019 | various | Pooled | 50,612 | FL | 1.23E-05 | 2.98 | This study |

**Table 1.3.** Table of seasonal estimates of median natural mortality (*M*), lower and upper credibility intervals from the working group's tag-return model (2021). Greyed-out rows below represent time steps in which no tags were released.

| Season (time step) | Lower CI | Median *M* | Upper CI |
|---|---|---|---|
| Autumn 2008 | 0.000057 | 0.0035 | 0.29 |
| Winter 2008 | 0.00014 | 0.46 | 0.94 |
| Spring 2009 | 0.000068 | 0.072 | 0.86 |
| Summer 2009 | 0.000058 | 0.0048 | 0.40 |
| Autumn 2009 | 0.000055 | 0.0027 | 0.24 |
| Winter 2009 | 0.94 | 1.5 | 2.1 |
| Spring 2010 | 0.000056 | 0.0037 | 0.34 |
| Summer 2010 | 0.000054 | 0.0017 | 0.12 |
| Autumn 2010 | 1.6 | 2.3 | 3.1 |
| Winter 2010 | 0.00021 | 0.58 | 1.3 |
| Spring 2011 | 0.000058 | 0.0050 | 0.40 |
| Summer 2011 | 0.0013 | 0.34 | 0.63 |
| Autumn 2011 | 0.000056 | 0.0037 | 0.23 |
| Winter 2011 | 0.000058 | 0.0055 | 0.36 |
| Spring 2012 | 0.28 | 0.82 | 1.2 |
| Summer 2012 | 0.000072 | 0.18 | 1.3 |
| Autumn 2012 | 0.000063 | 0.023 | 1.6 |
| Winter 2012 | 0.000061 | 0.020 | 1.9 |
| Spring 2013 | 0.000062 | 0.022 | 2.1 |
| Summer 2013 | 0.000060 | 0.017 | 2.2 |
| Autumn 2013 | 0.000060 | 0.013 | 2.2 |
| Winter 2013 | 0.000060 | 0.012 | 2.0 |
| Spring 2014 | 0.000058 | 0.0079 | 1.5 |

**Table 1.3.** (*continued*) Table of seasonal estimates of median natural mortality (*M*), lower and upper credibility intervals from the working group's tag-return model (2021). Greyed-out rows below represent time steps in which no tags were released.

| Season (time step) | Lower CI | Median *M* | Upper CI |
|---|---|---|---|
| Summer 2014 | 0.000057 | 0.0058 | 1.0 |
| Autumn 2014 | 0.000057 | 0.0031 | 0.30 |
| Winter 2014 | 0.000080 | 0.48 | 1.5 |
| Spring 2015 | 0.000059 | 0.0095 | 0.95 |
| Summer 2015 | 0.000059 | 0.010 | 0.97 |
| Autumn 2015 | 0.000058 | 0.0067 | 0.58 |
| Winter 2015 | 0.00070 | 1.7 | 2.6 |
| Spring 2016 | 0.000068 | 0.12 | 2.1 |
| Summer 2016 | 0.000082 | 0.24 | 0.95 |
| Autumn 2016 | 0.000059 | 0.010 | 0.49 |
| Winter 2016 | 0.000062 | 0.023 | 0.79 |
| Spring 2017 | 0.0028 | 0.73 | 1.2 |
| Summer 2017 | 0.000054 | 0.0015 | 0.090 |
| Autumn 2017 | 0.000071 | 0.19 | 1.3 |
| Winter 2017 | 0.0035 | 1.7 | 2.5 |
| Spring 2018 | 0.000061 | 0.015 | 1.4 |
| Summer 2018 | 0.000055 | 0.0023 | 0.19 |
| Autumn 2018 | 0.58 | 0.97 | 1.4 |
| Winter 2018 | 0.000054 | 0.0022 | 0.15 |
| Spring 2019 | 0.42 | 0.80 | 1.1 |
| Summer 2019 | 0.000071 | 0.077 | 0.50 |
| Autumn 2019 | 0.000058 | 0.0071 | 0.33 |
| Winter 2019 | 0.000063 | 0.036 | 2.3 |

**Table 1.4.** Total mortality of Spotted Seatrout in commercial gill nets by mesh size reported in Price and Gearhart (2002).

| Mesh Size (in) | n | Mortality |
|---|---|---|
| 2.5 | 48 | 90.0% |
| 3.0 | 70 | 90.0% |
| 3.5 | 71 | 77.0% |
| 4.0 | 57 | 67.0% |
| 4.5 | 29 | 66.0% |

**Table 1.5.** Total, at-net, and delayed mortality of Spotted Seatrout in commercial small-mesh gill nets by season reported in Price and Gearhart (2002).

| | Spring/Summer | Fall/Winter |
|---|---|---|
| **Total Mortality** | 82.7% | 73.8% |
| **At-Net Mortality** | 76.2% | 61.7% |
| **Delayed Mortality** | 28.9% | 31.7% |

**Table 1.6.** At-net mortality of Spotted Seatrout caught in Program 915 (mesh sizes 3–4.5" combined) by month reported in NCDMF (2012a).

| Month | Mortality | n |
|---|---|---|
| February | 20.0% | 15 |
| March | 35.0% | 31 |
| April | 40.0% | 95 |
| May | 53.0% | 185 |
| June | 75.0% | 134 |
| July | 76.0% | 110 |
| August | 74.0% | 99 |
| September | 87.0% | 224 |
| October | 64.0% | 198 |
| November | 37.0% | 186 |
| December | 17.0% | 63 |
| **Total** | 60.0% | 1,340 |

**Table 1.7.** Delayed mortality rates of Spotted Seatrout for high salinity (Outer Banks) and low salinity (rivers) areas reported in Price and Gearhart (2002).

| | **Outer Banks** | **Rivers** |
|---|---|---|
| **Spring/Summer** | 41.7% | 23.1% |
| **Fall/Winter** | 36.4% | 26.3% |

**Table 1.8.** Summary of recreational fishery release mortality estimates from a review of the literature.

| **Location** | **Mortality Estimate** | **Notes** | **Reference** |
|---|---|---|---|
| Texas | up to 55.6% | artificial and natural baits | Matlock and Dailey 1981 |
| Texas | 7.30% | artificial and natural baits | Matlock et al. 1993 |
| Texas | 37.0% | artificial and natural baits | Hegen et al. 1983 |
| Texas | 11.0% | artificial and natural baits | Stunz and McKee 2006 |
| Florida | 4.60% | hook and line | Murphy et al. 1995 |
| Louisiana | 17.5% | artificial and natural baits | Thomas et al. 1997 |
| Alabama | 14.1% | treble hooks (1994) | Duffy 2002 |
| Alabama | 16.3% | single hooks (1994) | Duffy 2002 |
| Alabama | 9.10% | treble hooks (1995) | Duffy 2002 |
| Alabama | 14.6% | single hooks (1995) | Duffy 2002 |
| North Carolina (River & Outer Banks sites in Pamlico, Core, & Roanoke sounds) | 14.8% | artificial and natural baits | Gearhart 2002 |
| North Carolina (Neuse River) | 25.2% | artificial and natural baits | Brown 2007 |

**Table 2.1.** Number of Spotted Seatrout lengths sampled from Virginia's commercial fisheries by season, 1991–2019. Season 1 is March through November and season 2 is December through February.

| Fishing Year | Season 1 | Season 2 |
|---|---|---|
| 1991 | 864 | 4 |
| 1992 | 311 | 0 |
| 1993 | 254 | 0 |
| 1994 | 680 | 8 |
| 1995 | 257 | 0 |
| 1996 | 71 | 9 |
| 1997 | 194 | 1 |
| 1998 | 537 | 28 |
| 1999 | 1,379 | 21 |
| 2000 | 181 | 2 |
| 2001 | 174 | 33 |
| 2002 | 491 | 0 |
| 2003 | 97 | 0 |
| 2004 | 184 | 0 |
| 2005 | 228 | 0 |
| 2006 | 698 | 114 |
| 2007 | 284 | 0 |
| 2008 | 205 | 0 |
| 2009 | 347 | 1 |
| 2010 | 231 | 0 |
| 2011 | 483 | 19 |
| 2012 | 776 | 0 |
| 2013 | 253 | 241 |
| 2014 | 646 | 616 |
| 2015 | 342 | 10 |
| 2016 | 852 | 4 |
| 2017 | 1,383 | 18 |
| 2018 | 876 | 13 |
| 2019 | 2,104 | 0 |

**Table 2.2.** Number of Spotted Seatrout lengths sampled from North Carolina's commercial fisheries by season, 1991–2019. Season 1 is March through November and season 2 is December through February.

| Fishing Year | Season 1 | Season 2 |
|---|---|---|
| 1991 | 1,098 | 332 |
| 1992 | 1,681 | 347 |
| 1993 | 1,039 | 116 |
| 1994 | 598 | 435 |
| 1995 | 1,328 | 162 |
| 1996 | 630 | 30 |
| 1997 | 3,098 | 362 |
| 1998 | 3,649 | 698 |
| 1999 | 4,314 | 1,091 |
| 2000 | 1,701 | 233 |
| 2001 | 1,142 | 353 |
| 2002 | 2,575 | 958 |
| 2003 | 1,032 | 335 |
| 2004 | 1,638 | 638 |
| 2005 | 1,324 | 168 |
| 2006 | 3,969 | 2,005 |
| 2007 | 4,322 | 1,692 |
| 2008 | 3,463 | 740 |
| 2009 | 4,471 | 2,148 |
| 2010 | 1,546 | 354 |
| 2011 | 926 | 200 |
| 2012 | 2,866 | 2,235 |
| 2013 | 3,041 | 862 |
| 2014 | 1,758 | 1,071 |
| 2015 | 885 | 440 |
| 2016 | 2,237 | 530 |
| 2017 | 1,543 | 404 |
| 2018 | 434 | 99 |
| 2019 | 2,046 | 996 |

**Table 2.3.** Annual commercial fishery landings (metric tons) of Spotted Seatrout by state and season, 1991–2019.

| Fishing Year | North Carolina | | Virginia | | Combined | |
|---|---|---|---|---|---|---|
| | Season 1 | Season 2 | Season 1 | Season 2 | Season 1 | Season 2 |
| 1991 | 245.1 | 89.78 | 9.28 | 0.77 | 254.4 | 90.55 |
| 1992 | 172.8 | 45.92 | 3.93 | 0.08 | 176.7 | 46 |
| 1993 | 152.8 | 68.34 | 16.62 | 0.56 | 169.5 | 68.9 |
| 1994 | 123.3 | 94.07 | 19.75 | 0.54 | 143.1 | 94.62 |
| 1995 | 141.8 | 103.6 | 11.9 | 1.19 | 153.7 | 104.8 |
| 1996 | 45.53 | 19.21 | 1.83 | 0.13 | 47.36 | 19.34 |
| 1997 | 77.86 | 26.09 | 5.05 | 0.25 | 82.91 | 26.34 |
| 1998 | 114.8 | 54.29 | 9.21 | 0.8 | 124.0 | 55.09 |
| 1999 | 161.1 | 145.1 | 16.83 | 0.67 | 178.0 | 145.8 |
| 2000 | 57.03 | 30.12 | 8.81 | 0.02 | 65.84 | 30.13 |
| 2001 | 29.73 | 11.04 | 8.87 | 0.51 | 38.6 | 11.55 |
| 2002 | 54.22 | 46.77 | 3.88 | 0.06 | 58.1 | 46.82 |
| 2003 | 42.67 | 22.68 | 2.39 | 0.03 | 45.07 | 22.71 |
| 2004 | 38.4 | 19.4 | 4.75 | 0.05 | 43.15 | 19.46 |
| 2005 | 40.25 | 15.97 | 7.31 | 0.51 | 47.56 | 16.48 |
| 2006 | 101.1 | 73.79 | 21.14 | 1.96 | 122.2 | 75.75 |
| 2007 | 105.7 | 41.82 | 16.11 | 0.78 | 121.8 | 42.6 |
| 2008 | 90.27 | 54.16 | 20.3 | 0.33 | 110.6 | 54.49 |
| 2009 | 93.99 | 70.57 | 10.9 | 0.5 | 104.9 | 71.06 |
| 2010 | 38.54 | 12.58 | 8.64 | 0.13 | 47.18 | 12.71 |
| 2011 | 24.04 | 14 | 6.89 | 0.71 | 30.93 | 14.71 |
| 2012 | 89.17 | 53.77 | 52.56 | 0.01 | 141.7 | 53.78 |
| 2013 | 115.3 | 49.83 | 17.11 | 9.89 | 132.4 | 59.72 |
| 2014 | 59.87 | 42.83 | 30.77 | 1.63 | 90.63 | 44.46 |
| 2015 | 30.89 | 21.52 | 2.06 | 0.13 | 32.95 | 21.65 |
| 2016 | 80.55 | 43.66 | 7.17 | 0.06 | 87.73 | 43.72 |
| 2017 | 86.07 | 31.6 | 24.94 | 0.38 | 111.0 | 31.98 |
| 2018 | 34.25 | 34.56 | 7.05 | 0.97 | 41.31 | 35.53 |
| 2019 | 111.3 | 89.94 | 45.37 | 0.44 | 156.7 | 90.38 |

**Table 2.4.** Numbers of Spotted Seatrout sampled and measured by MRIP by state and season, 1991–2019.

| Fishing Year | North Carolina | | Virginia | |
|---|---|---|---|---|
| | n Sampled | n Measured | n Sampled | n Measured |
| 1991 | 1,306 | 745 | 52 | 46 |
| 1992 | 924 | 543 | 59 | 57 |
| 1993 | 668 | 485 | 89 | 69 |
| 1994 | 1,545 | 1,076 | 263 | 195 |
| 1995 | 1,299 | 853 | 170 | 152 |
| 1996 | 637 | 307 | 84 | 72 |
| 1997 | 897 | 622 | 144 | 109 |
| 1998 | 920 | 551 | 48 | 46 |
| 1999 | 920 | 699 | 115 | 97 |
| 2000 | 512 | 330 | 82 | 75 |
| 2001 | 462 | 326 | 18 | 18 |
| 2002 | 396 | 283 | 27 | 23 |
| 2003 | 204 | 130 | 110 | 80 |
| 2004 | 578 | 294 | 77 | 71 |
| 2005 | 1,051 | 664 | 21 | 17 |
| 2006 | 1,492 | 706 | 47 | 30 |
| 2007 | 1,304 | 521 | 168 | 103 |
| 2008 | 1,133 | 790 | 152 | 108 |
| 2009 | 1,054 | 779 | 56 | 45 |
| 2010 | 444 | 336 | 42 | 32 |
| 2011 | 754 | 638 | 86 | 67 |
| 2012 | 1,418 | 939 | 164 | 85 |
| 2013 | 1,032 | 865 | 79 | 57 |
| 2014 | 546 | 381 | 56 | 45 |
| 2015 | 192 | 154 | 6 | 6 |
| 2016 | 841 | 647 | 106 | 102 |
| 2017 | 1,385 | 864 | 202 | 143 |
| 2018 | 376 | 274 | 133 | 114 |
| 2019 | 2,264 | 1,574 | | |

**Table 2.5.** Annual recreational fishery statistics of Spotted Seatrout in North Carolina and Virginia in season 1 (March–November), 1991–2019.

| Fishing Year | Harvest (A+B1) | | | | Released Alive (B2) | | Dead Discards |
|---|---|---|---|---|---|---|---|
| | Number | PSE[Num] | Metric Tons | PSE[Mt] | Number | PSE[Num] | Number |
| 1991 | 1,127,571 | 11 | 728 | 6.77 | 650,402 | 13 | 65,040 |
| 1992 | 1,010,921 | 15 | 728 | 11.03 | 482,724 | 27 | 48,272 |
| 1993 | 788,468 | 13 | 589 | 9.6 | 576,261 | 21 | 57,626 |
| 1994 | 956,829 | 11 | 672 | 7.74 | 897,975 | 22 | 89,798 |
| 1995 | 853,501 | 13 | 583 | 7.03 | 1,009,116 | 20 | 100,912 |
| 1996 | 697,510 | 22 | 444 | 11.21 | 1,038,455 | 16 | 103,846 |
| 1997 | 810,741 | 13 | 587 | 8.71 | 510,047 | 13 | 51,005 |
| 1998 | 755,707 | 15 | 566 | 11.08 | 258,222 | 14 | 25,822 |
| 1999 | 1,311,626 | 13 | 1,101 | 10.34 | 882,511 | 20 | 88,251 |
| 2000 | 846,779 | 17 | 616 | 11.41 | 528,706 | 12 | 52,871 |
| 2001 | 501,885 | 14 | 318 | 10.09 | 655,730 | 16 | 65,573 |
| 2002 | 770,225 | 25 | 456 | 14.28 | 1,694,938 | 22 | 169,494 |
| 2003 | 477,748 | 14 | 346 | 8.49 | 864,791 | 24 | 86,479 |
| 2004 | 492,830 | 12 | 307 | 7.79 | 889,658 | 10 | 88,966 |
| 2005 | 1,381,561 | 41 | 724 | 22.09 | 3,147,563 | 34 | 314,756 |
| 2006 | 1,330,493 | 18 | 870 | 11.97 | 1,706,549 | 21 | 170,655 |
| 2007 | 1,191,955 | 13 | 934 | 7.3 | 2,038,182 | 16 | 203,818 |
| 2008 | 1,407,530 | 15 | 1,101 | 11.86 | 2,788,068 | 17 | 278,807 |
| 2009 | 1,651,295 | 17 | 1,158 | 11.16 | 4,003,605 | 29 | 400,361 |
| 2010 | 634,770 | 26 | 587 | 18.67 | 8,373,833 | 13 | 837,383 |
| 2011 | 920,058 | 17 | 833 | 14.35 | 7,932,476 | 15 | 793,248 |
| 2012 | 1,657,128 | 9.7 | 1,256 | 7.56 | 4,837,791 | 8.4 | 483,779 |
| 2013 | 1,073,405 | 9.8 | 877 | 7.52 | 3,911,490 | 11 | 391,149 |
| 2014 | 629,683 | 14 | 512 | 9.07 | 3,533,416 | 14 | 353,342 |
| 2015 | 203,825 | 21 | 164 | 14.34 | 3,215,331 | 17 | 321,533 |
| 2016 | 1,039,799 | 10 | 862 | 8.79 | 8,445,350 | 13 | 844,535 |
| 2017 | 1,123,038 | 12 | 907 | 8.04 | 6,991,950 | 11 | 699,195 |
| 2018 | 566,162 | 15 | 350 | 10.21 | 18,635,273 | 38 | 1,863,527 |
| 2019 | 2,149,484 | 12 | 1,769 | 8.64 | 7,850,741 | 13 | 785,074 |

**Table 2.6.** Annual recreational fishery statistics of Spotted Seatrout in North Carolina and Virginia in season 2 (December–February), 1991–2019.

| Fishing Year | Harvest (A+B1) | | | | Released Alive (B2) | | Dead Discards |
|---|---|---|---|---|---|---|---|
| | Number | PSE[Num] | Metric Tons | PSE[Mt] | Number | PSE[Num] | Number |
| 1991 | 41,005 | 61 | 33 | 35 | 50,028 | 99 | 5,003 |
| 1992 | 1,087 | 0 | 0.60 | 0 | 3,261 | 0 | 326 |
| 1993 | 27,883 | 0 | 23 | 0 | 19,362 | 0 | 1,936 |
| 1994 | 98,823 | 43 | 79 | 29 | 55,785 | 62 | 5,579 |
| 1995 | 217,622 | 15 | 177 | 11 | 147,337 | 34 | 14,734 |
| 1996 | 7,389 | 23 | 6.2 | 8.5 | 5,889 | 0 | 589 |
| 1997 | 105,912 | 40 | 89 | 23 | 15,050 | 37 | 1,505 |
| 1998 | 27,781 | 0 | 23 | 0 | 6,623 | 0 | 662 |
| 1999 | 67,402 | 26 | 69 | 18 | 90,540 | 66 | 9,054 |
| 2000 | 14,245 | 9.9 | 18 | 14 | 4,256 | 0 | 426 |
| 2001 | 26,273 | 36 | 10 | 19 | 46,462 | 2.3 | 4,646 |
| 2002 | 1,802 | 0 | 1.5 | 0 | 2,859 | 0 | 286 |
| 2003 | 41,135 | 50 | 23 | 43 | 22,454 | 85 | 2,245 |
| 2004 | 182,668 | 35 | 125 | 23 | 135,967 | 47 | 13,597 |
| 2005 | 233,449 | 19 | 134 | 10 | 383,235 | 21 | 38,324 |
| 2006 | 181,319 | 32 | 145 | 25 | 41,727 | 68 | 4,173 |
| 2007 | 414,157 | 19 | 352 | 13 | 840,604 | 28 | 84,060 |
| 2008 | 202,212 | 47 | 128 | 18 | 342,387 | 12 | 34,239 |
| 2009 | 266,973 | 38 | 197 | 27 | 1,008,131 | 19 | 100,813 |
| 2010 | 65,895 | 49 | 49 | 32 | 1,895,812 | 74 | 189,581 |
| 2011 | 482,267 | 8.6 | 490 | 6.3 | 3,110,866 | 24 | 311,087 |
| 2012 | 401,412 | 18 | 311 | 13 | 1,238,806 | 21.1 | 123,881 |
| 2013 | 135,866 | 34 | 183 | 33 | 1,381,484 | 15 | 138,148 |
| 2014 | 192,199 | 14 | 165 | 9.1 | 1,084,535 | 18 | 108,454 |
| 2015 | 21,940 | 47 | 11 | 33 | 3,004,582 | 40 | 300,458 |
| 2016 | 254,412 | 33 | 207 | 23 | 1,363,890 | 17 | 136,389 |
| 2017 | 103,749 | 30 | 89 | 21 | 688,599 | 34 | 68,860 |
| 2018 | 122,938 | 28 | 83 | 20 | 2,246,592 | 21 | 224,659 |
| 2019 | 862,336 | 21 | 716 | 13 | 2,065,385 | 18 | 206,539 |

**Table 2.7.** Number of length samples collected in Program 915, 2003–2019.

| Fishing Year | Spring | Fall |
|---|---|---|
| 2003 | | 74 |
| 2004 | 23 | 65 |
| 2005 | 21 | 58 |
| 2006 | 115 | 204 |
| 2007 | 124 | 127 |
| 2008 | 113 | 166 |
| 2009 | 216 | 197 |
| 2010 | 62 | 126 |
| 2011 | 17 | 84 |
| 2012 | 129 | 177 |
| 2013 | 146 | 144 |
| 2014 | 103 | 134 |
| 2015 | 47 | 80 |
| 2016 | 49 | 152 |
| 2017 | 91 | 153 |
| 2018 | 35 | 103 |
| 2019 | 215 | 358 |

**Table 3.1.** Input data overview.

| Data | Unit | CV/SE | Availability | Length composition | State |
|---|---|---|---|---|---|
| **Landings** | | | | | |
| ComLanding | Number | 0.05 | 1991–2019 | 1991–2019 | NC and VA |
| RecLanding | Number | 0.1 | 1991–2019 | 1991–2019 | NC and VA |
| **Discards** | | | | | |
| ComDiscard | Number | 0.25 | 1991–2019 | NA | NC |
| RecDiscard | Number | 0.25 | 1991–2019 | NA | NC and VA |
| **Indices** | | | | | |
| P915NorthSpring | Number per unit effort | Estimate d | 2004–2019 | 2004–2019 | NC |
| P915NorthFall | Number per unit effort | Estimate d | 2003–2019 | 2003–2019 | NC |

**Table 3.2.** Overview of the sensitivity analyses.

| Scenario | Configurations |
|---|---|
| P915Srm | P915NorthSpring survey index and length composition were removed |
| P915Frm | P915NorthFall survey index and length composition were removed |
| Ini2003 | Initial year was set to 2003 |
| LowM | Annual average natural mortality was set to 0.4, lower than the base model (0.6) |
| HighM | Annual average natural mortality was set to 0.8, higher than the base model (0.6) |
| Low2018 | Season 1 (non-winter, March-November) recreational discards was set to the average of the previous five years (2013–2017; 521.951 thousands of fish), lower than the base model (1,863.527 thousands of fish) |
| Block | Two time blocks were set up for fleet selectivity, 1991–2008 and 2009–2019 |

**Table 3.3.** Results of the runs test for randomness and the Shapiro-Wilk test for normality applied to the residuals of the fits to the fishery-independent survey indices from the base model of the stock assessment. The significance level was set at 0.05.

| Survey | Runs test | | Shapiro-Wilk | |
|---|---|---|---|---|
| | Statistic | P-value | Statistic | P-value |
| P915NorthSpring | -1.553 | 0.121 | 0.916 | 0.148 |
| P915NorthFall | -1.035 | 0.301 | 0.954 | 0.531 |

**Table 3.4.** Predicted fishing mortality (per year) and spawning stock biomass (metric tons) from the base model (Base) and the retrospective runs (Retro), the relative bias (RelBias), and the Mohn's $\rho$ value from the retrospective analysis in which the model started with the data from 1991 to 2014, and added one additional year of data at a time up to 2019.

| Year | Base | Retro | RelBias |
|---|---|---|---|
| Fishing mortality (per year) | | | |
| 2014 | 0.541 | 0.592 | 0.094 |
| 2015 | 0.241 | 0.427 | 0.772 |
| 2016 | 0.578 | 1.060 | 0.835 |
| 2017 | 0.656 | 0.920 | 0.402 |
| 2018 | 0.434 | 1.175 | 1.706 |
| Mohn's $\rho$ | | | 0.762 |
| | | | |
| Spawning stock biomass (metric tons) | | | |
| 2014 | 1,851.341 | 1,849.510 | -0.001 |
| 2015 | 1,870.260 | 1,314.664 | -0.297 |
| 2016 | 2,298.879 | 1,439.140 | -0.374 |
| 2017 | 2,141.867 | 1,668.463 | -0.221 |
| 2018 | 2,350.865 | 1,117.150 | -0.525 |
| Mohn's $\rho$ | | | -0.284 |

## 9 FIGURES

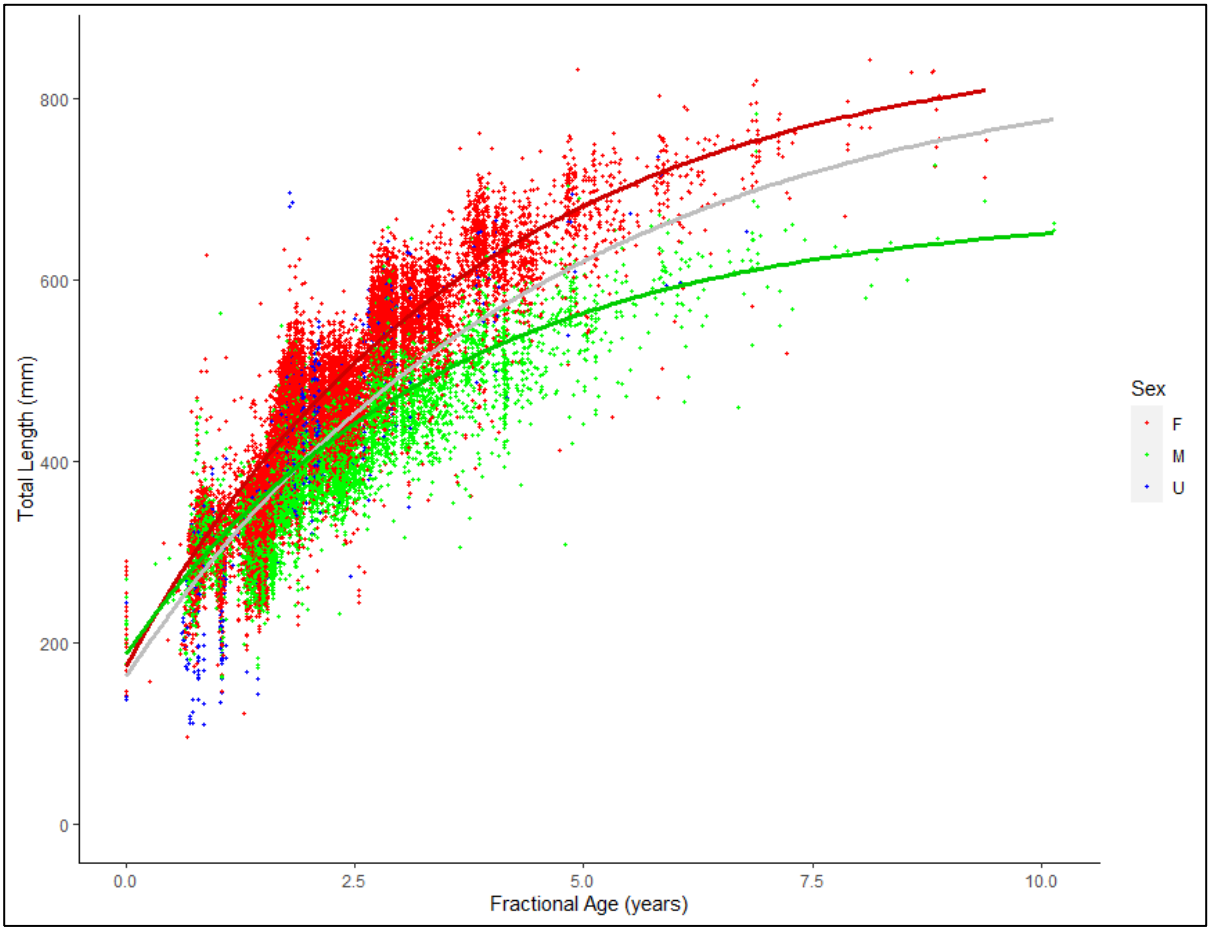


**Figure 1.1.** Fit of the length-at-age function to available age data for females (red line, n=14,664), males (green line, n = 9,014), and sex-aggregated (grey line, n=24,386) Spotted Seatrout data from Virginia and North Carolina.

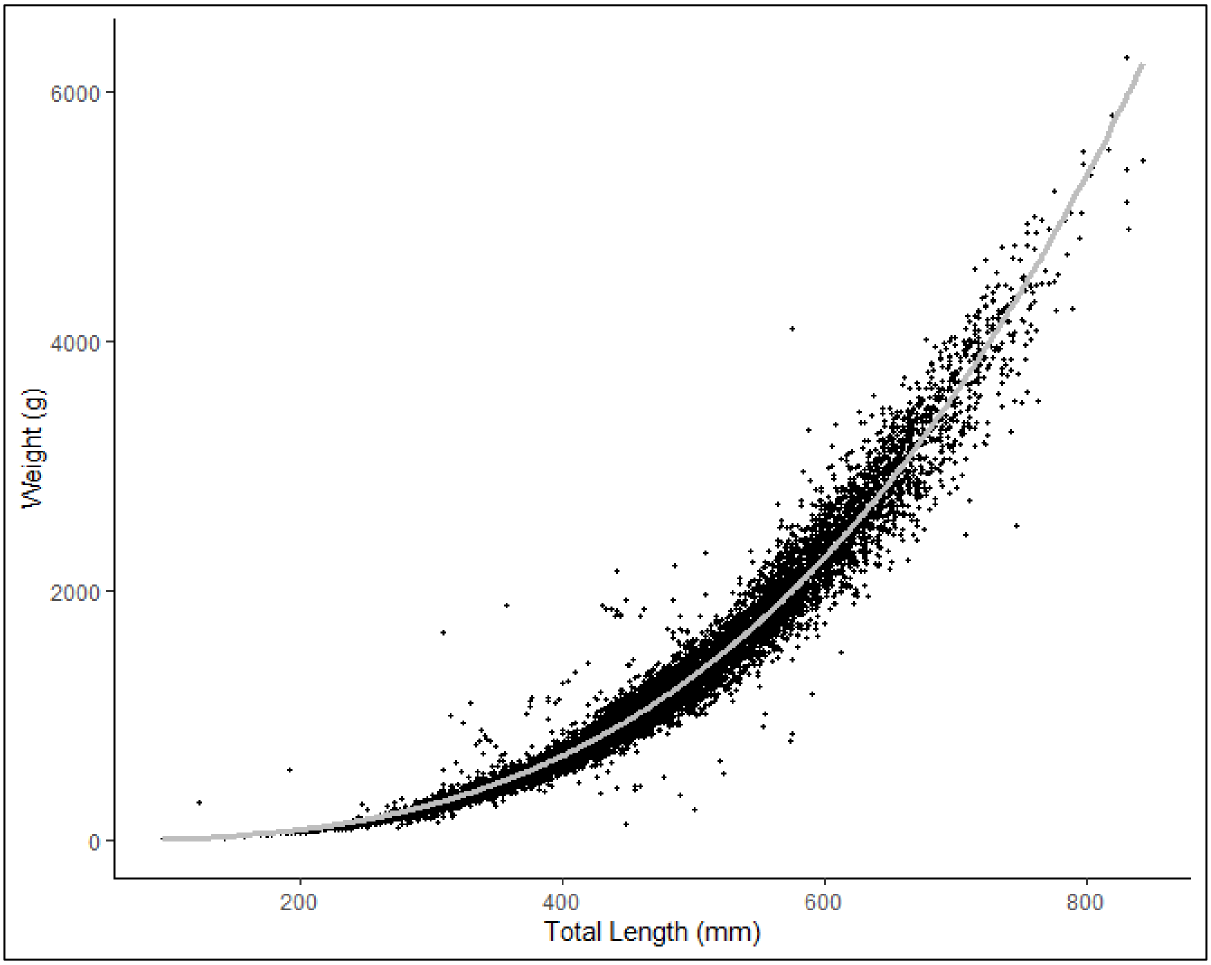


**Figure 1.2.** Fit of the length-weight function to available biological data for female Spotted Seatrout from Virginia and North Carolina (n = 13,264).

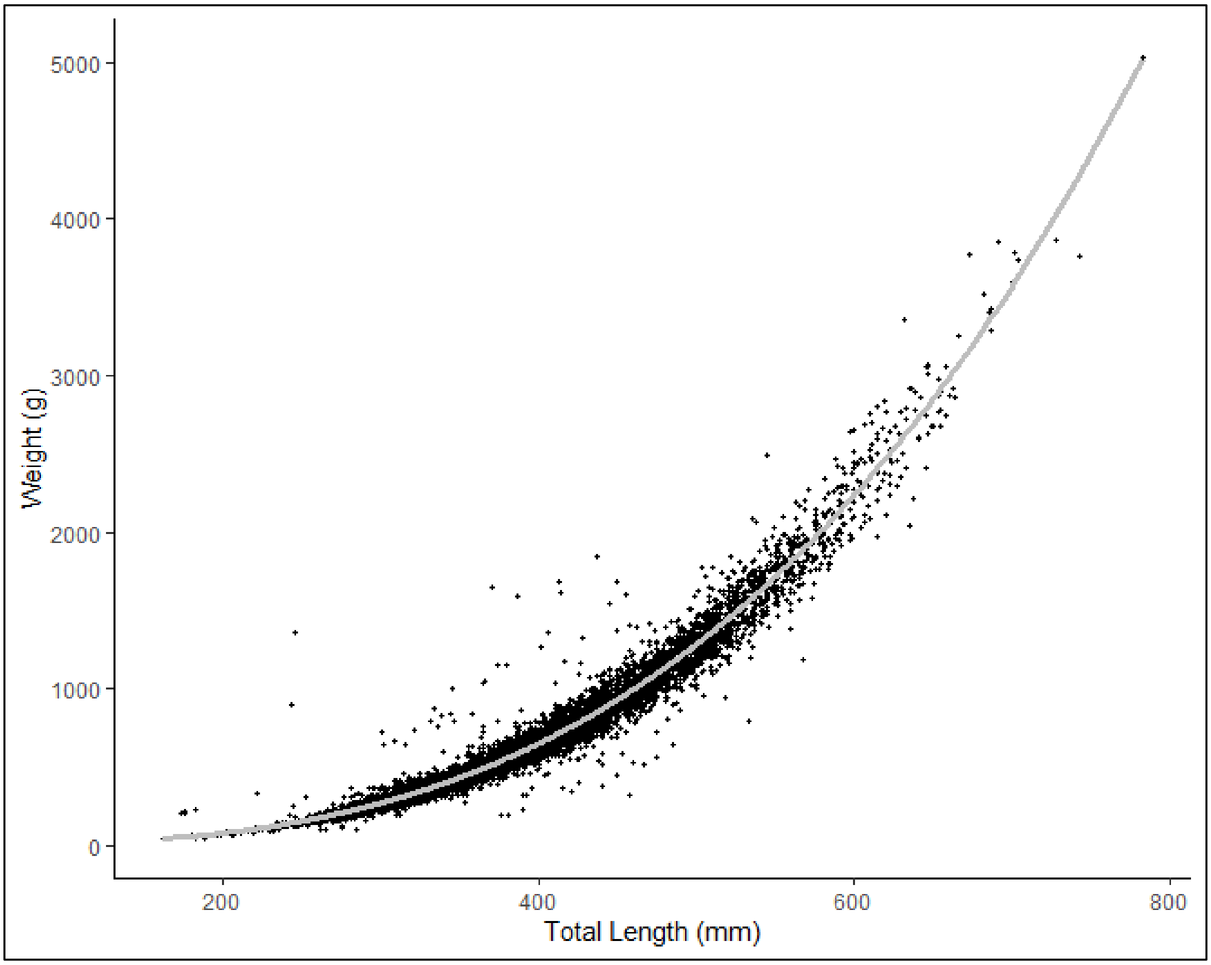


**Figure 1.3.** Fit of the length-weight function to available biological data for male Spotted Seatrout from Virginia and North Carolina (n = 9,249).

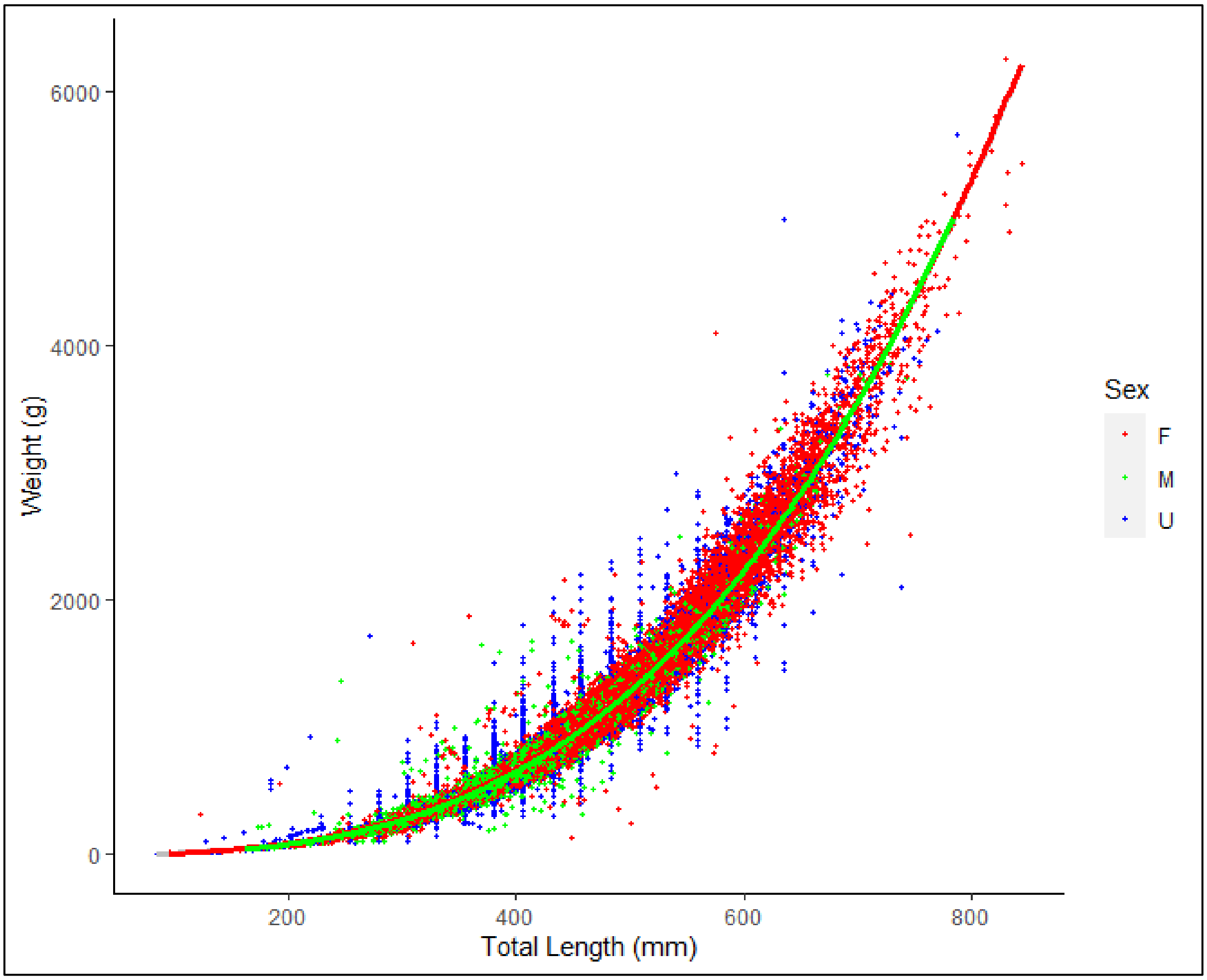


**Figure 1.4.** Fit of the length-weight function to available biological data for females (red line, n = 13,264), males (green line, n = 9,249), and sex-aggregated including unknown (grey line, n = 50,612) of Spotted Seatrout from Virginia and North Carolina. Sex categories of individual data points include female (F), male (M), and unknown (U).

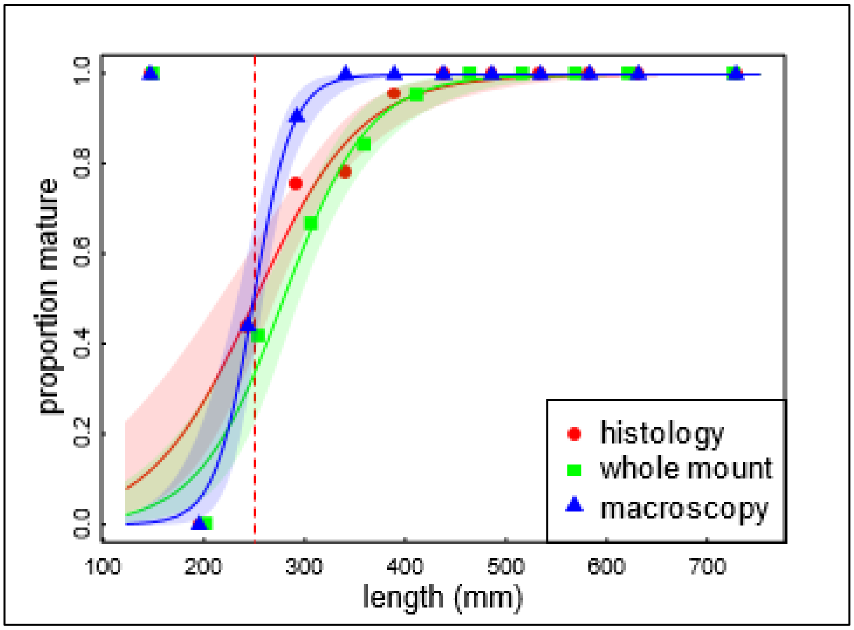


**Figure 1.5.** Fit of maturity curves to female Spotted Seatrout data collected in North Carolina for three maturity staging methods. The solid lines represent the best-fitting logistic regression and the shaded area represent the 95% confidence bands. The vertical dashed lines represent the predicted length at 50% maturity, $L_{50}$. The points represent the observed data. (Source: NCDMF 2021.)

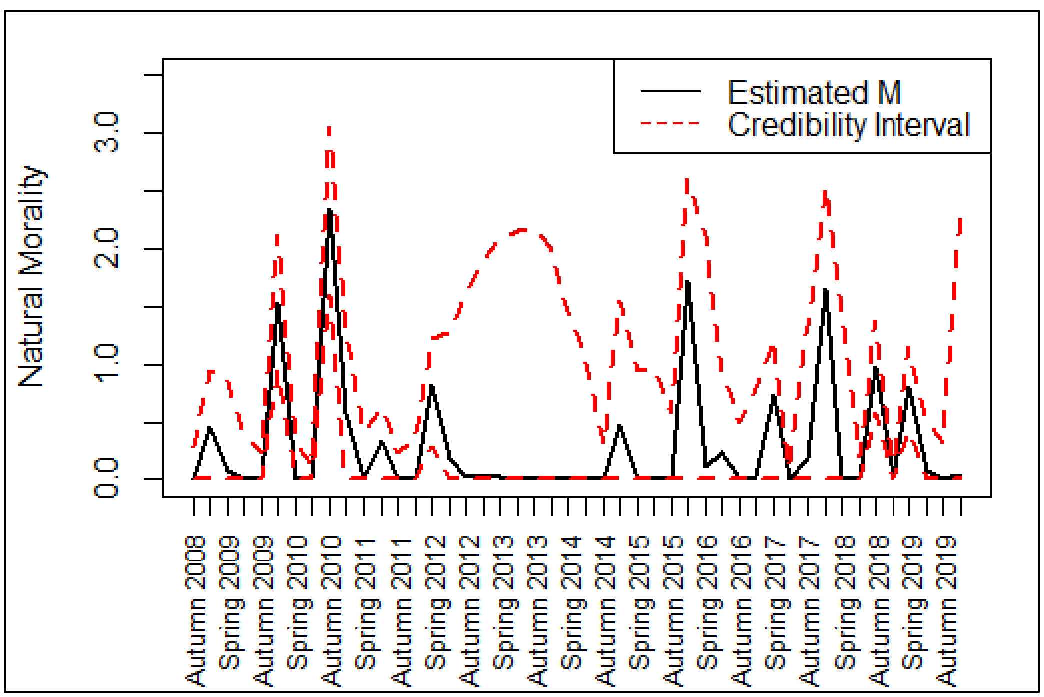


**Figure 1.6.** Time series plot of seasonal estimates of median natural mortality (black line) and lower and upper credibility intervals (red dashed line) from the working group's tag-return model (2021) from autumn 2008 until winter 2019.

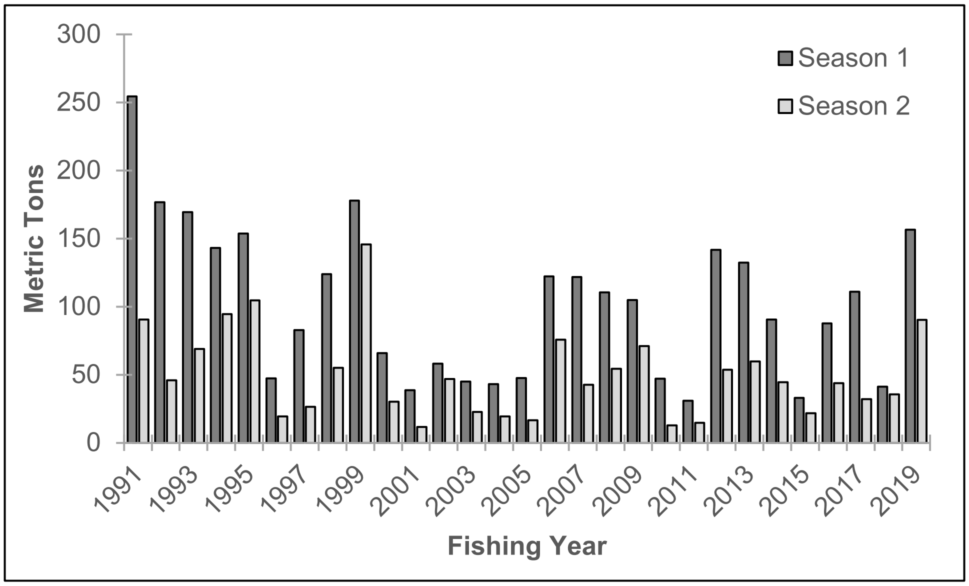


**Figure 2.1.** Annual commercial landings of Spotted Seatrout in Virginia and North Carolina by season, 1991–2019.

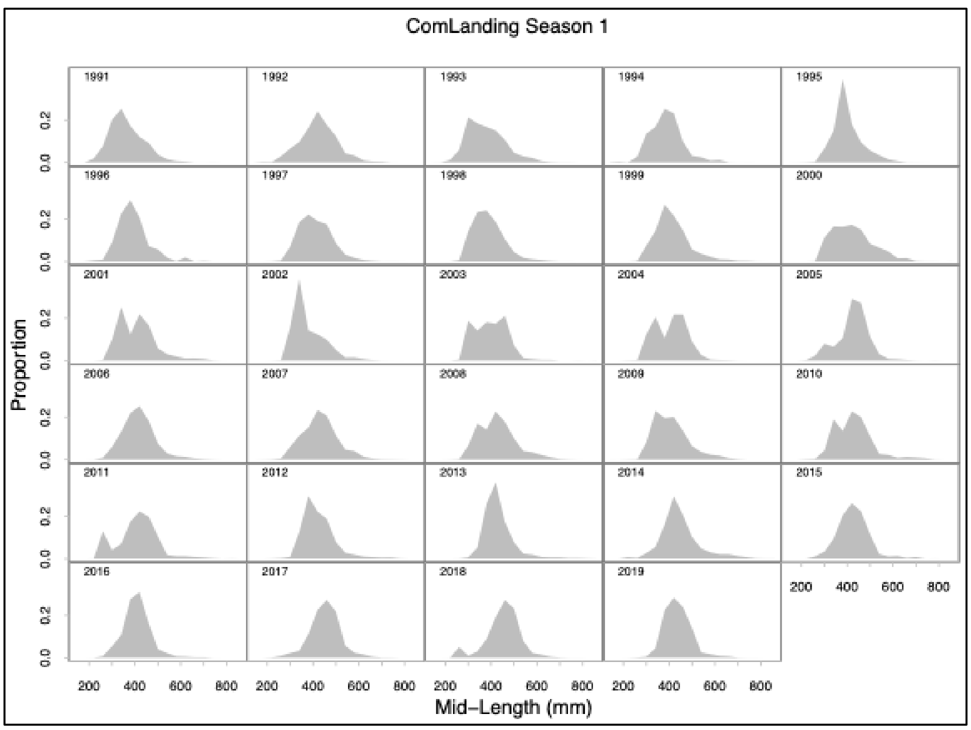


**Figure 2.2.** Length composition of commercial landings of Spotted Seatrout in Virginia and North Carolina in Season 1 (non-winter season, March–November), 1991–2019.

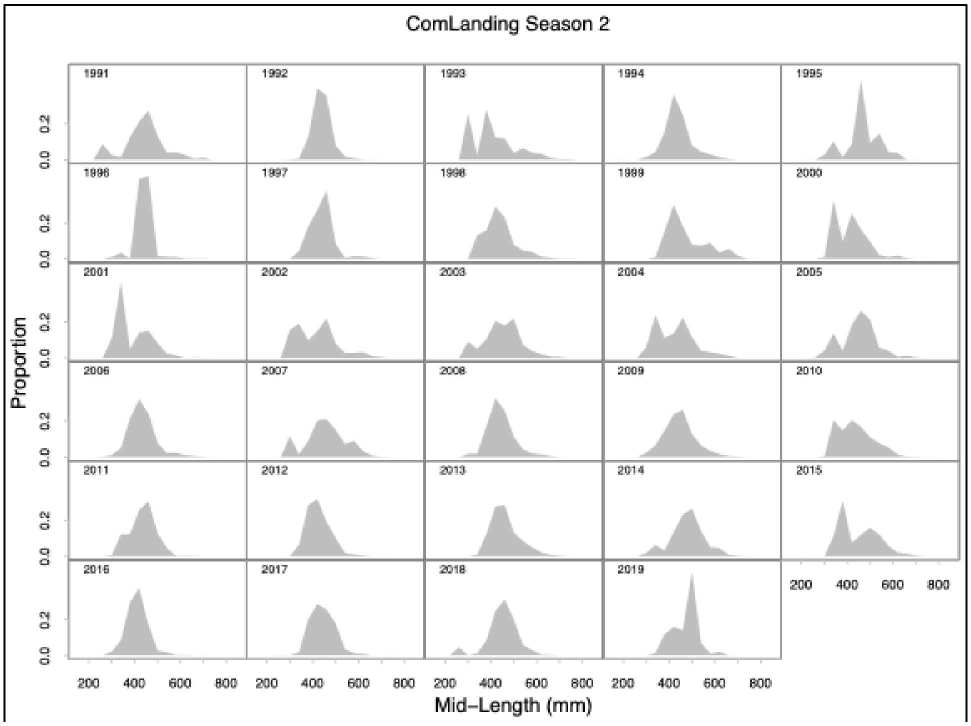


**Figure 2.3.** Length composition of commercial landings of Spotted Seatrout in Virginia and North Carolina in Season 2 (winter season, December–February), 1991–2019.

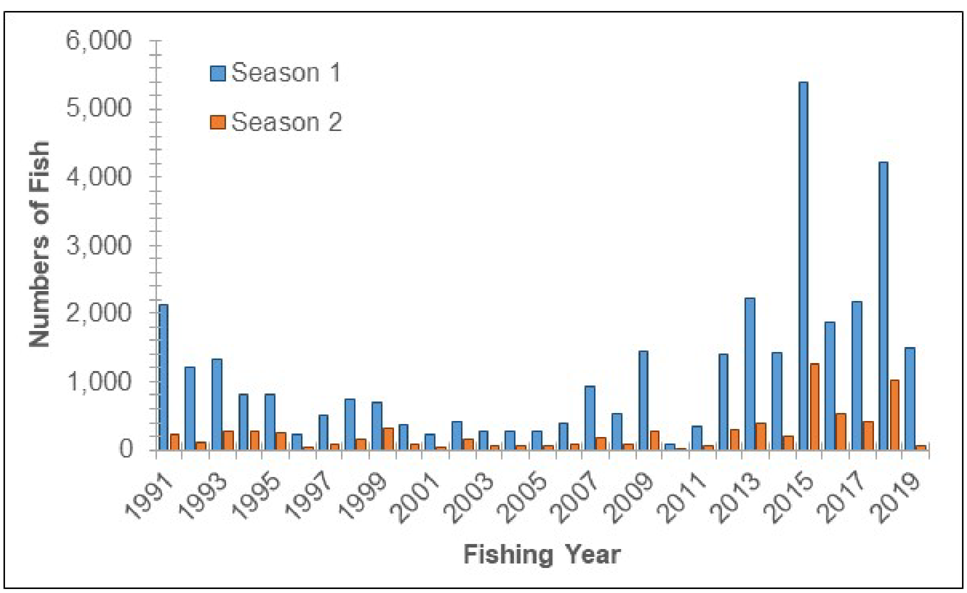


**Figure 2.4.** Annual commercial gill-net fishery dead discards of Spotted Seatrout in North Carolina by season, 1991–2019.

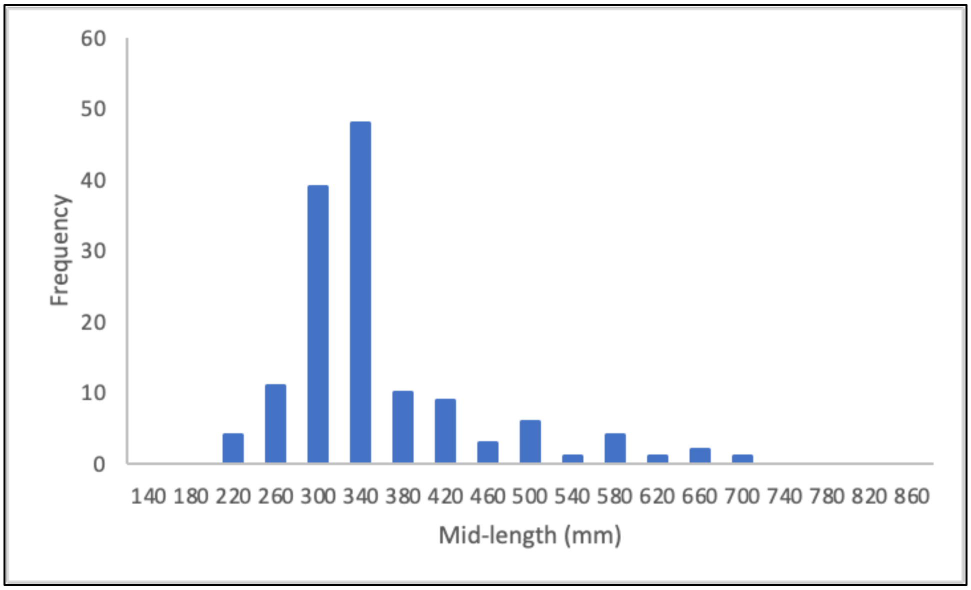


**Figure 2.5.** Annual length-frequency distributions of Spotted Seatrout sampled from North Carolina commercial gill-net estuarine fishery discards (pooled over years and seasons), 2004–2019.

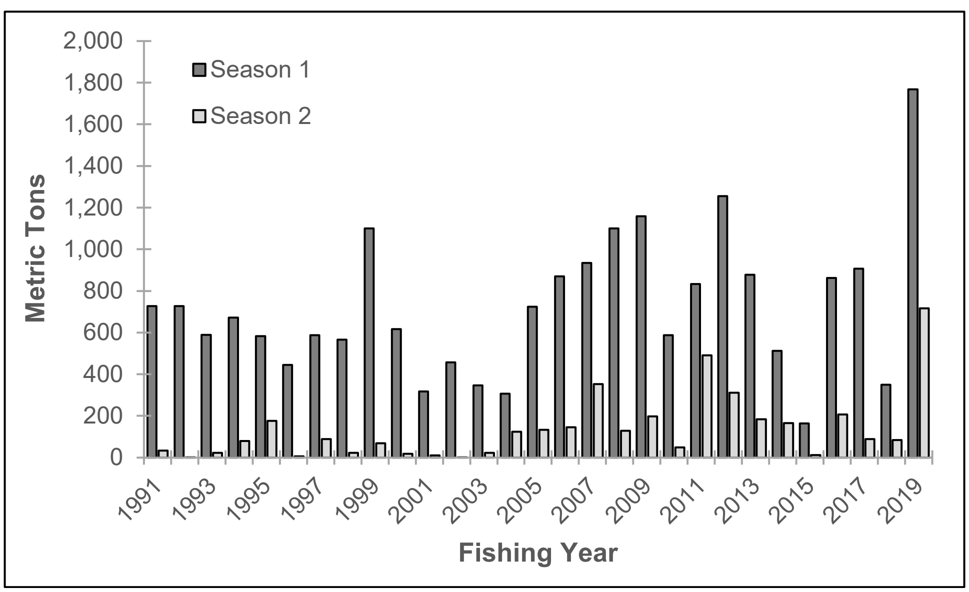


**Figure 2.6.** Annual recreational harvest (Type A+B1) in weight of Spotted Seatrout in Virginia and North Carolina by season, 1991–2019.

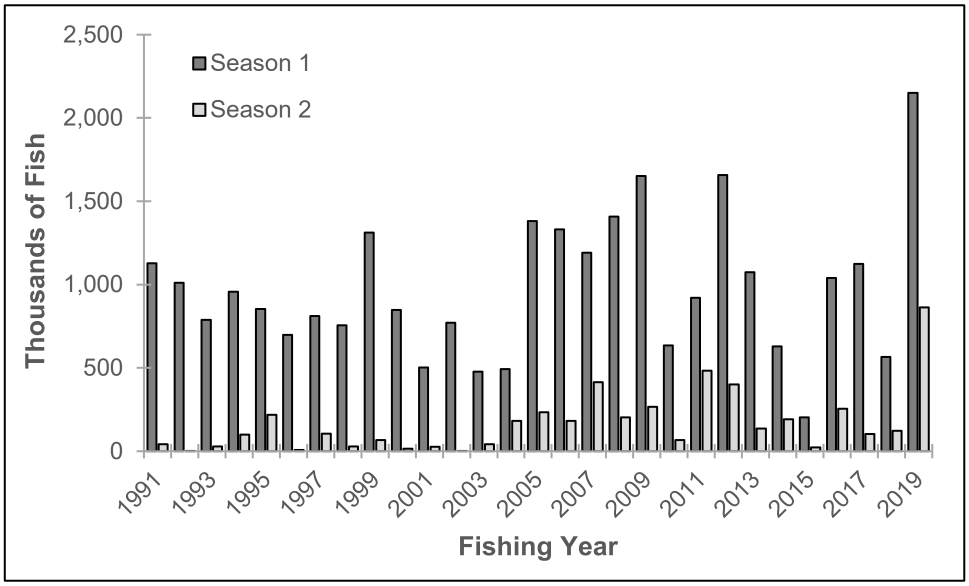


**Figure 2.7.** Annual recreational harvest (Type A+B1) in numbers of Spotted Seatrout in Virginia and North Carolina by season, 1991–2019.

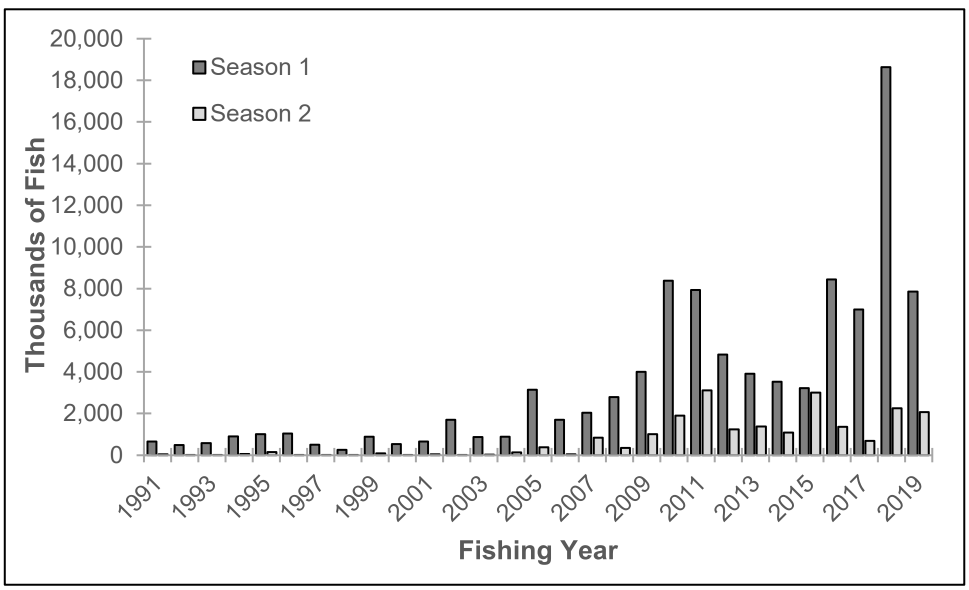


**Figure 2.8.** Annual recreational live releases (Type B2) in numbers of Spotted Seatrout in Virginia and North Carolina by season, 1991–2019.

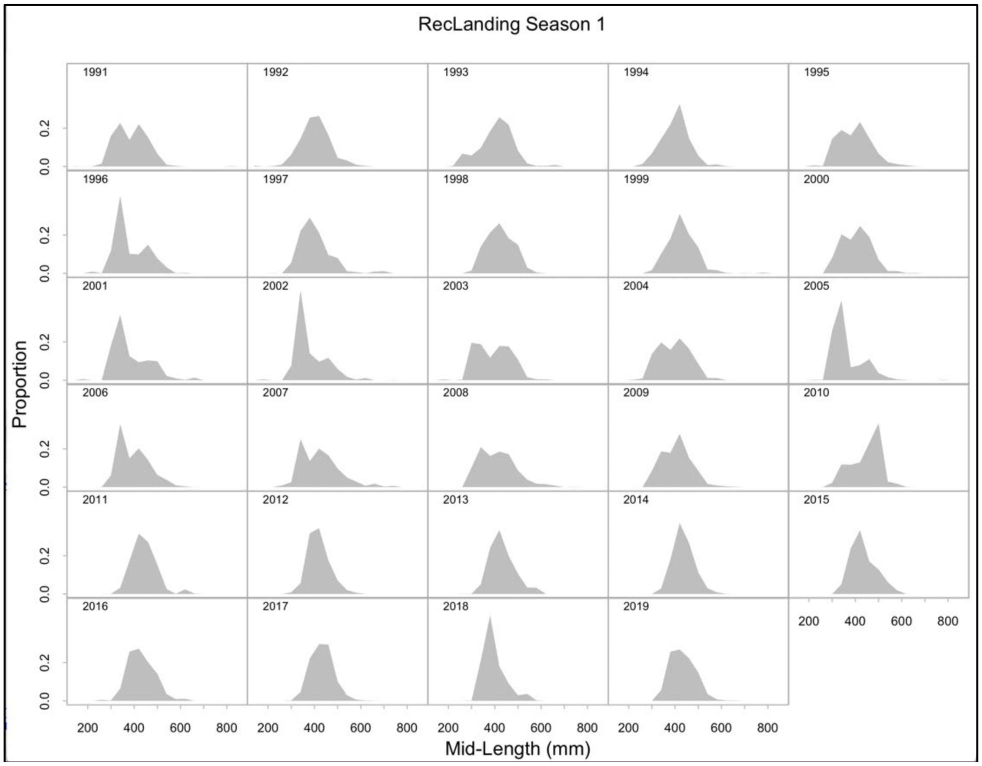


**Figure 2.9.** Length composition of recreational landings of Spotted Seatrout in Virginia and North Carolina in Season 1 (non-winter season, March–November), 1991–2019.

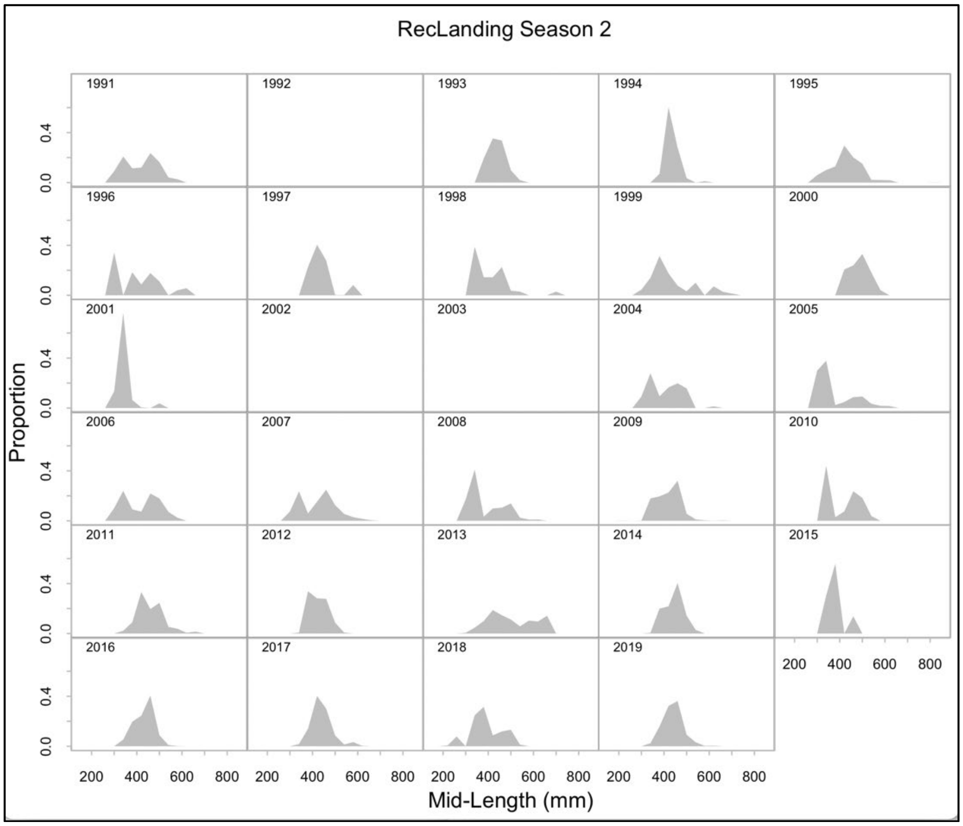


**Figure 2.10.** Length composition of recreational landings of Spotted Seatrout in Virginia and North Carolina in Season 2 (winter season, December–February), 1991–2019.

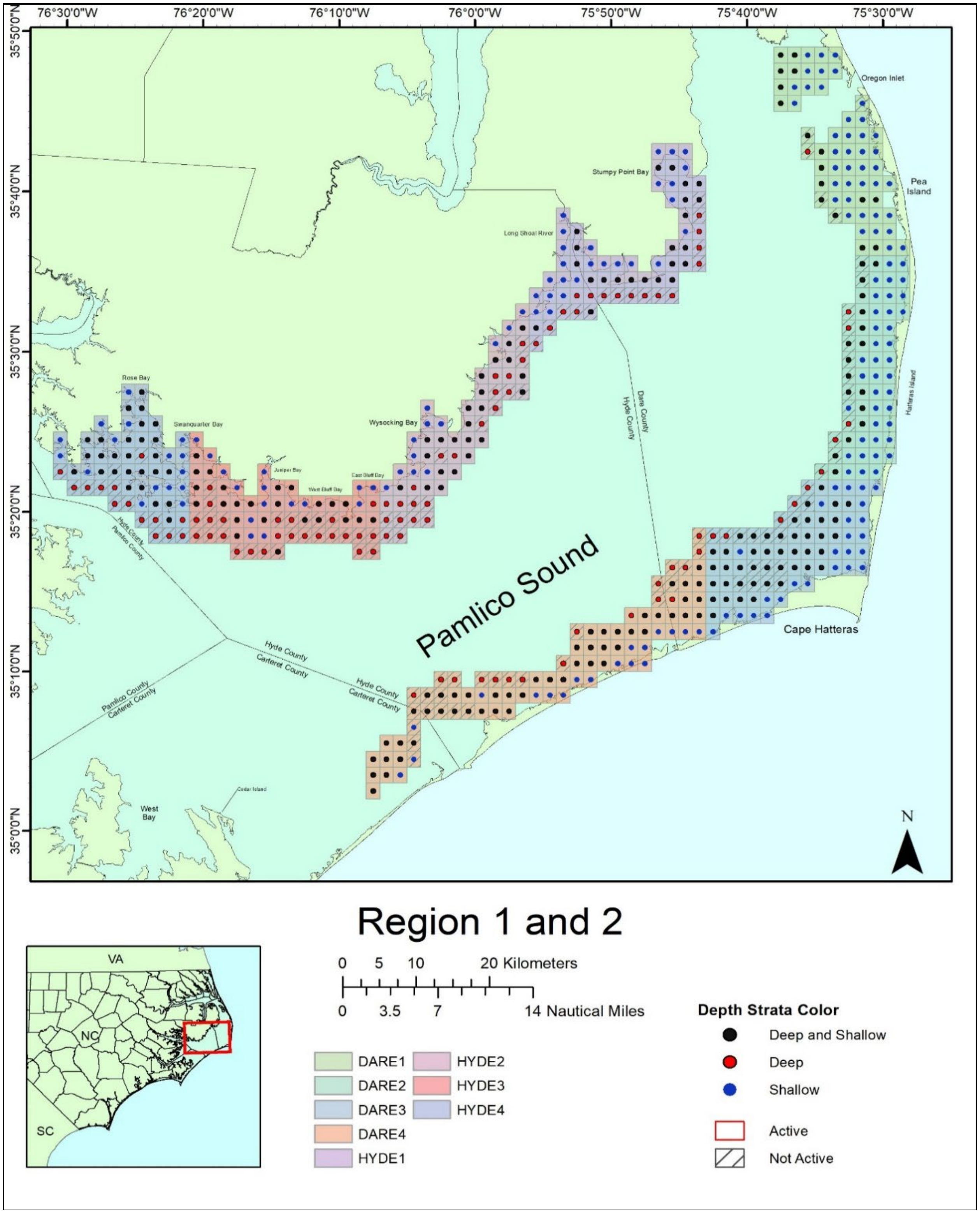


**Figure 2.11.** The sample regions and grid system for the Pamlico Sound portion of Program 915.

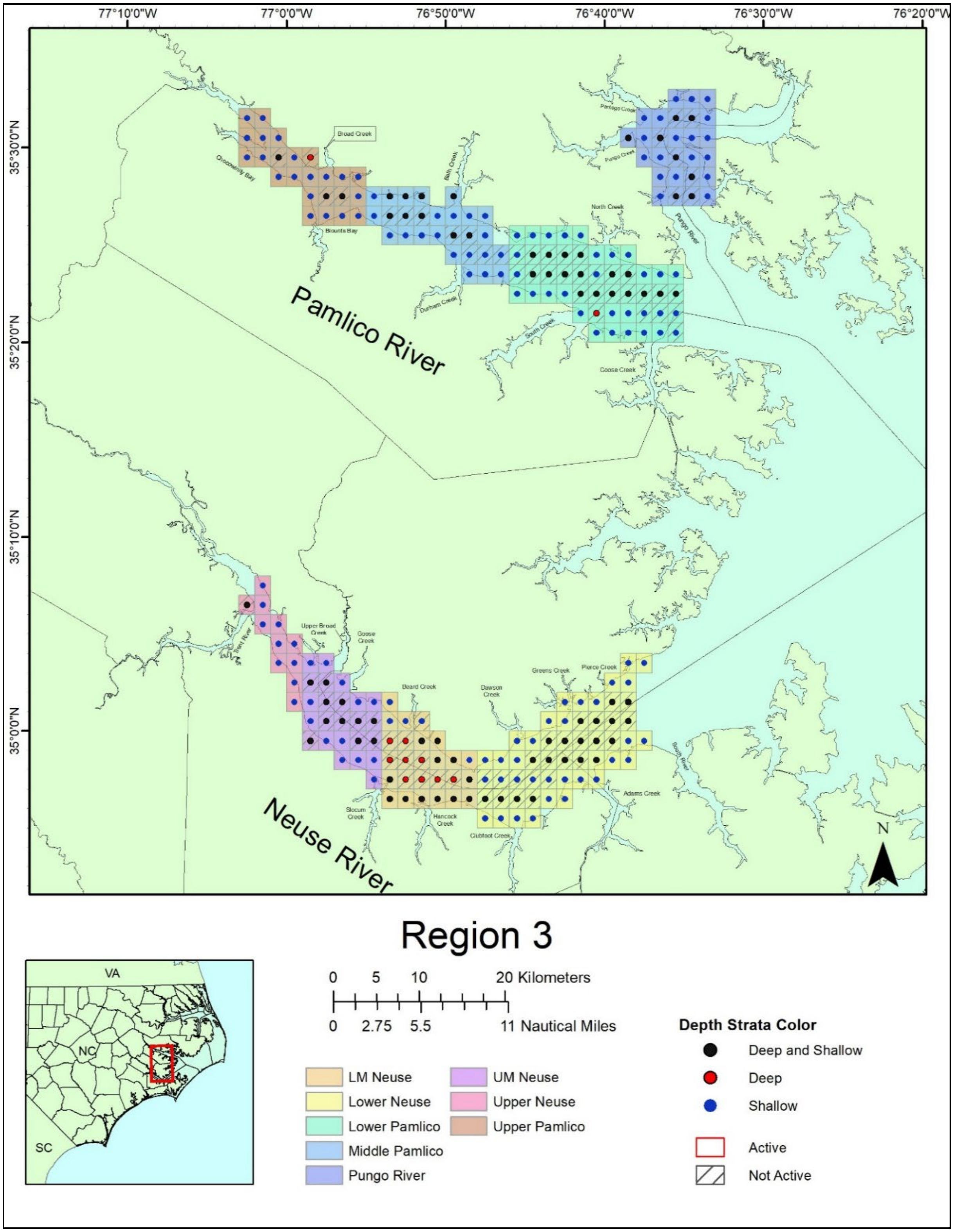


**Figure 2.12.** The sample regions and grid system for the Neuse, Pamlico, and Pungo rivers portion of Program 915.

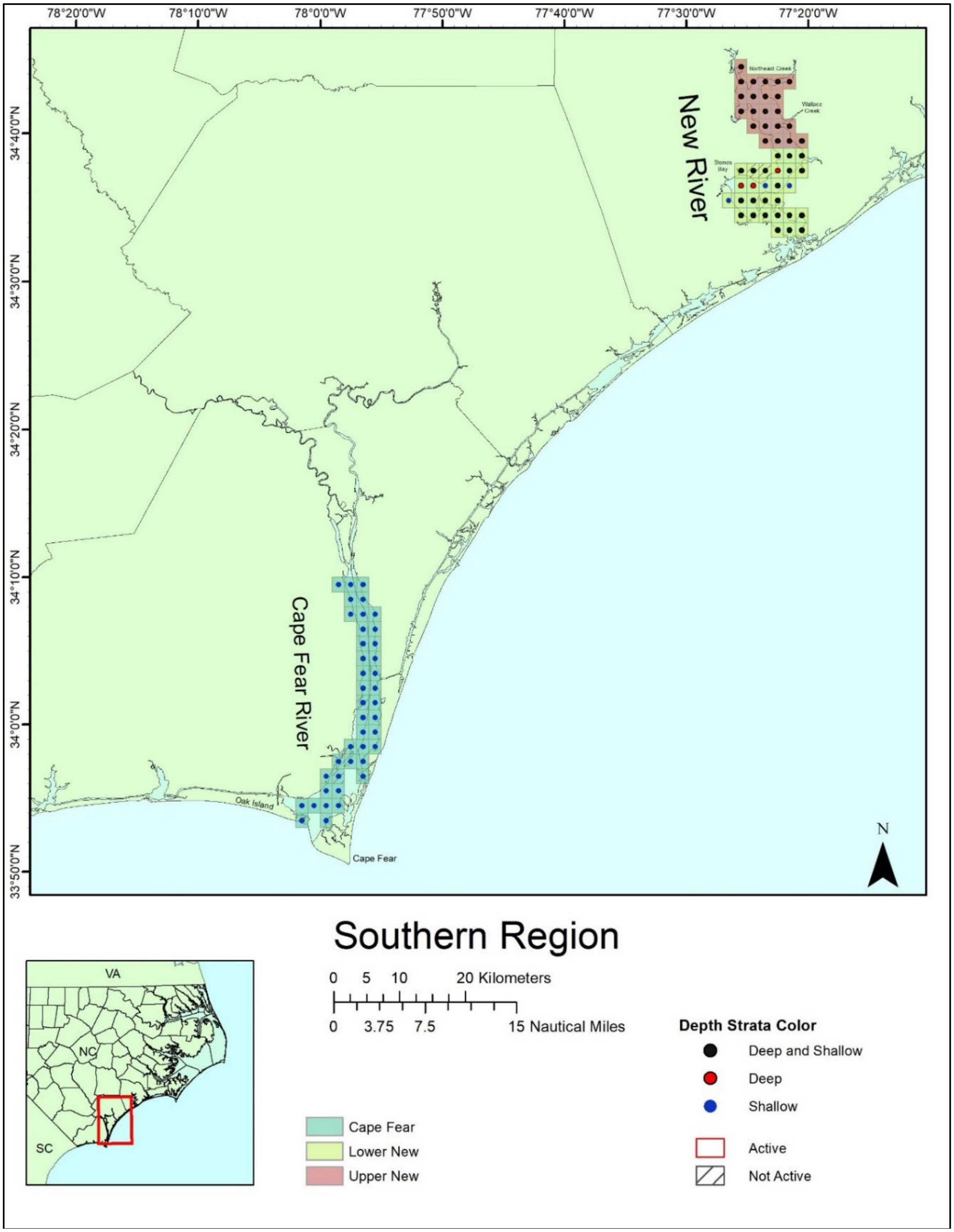


**Figure 2.13.** The sample regions and grid system for the New and Cape Fear rivers portion of Program 915.

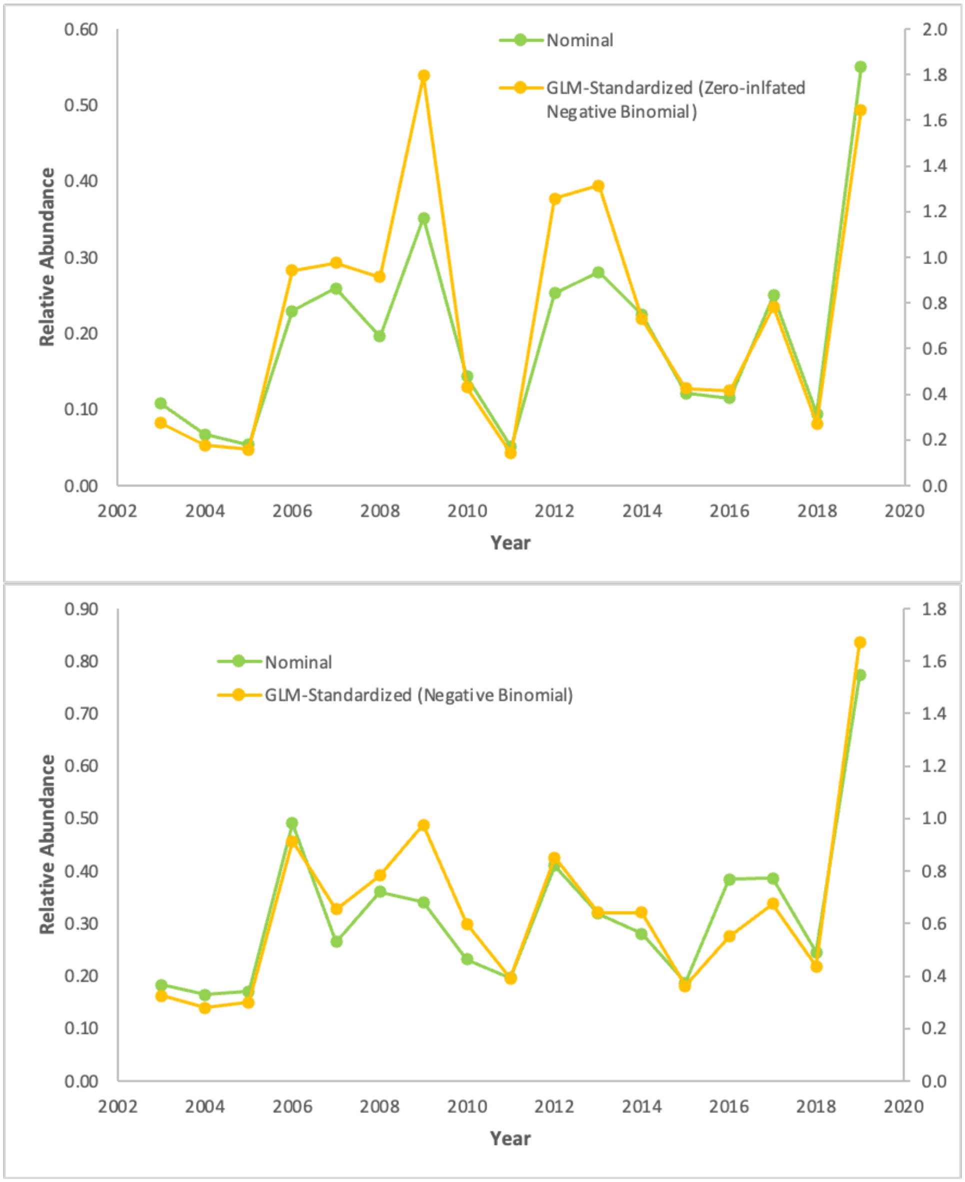


**Figure 2.14.** Nominal and standardized abundance indices of Program 915 spring (top) and fall (bottom) surveys, 2003–2019.

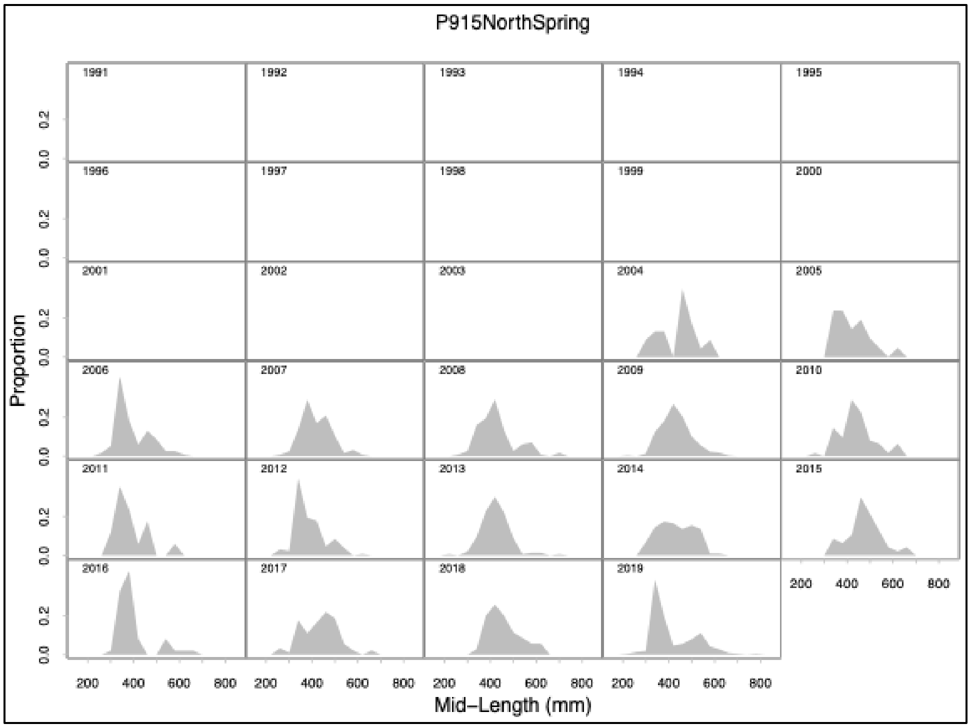


**Figure 2.15.** Length composition of Program 915 spring survey of Spotted Seatrout, 2004–2019.

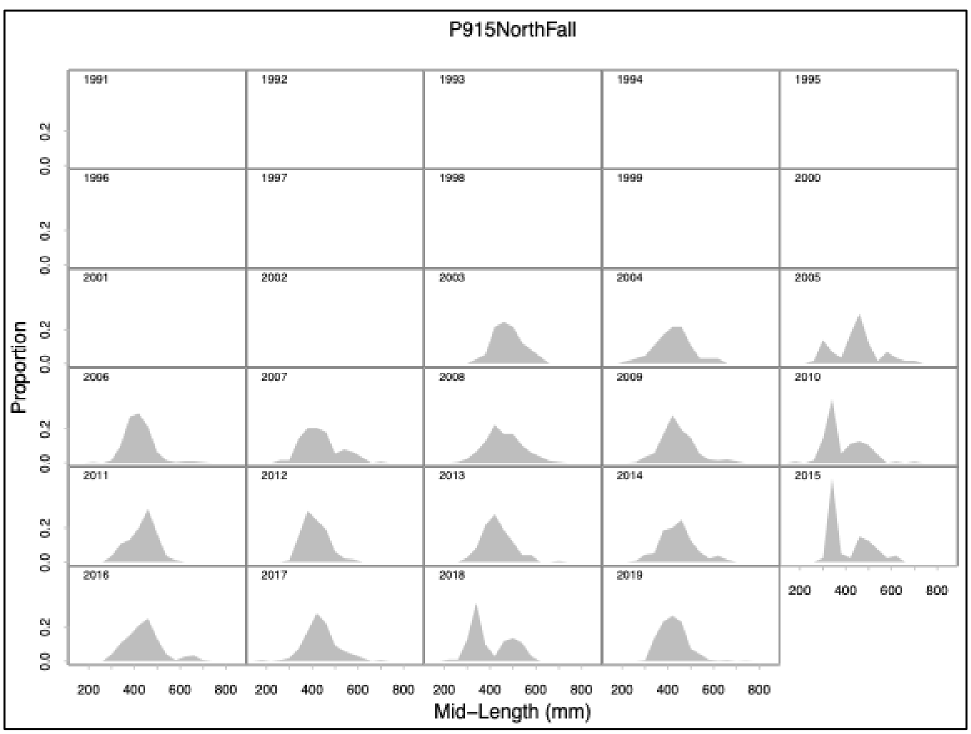


**Figure 2.16.** Length composition of Program 915 fall survey of Spotted Seatrout, 2003–2019.

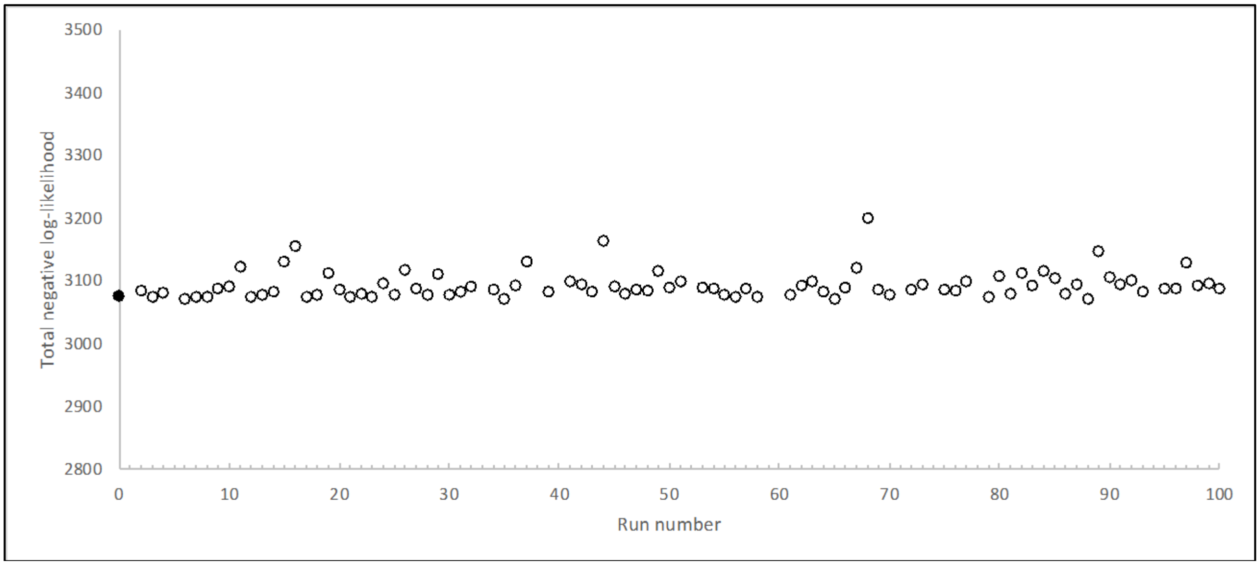


**Figure 3.1.** Negative log-likelihood values produced from the 100 jitter runs in which initial parameter values were jittered by 10%. The solid black circle is the value from the base model. Figure only shows values from the converged runs.

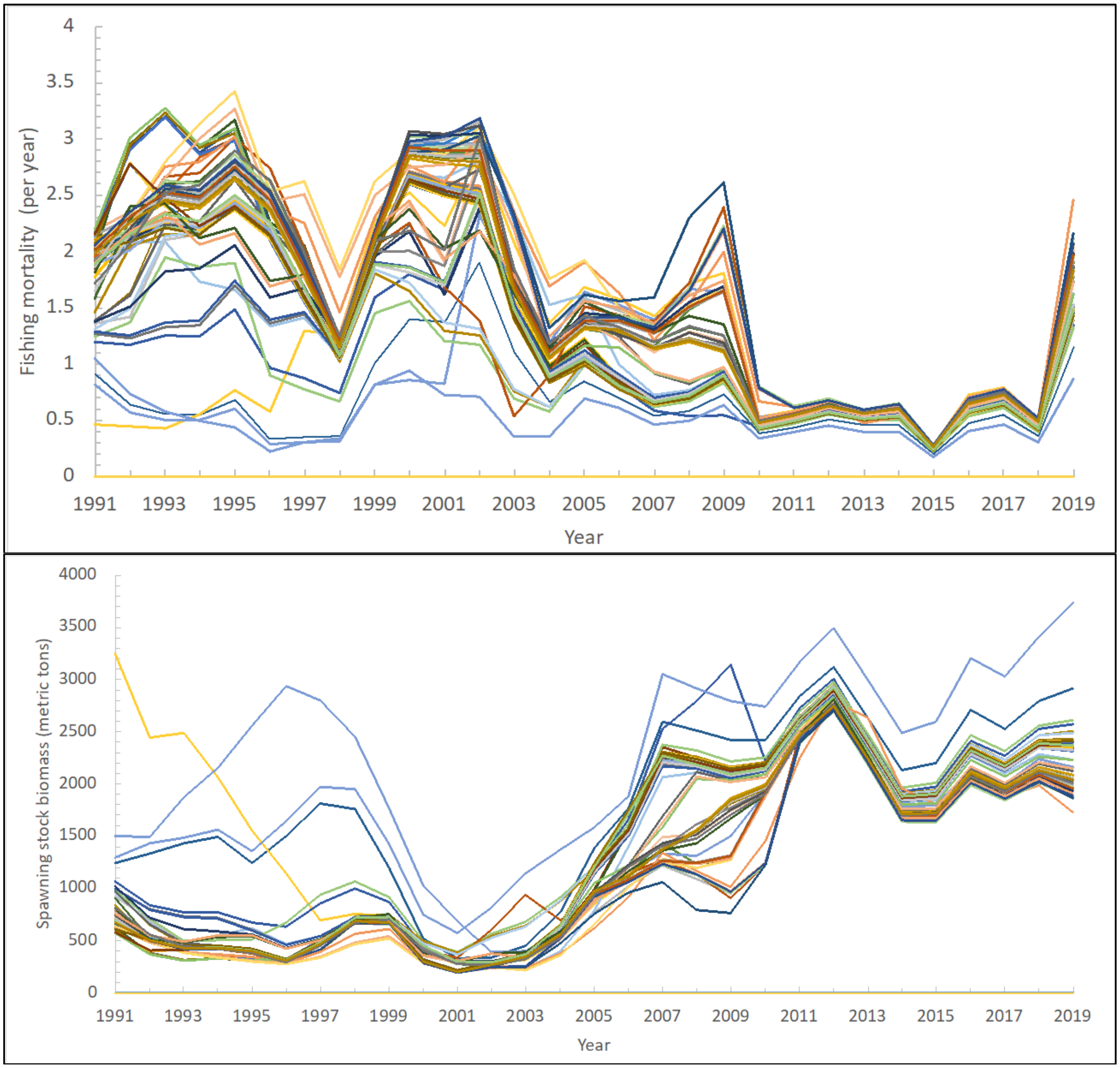


**Figure 3.2.** Predicted fishing mortality (per year; top panel) and spawning stock biomass (metric tons; bottom panel) from the converged jitter runs in which initial parameter values were jittered by 10%.

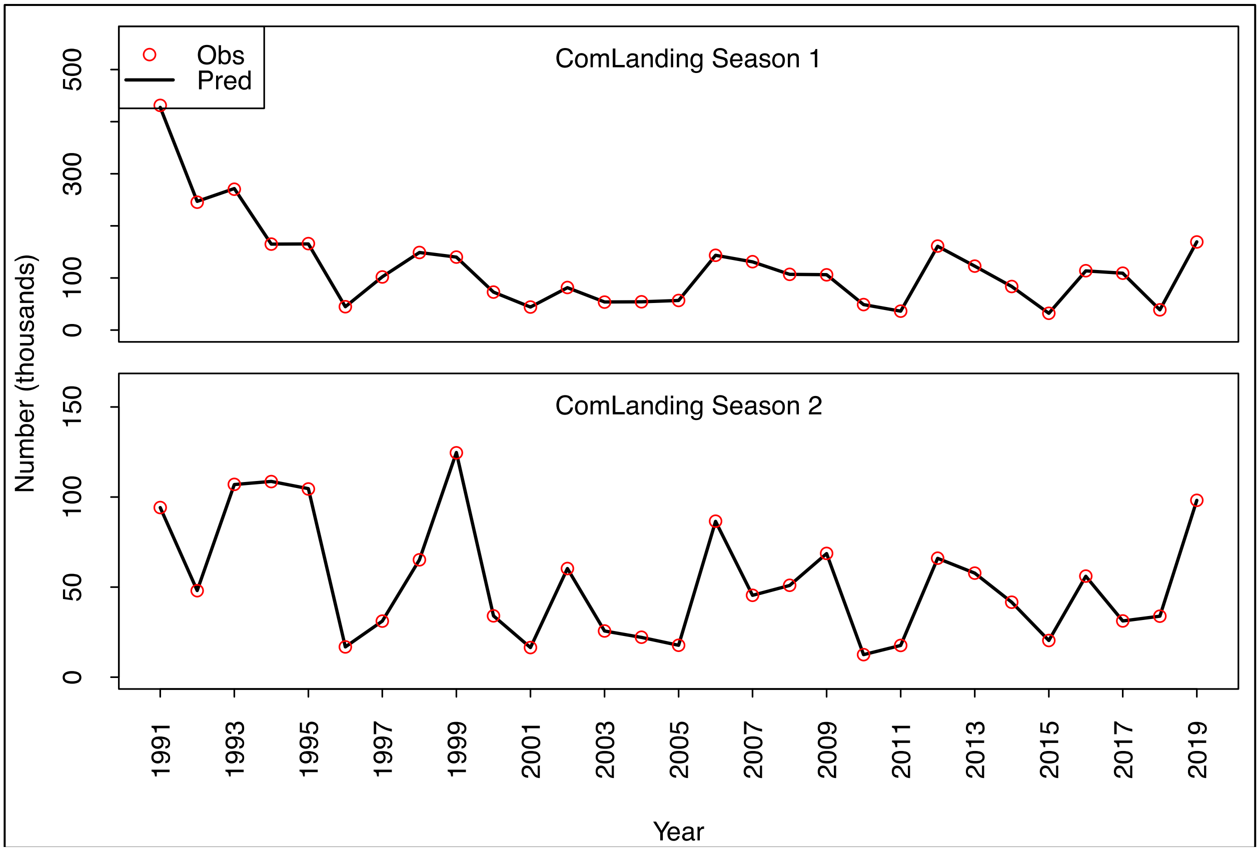


**Figure 3.3.** Predicted (line) and observed (circle) commercial landings (thousands of fish) of Spotted Seatrout from the base model of the stock assessment, 1991–2019. Season 1—non-winter season, March–November; Season 2—winter season, December–February.

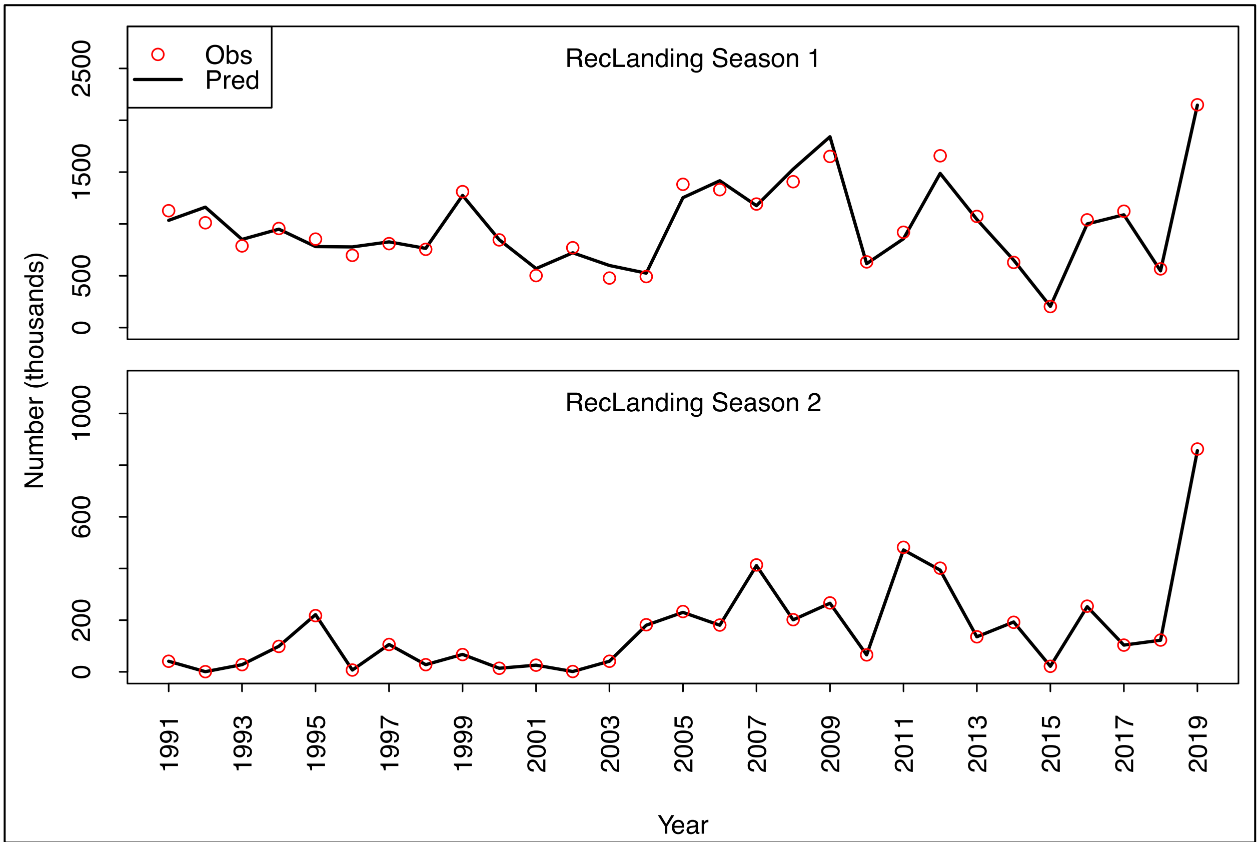


**Figure 3.4.** Predicted (line) and observed (circle) recreational landings (thousands of fish) of Spotted Seatrout from the base model of the stock assessment, 1991–2019. Season 1—non-winter season, March–November; Season 2—winter season, December–February.

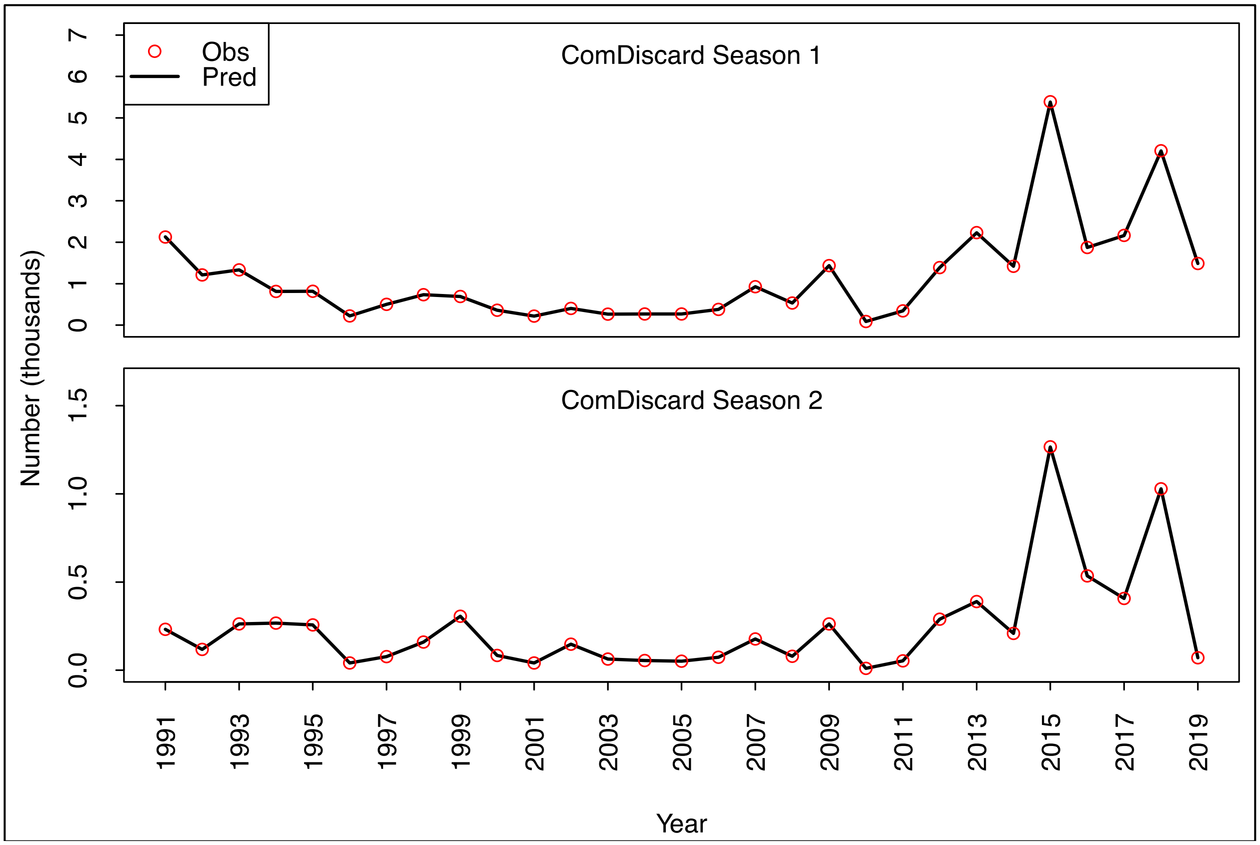


**Figure 3.5.** Predicted (line) and observed (circle) commercial discards (thousands of fish) of Spotted Seatrout from the base model of the stock assessment, 1991–2019. Season 1—non-winter season, March–November; Season 2—winter season, December–February.

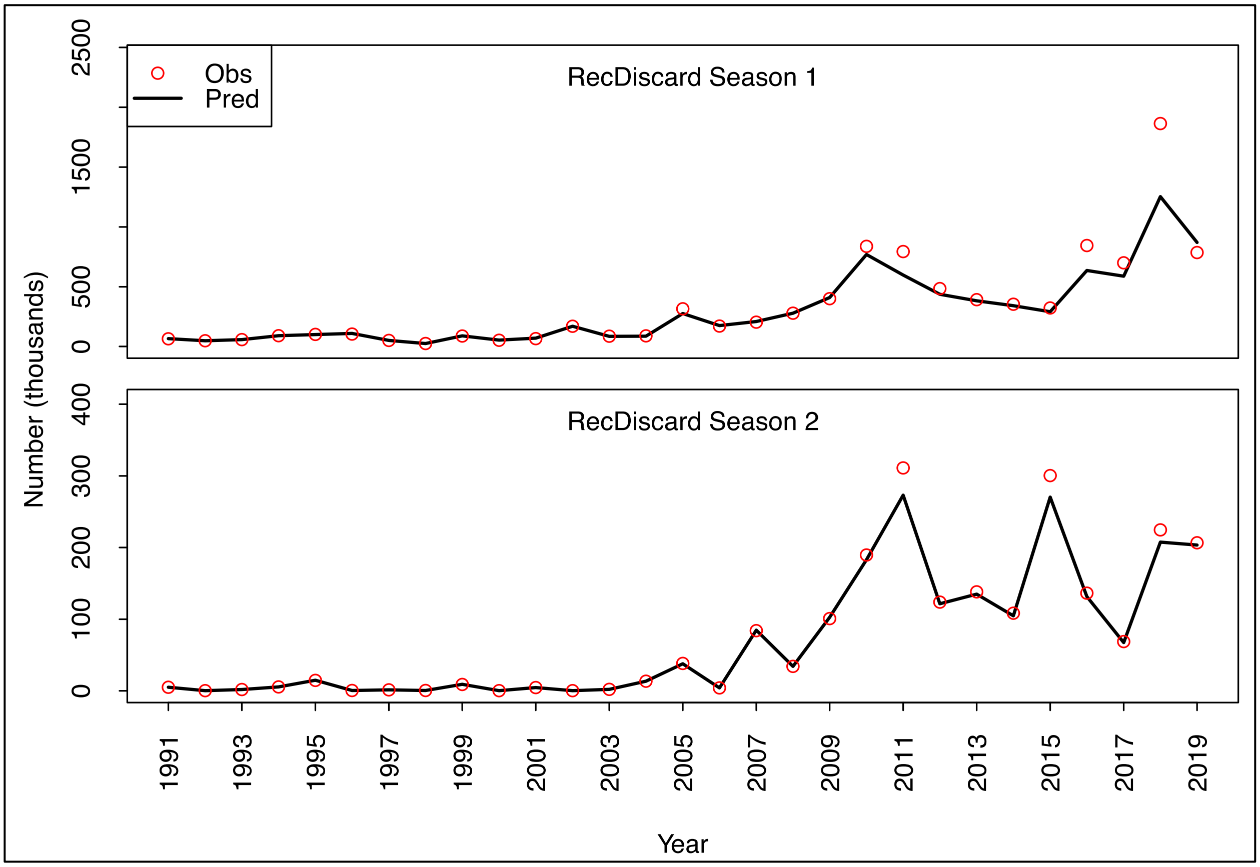


**Figure 3.6.** Predicted (line) and observed (circle) recreational discards (thousands of fish) of Spotted Seatrout from the base model of the stock assessment, 1991–2019. Season 1—non-winter season, March–November; Season 2—winter season, December–February.

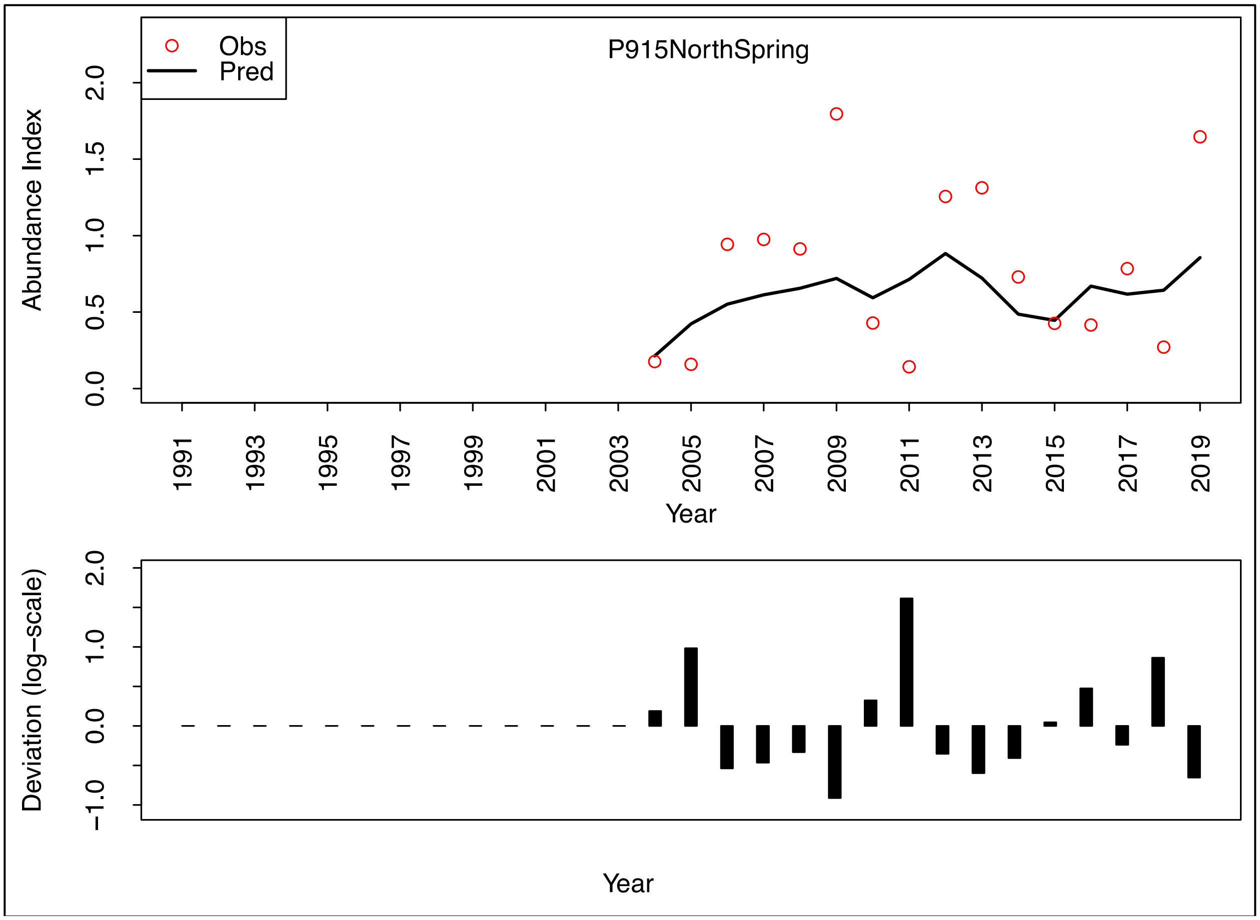


**Figure 3.7.** Predicted (line) and observed (circle) abundance index (top panel) and residuals (log-scale; bottom panel) for the P915NorthSpring survey from the base model of the stock assessment, 2004–2019.

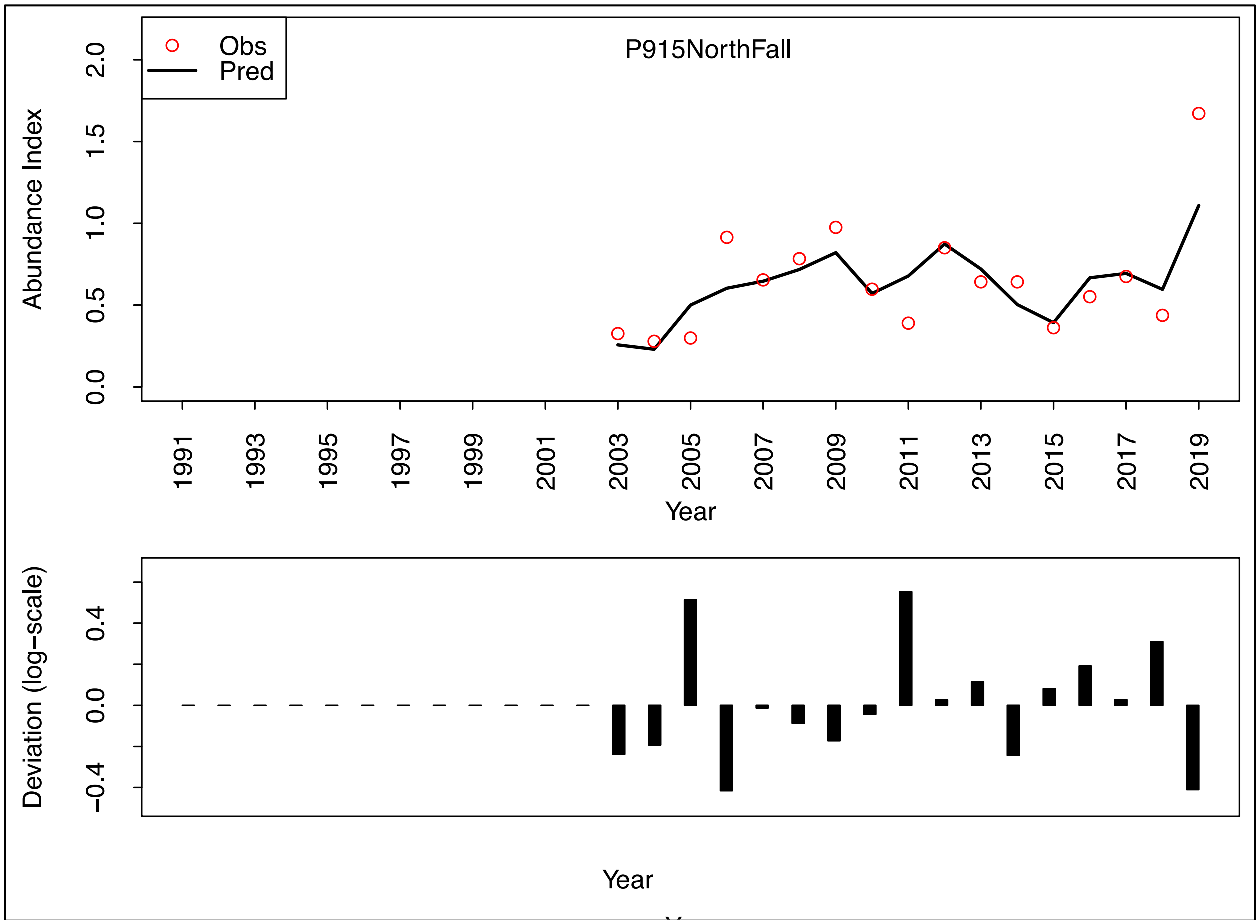


**Figure 3.8.** Predicted (line) and observed (circle) abundance index (top panel) and residuals (log-scale; bottom panel) for the P915NorthFall survey from the base model of the stock assessment, 2003–2019.

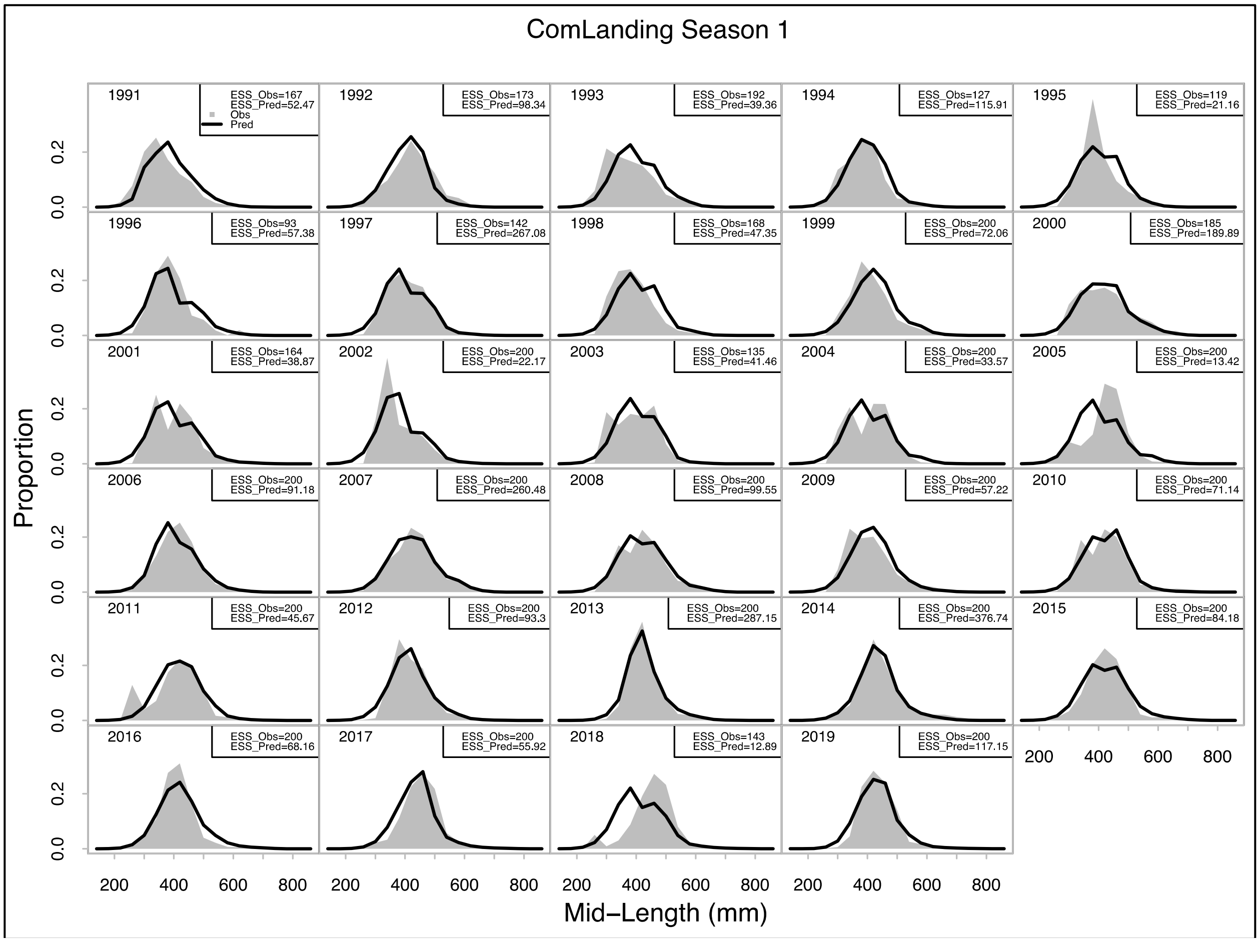


**Figure 3.9.** Predicted (line) and observed (shaded area) length composition for commercial landings of Spotted Seatrout from the base model of the stock assessment, 1991–2019, for Season 1 (non-winter season, March–November). ESS = effective sample size.

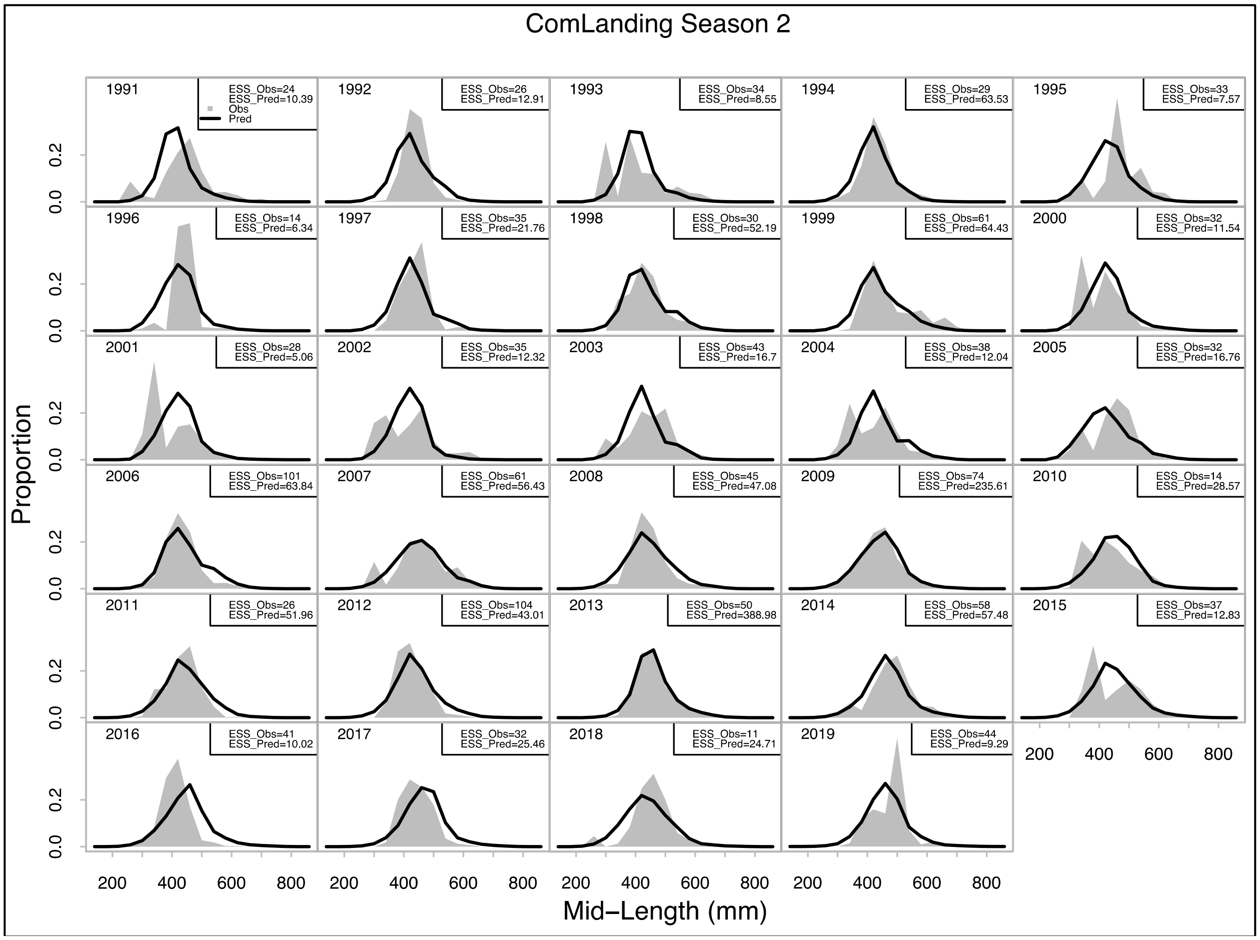


**Figure 3.10.** Predicted (line) and observed (shaded area) length composition for commercial landings of Spotted Seatrout from the base model of the stock assessment, 1991–2019, for Season 2 (winter season, December–February). ESS = effective sample size.

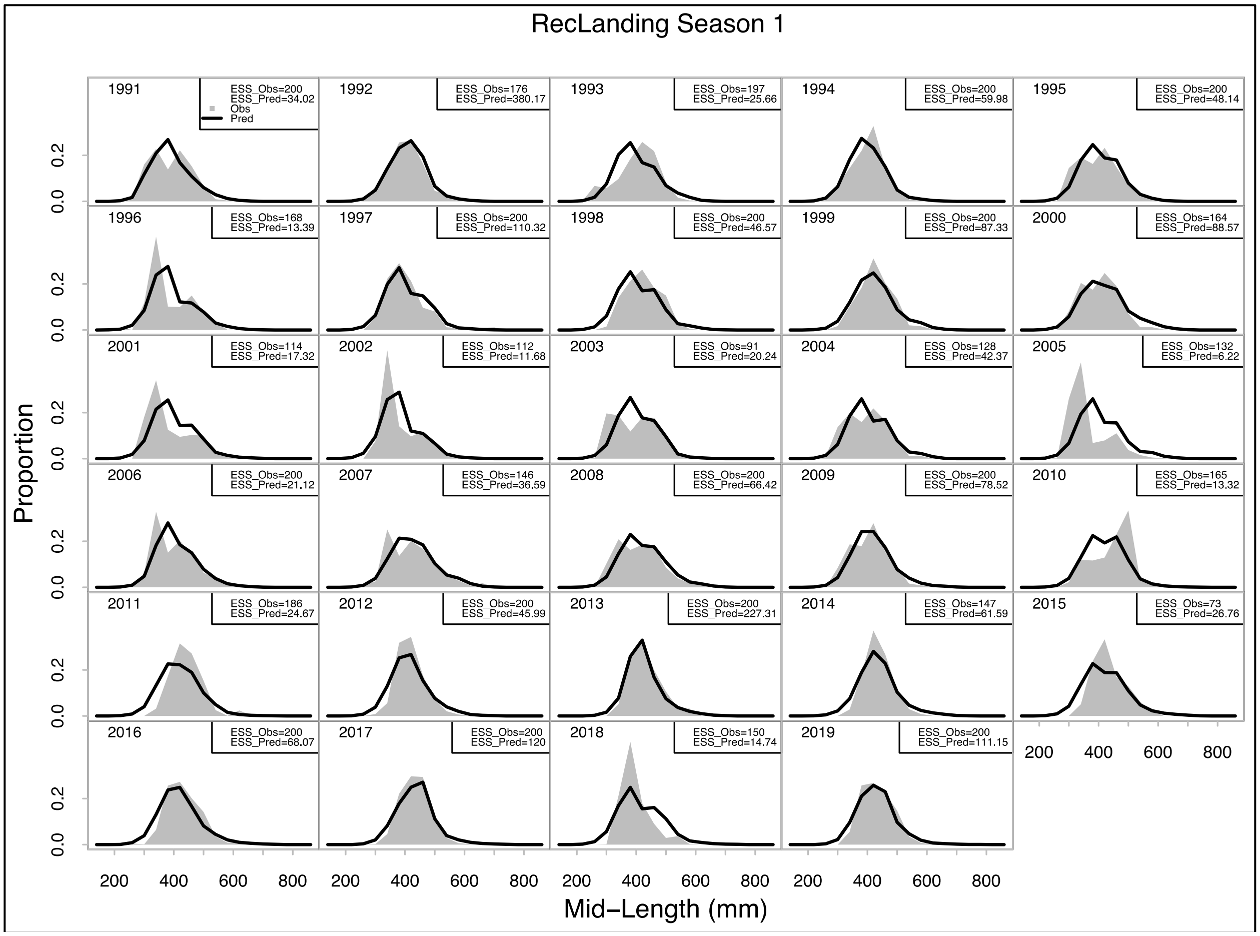


**Figure 3.11.** Predicted (line) and observed (shaded area) length composition for recreational landings of Spotted Seatrout from the base model of the stock assessment, 1991–2019, for Season 1 (non-winter season, March–November). ESS = effective sample size.

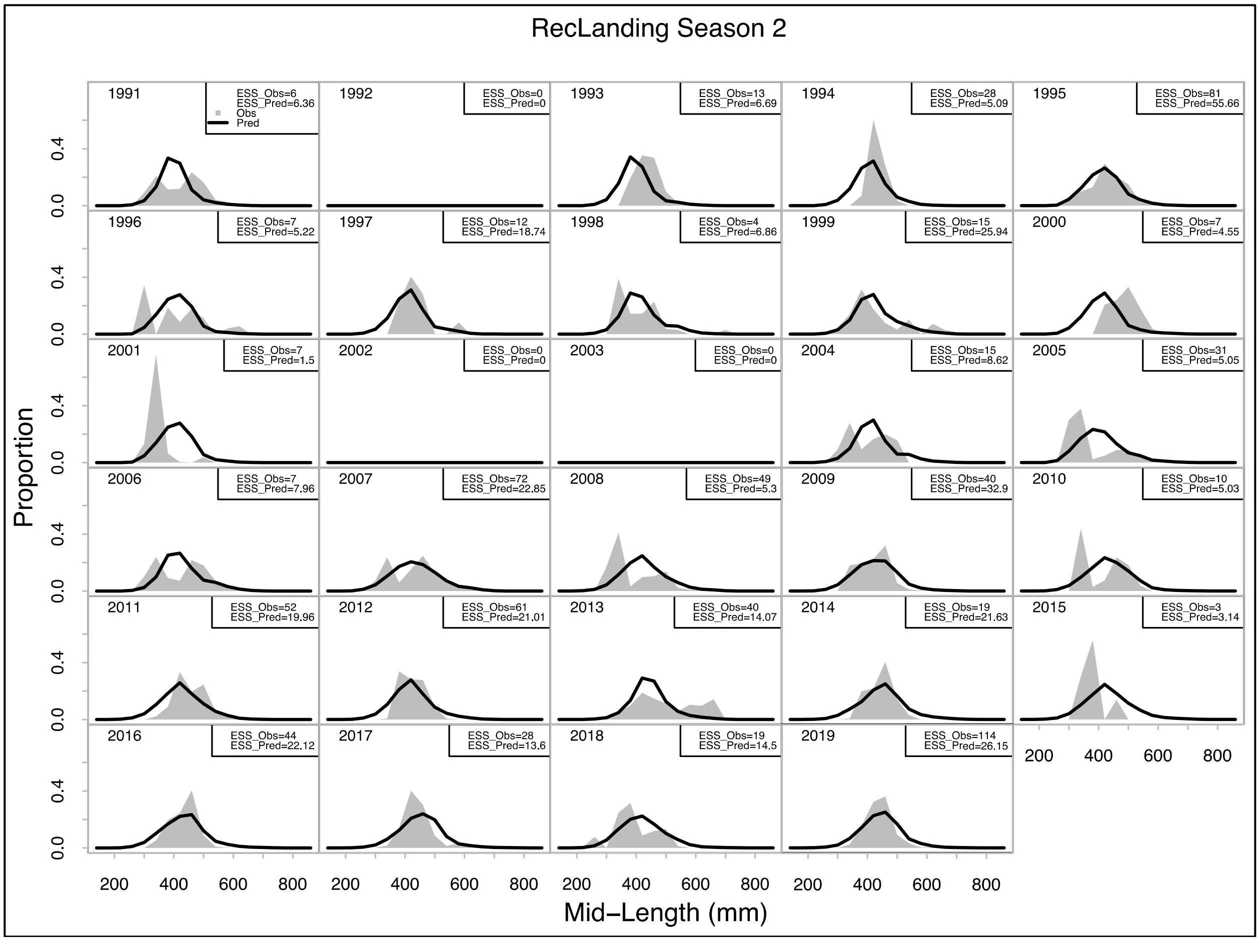


**Figure 3.12.** Predicted (line) and observed (shaded area) length composition for recreational landings of Spotted Seatrout from the base model of the stock assessment, 1991–2019, for Season 2 (winter season, December–February). ESS = effective sample size. The data in 1992, 2002 and 2003 were removed due to extremely small effective sample size (< 2).

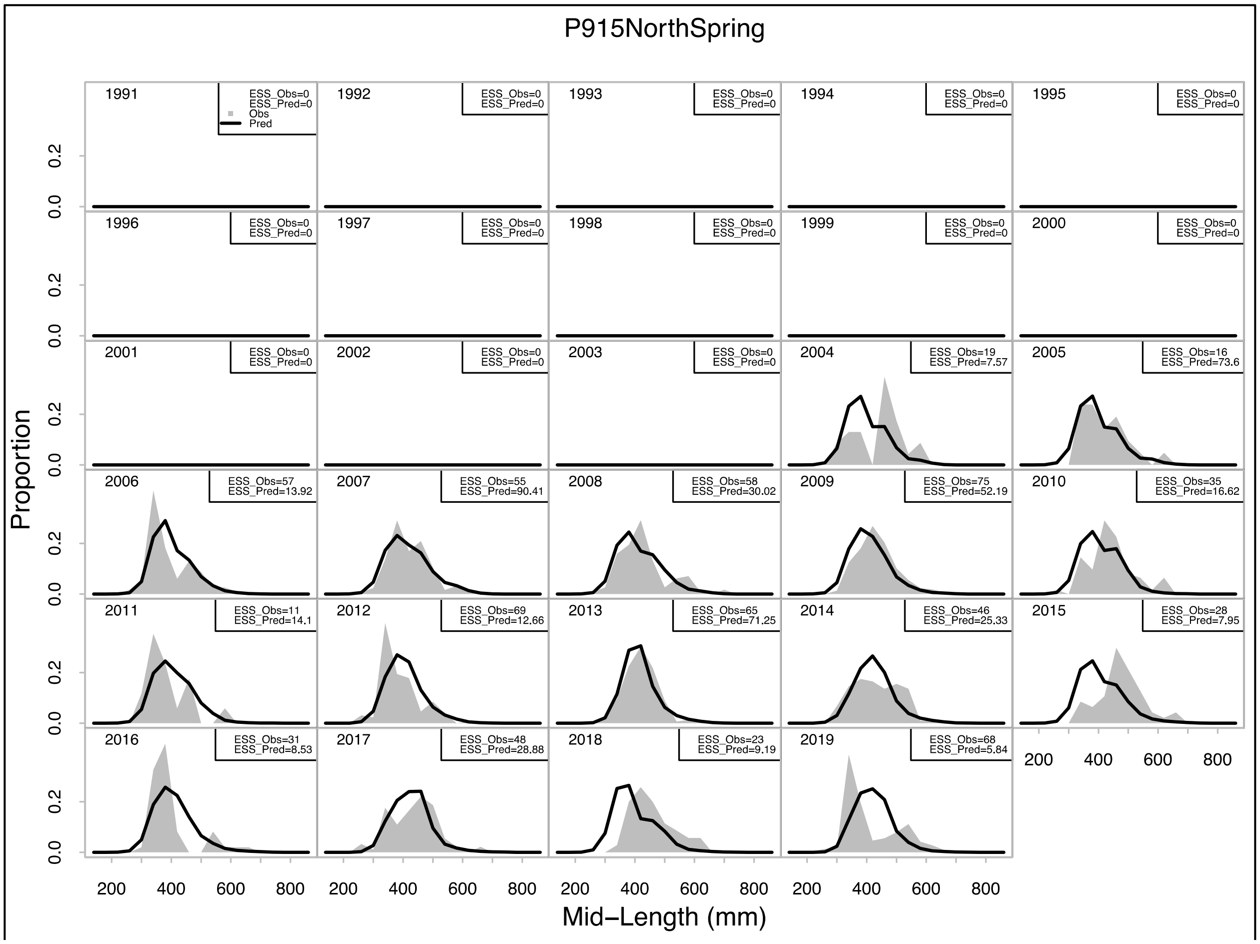


**Figure 3.13.** Predicted (line) and observed (shaded area) length composition for the P915NorthSpring survey from the base model of the stock assessment, 2004–2019. ESS = effective sample size.

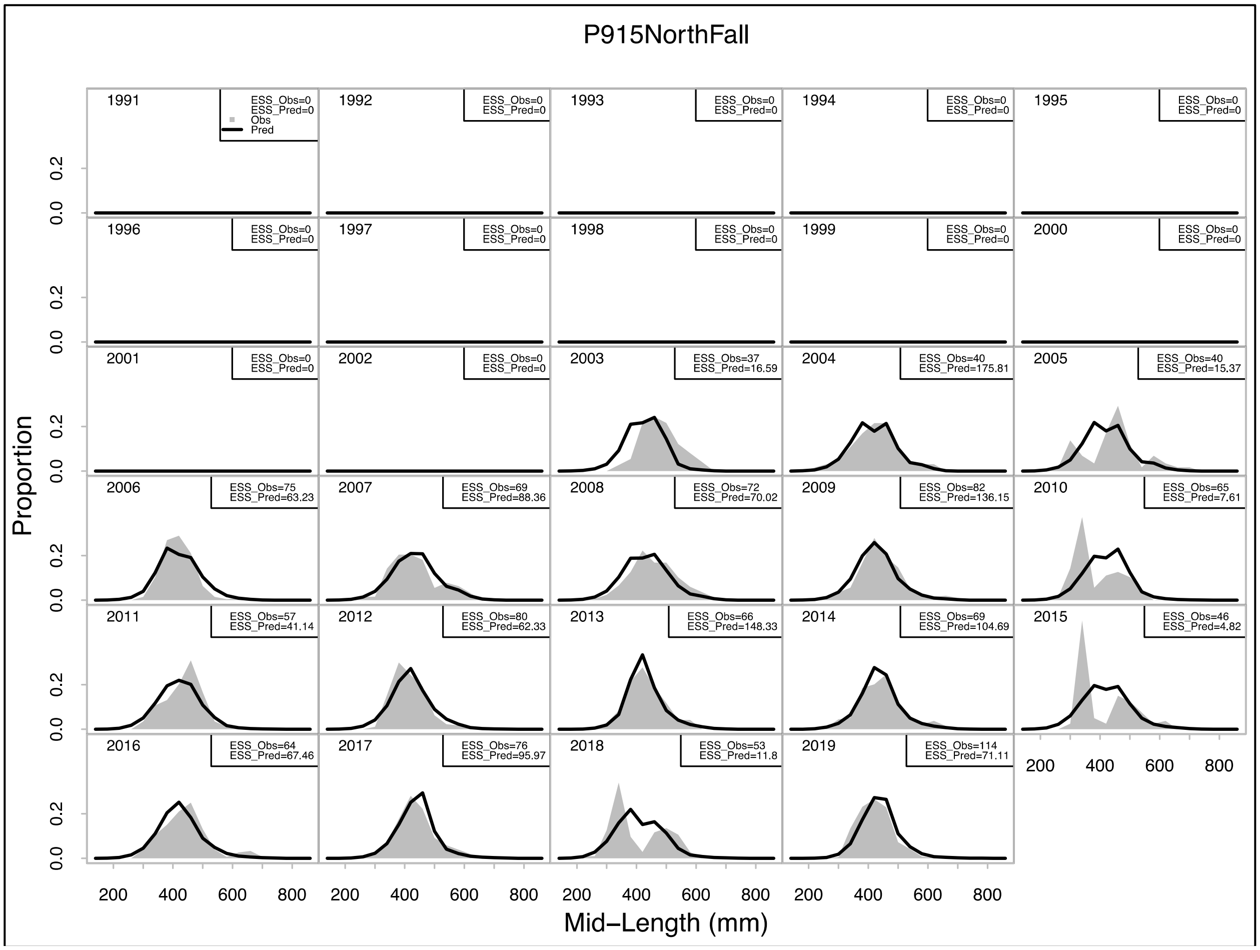


**Figure 3.14.** Predicted (line) and observed (shaded area) length composition for the P915NorthFall survey from the base model of the stock assessment, 2003–2019. ESS = effective sample size.

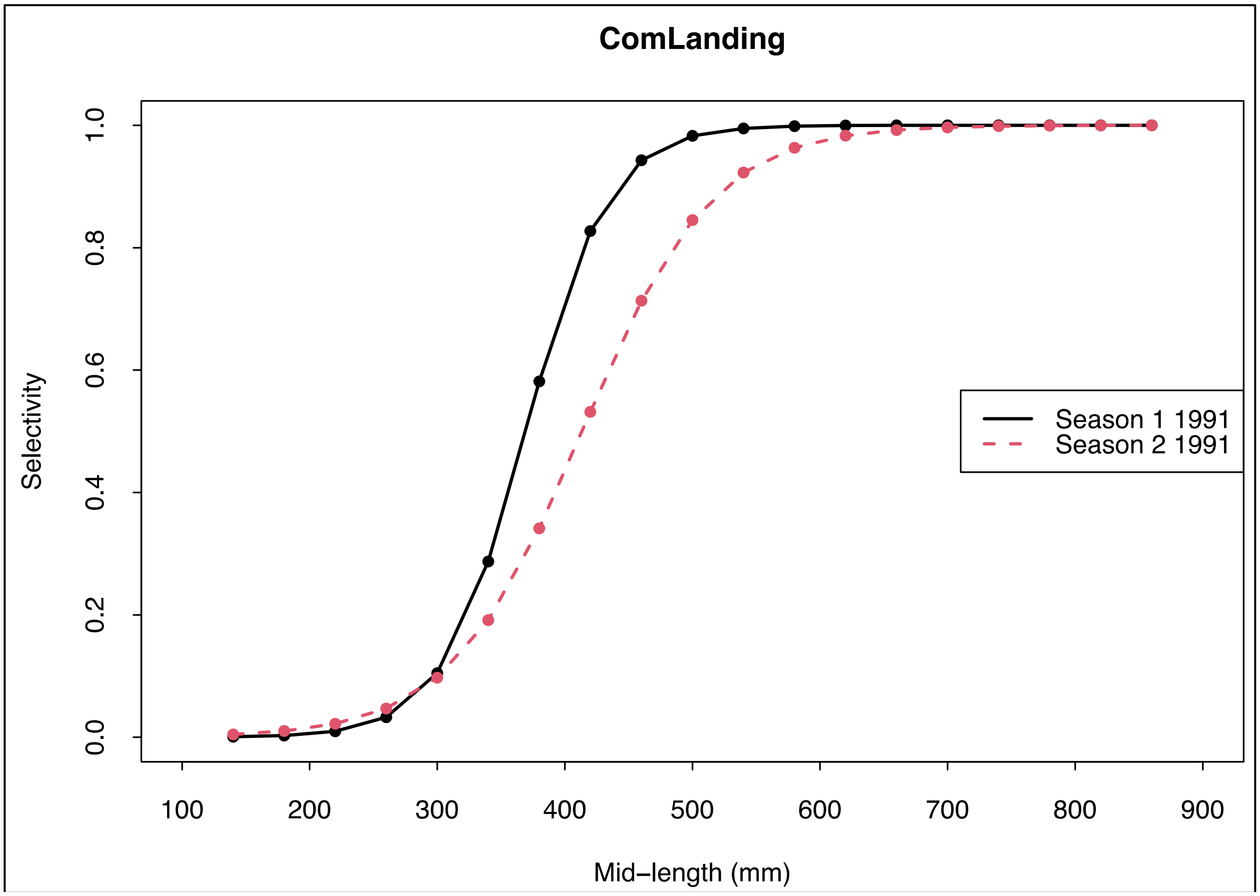


**Figure 3.15.** Predicted length-based selectivity for the commercial landing fleet from the base model of the stock assessment. Season 1—non-winter season, March–November; Season 2—winter season, December–February.

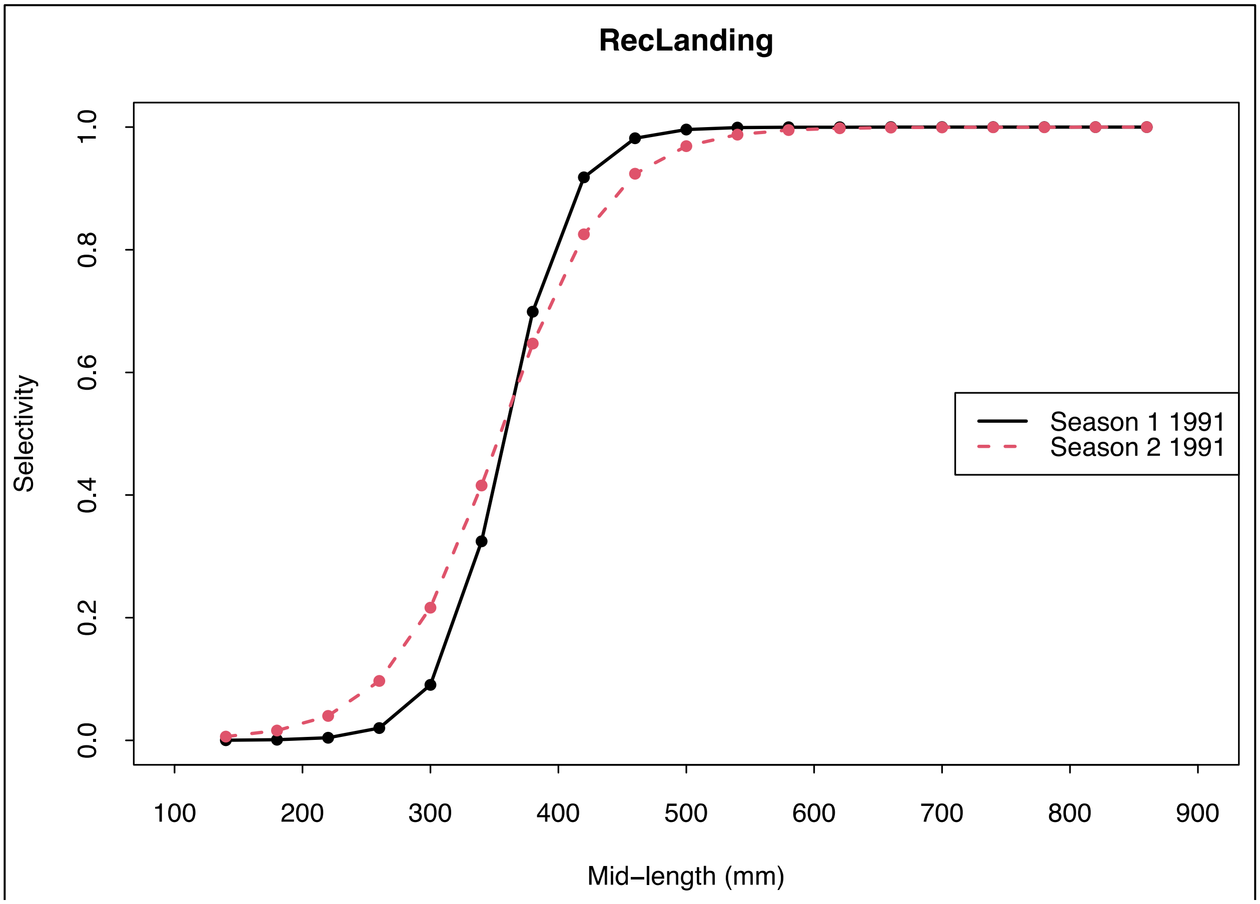


**Figure 3.16.** Predicted length-based selectivity for the recreational landing fleet from the base model of the stock assessment. Season 1—non-winter season, March–November; Season 2—winter season, December–February.

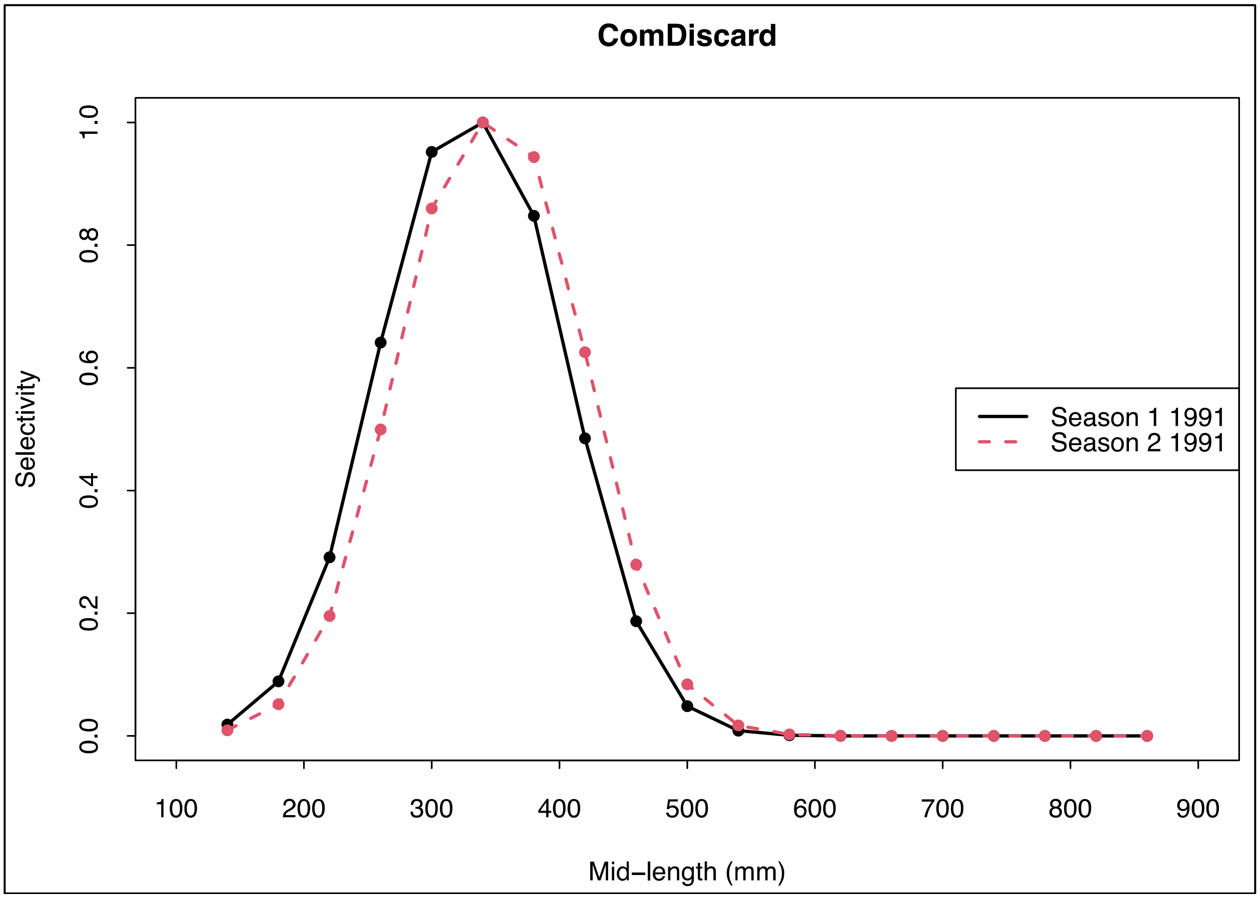


**Figure 3.17.** Predicted length-based selectivity for the commercial discard fleet from the base model of the stock assessment. Season 1—non-winter season, March–November; Season 2—winter season, December–February.

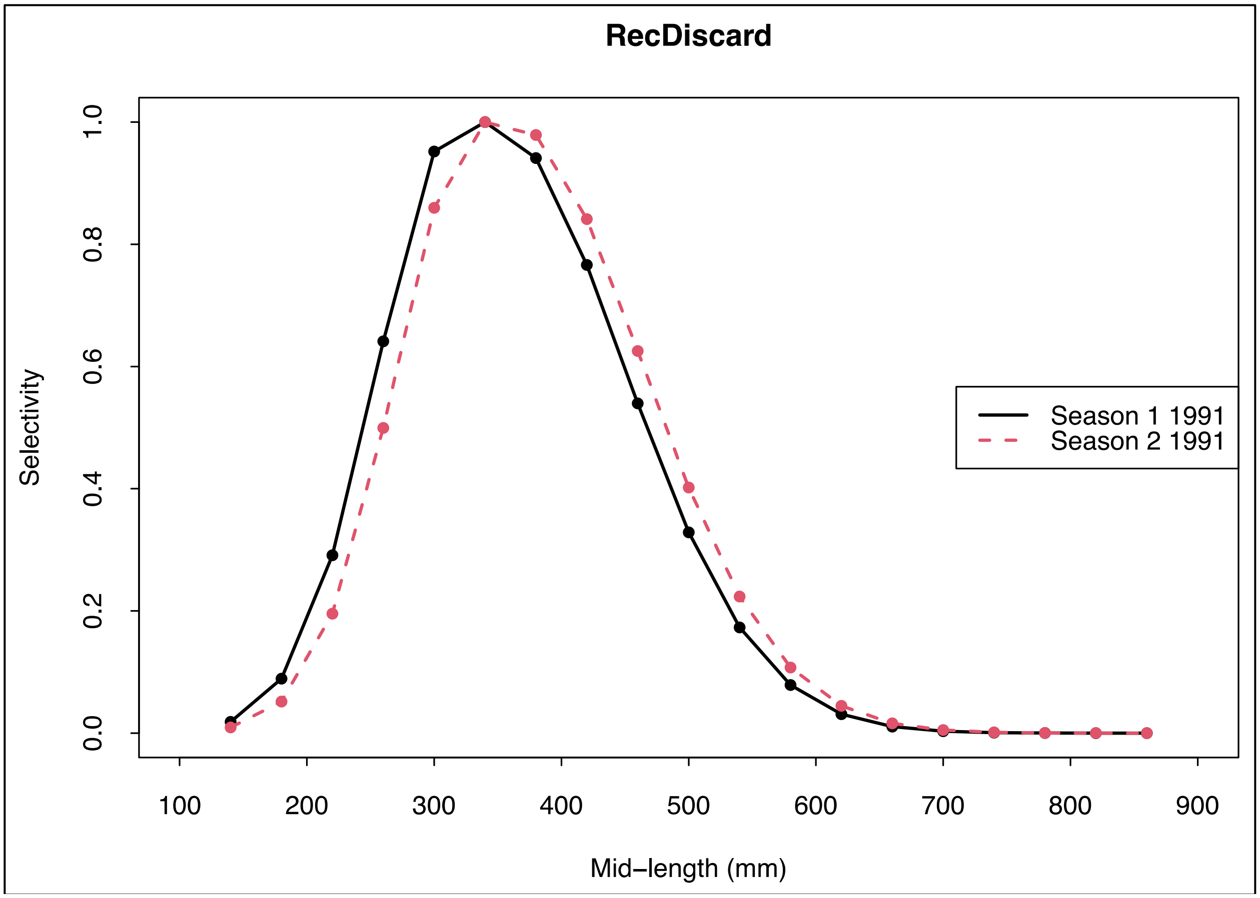


**Figure 3.18.** Predicted length-based selectivity for the recreational discard fleet from the base model of the stock assessment. Season 1—non-winter season, March–November; Season 2—winter season, December–February.

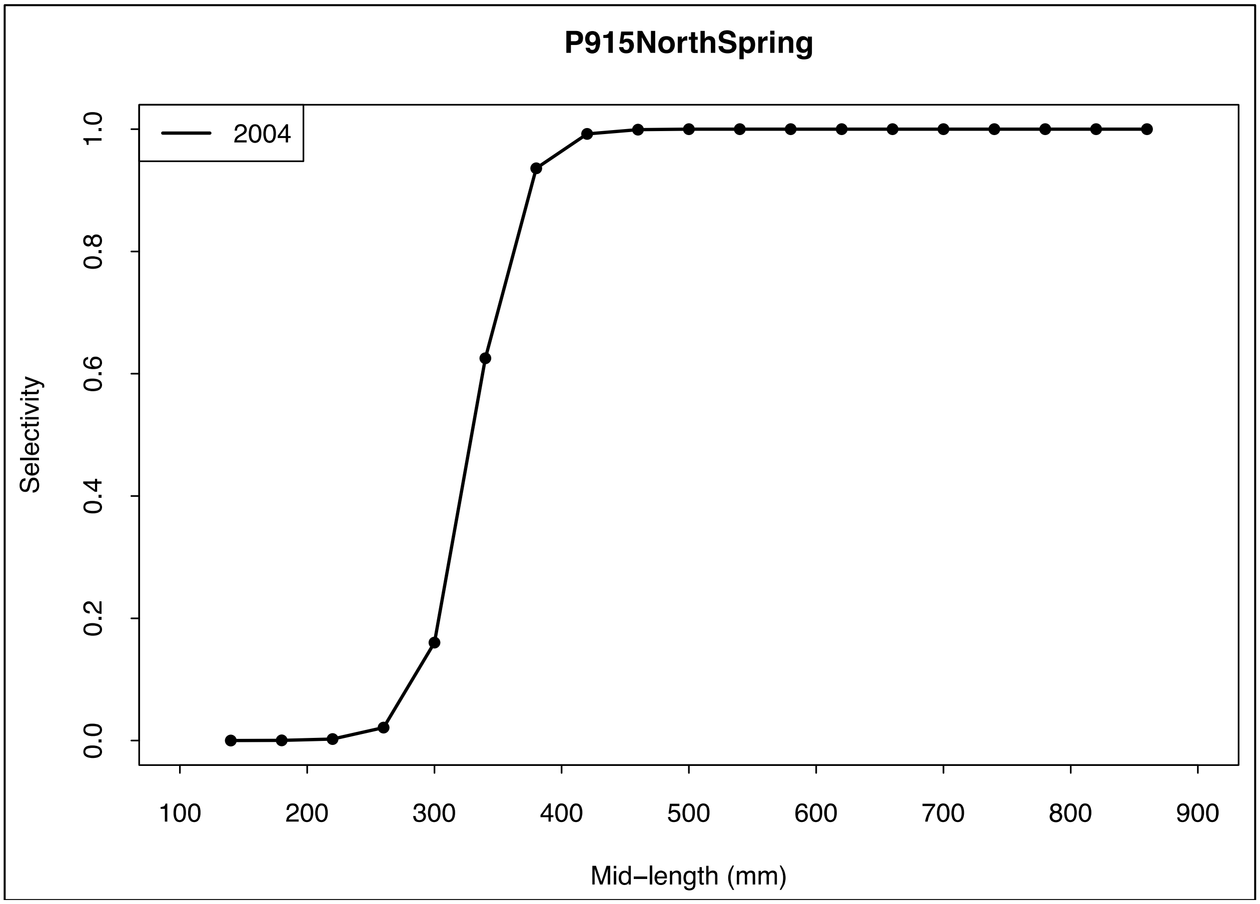


**Figure 3.19.** Predicted length-based selectivity for the P915NorthSpring survey from the base model of the stock assessment.

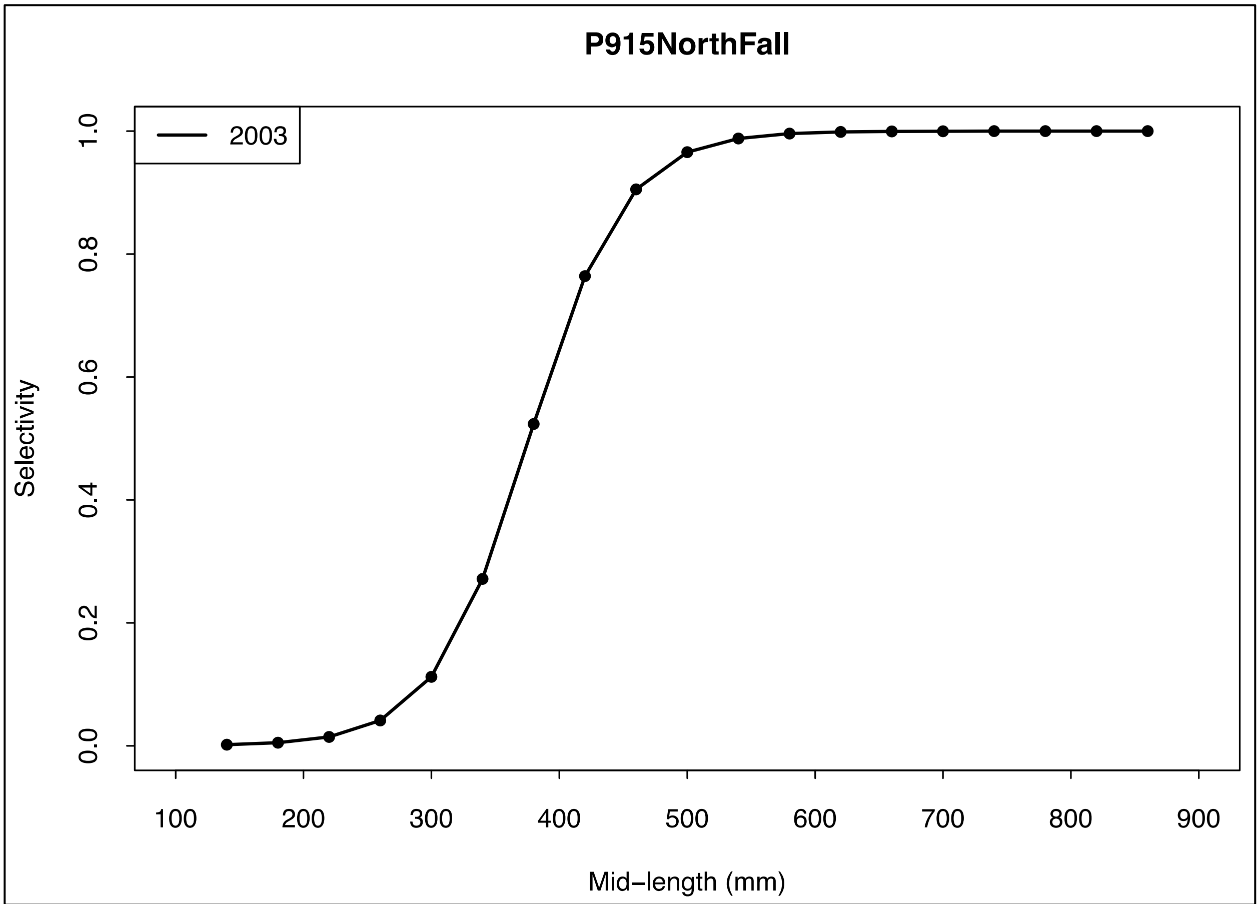


**Figure 3.20.** Predicted length-based selectivity for the P915NorthFall survey from the base model of the stock assessment.

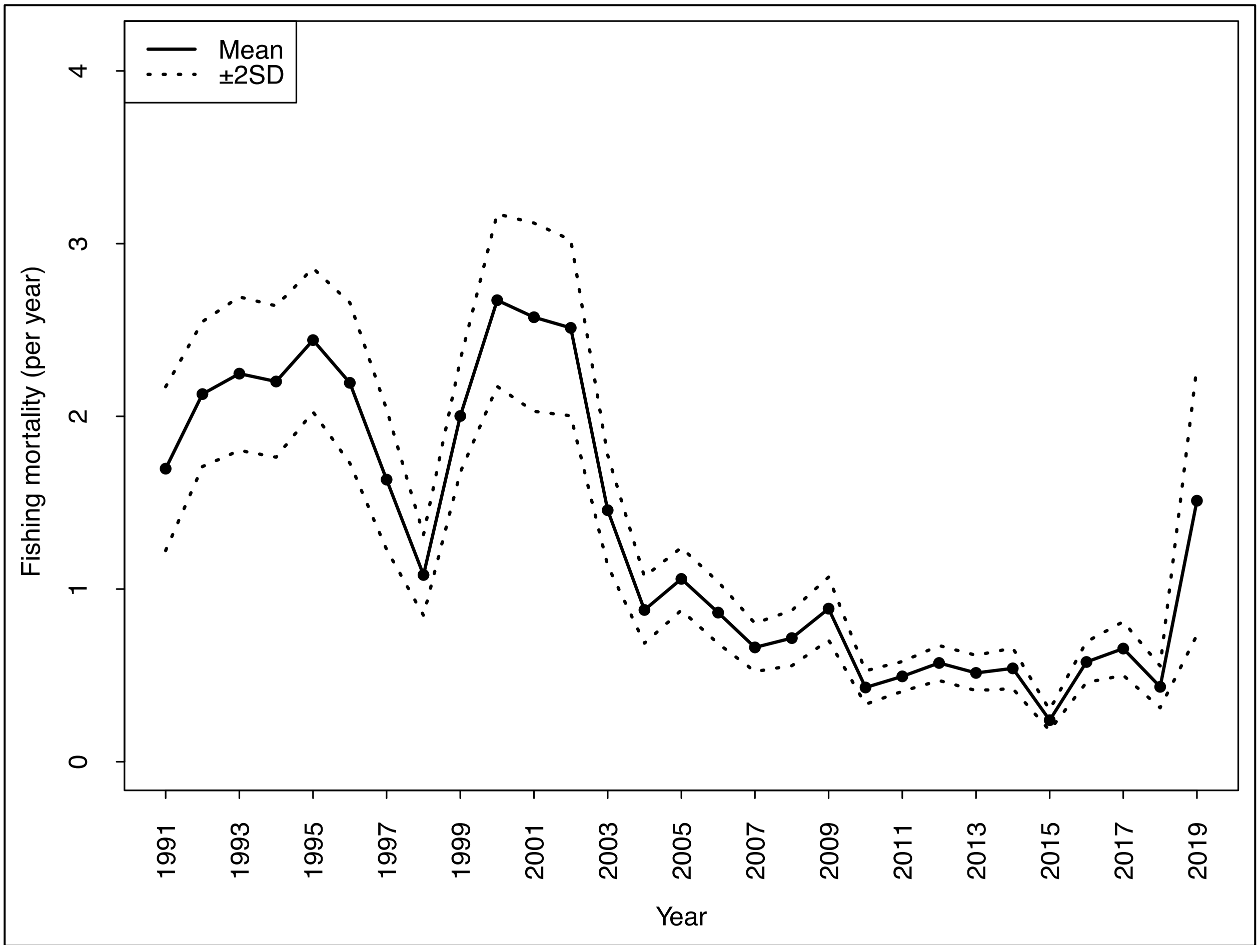


**Figure 3.21.** Predicted fishing mortality (per year) from the base model of the stock assessment, 1991–2019.

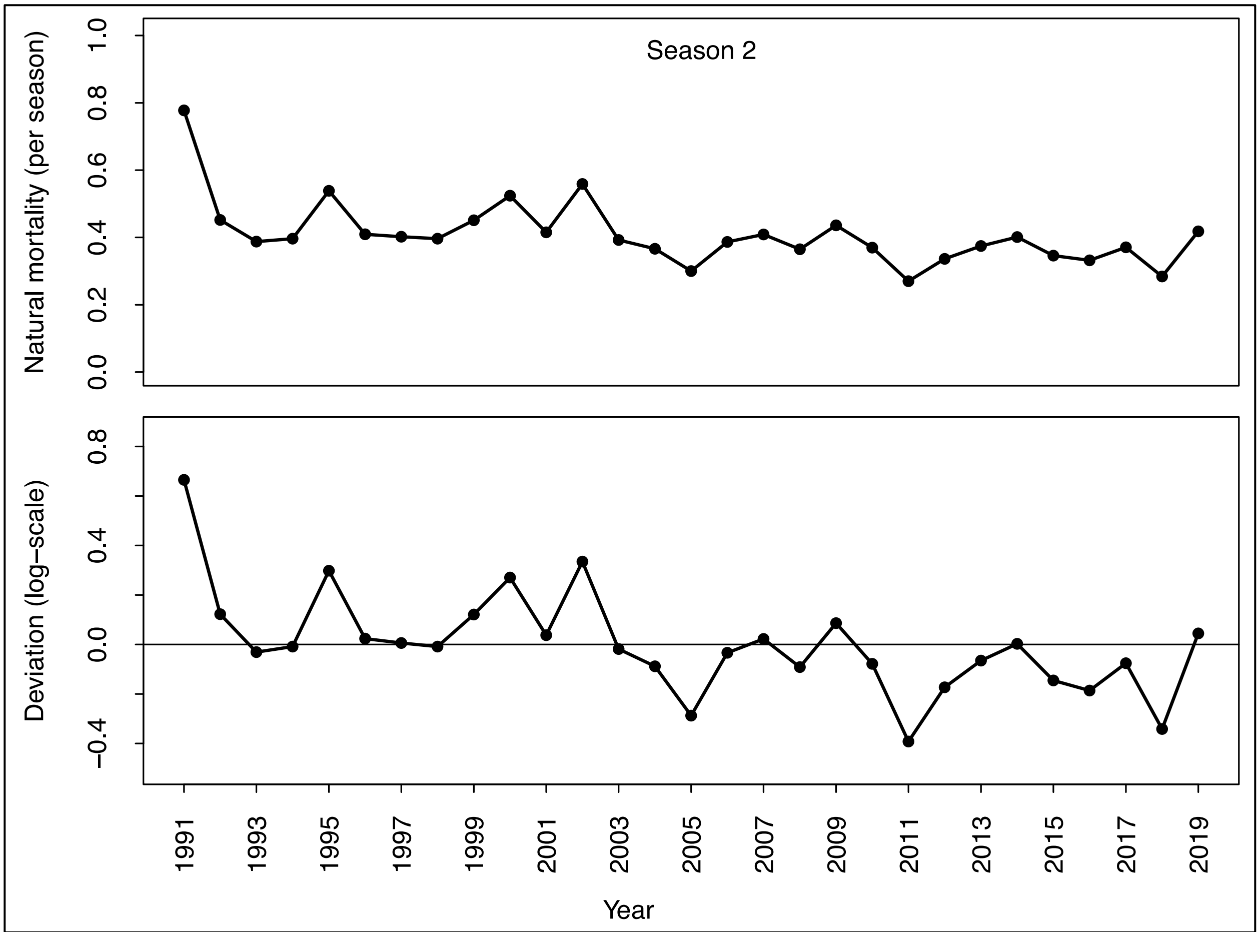


**Figure 3.22.** Predicted mean natual mortality (per season; top panel) and deviation (log-scale; bottom panel) for Season 2 (winter season, December–February) from the base model of the stock assessment, 1991–2019.

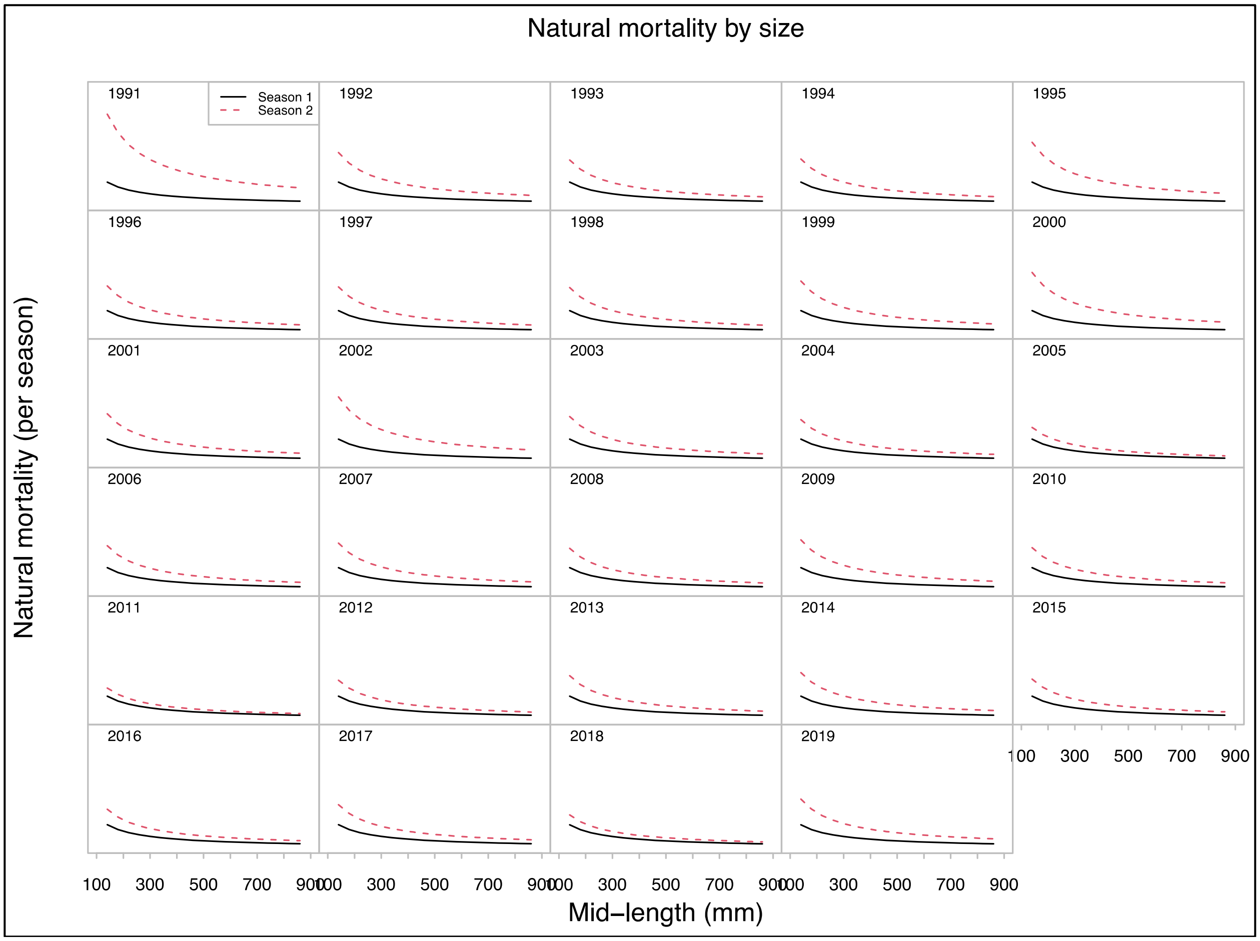


**Figure 3.23.** Predicted length-based natual mortality (per season) from the base model of the stock assessment, 1991–2019. Season 1—non-winter season, March–November; Season 2—winter season, December–February.

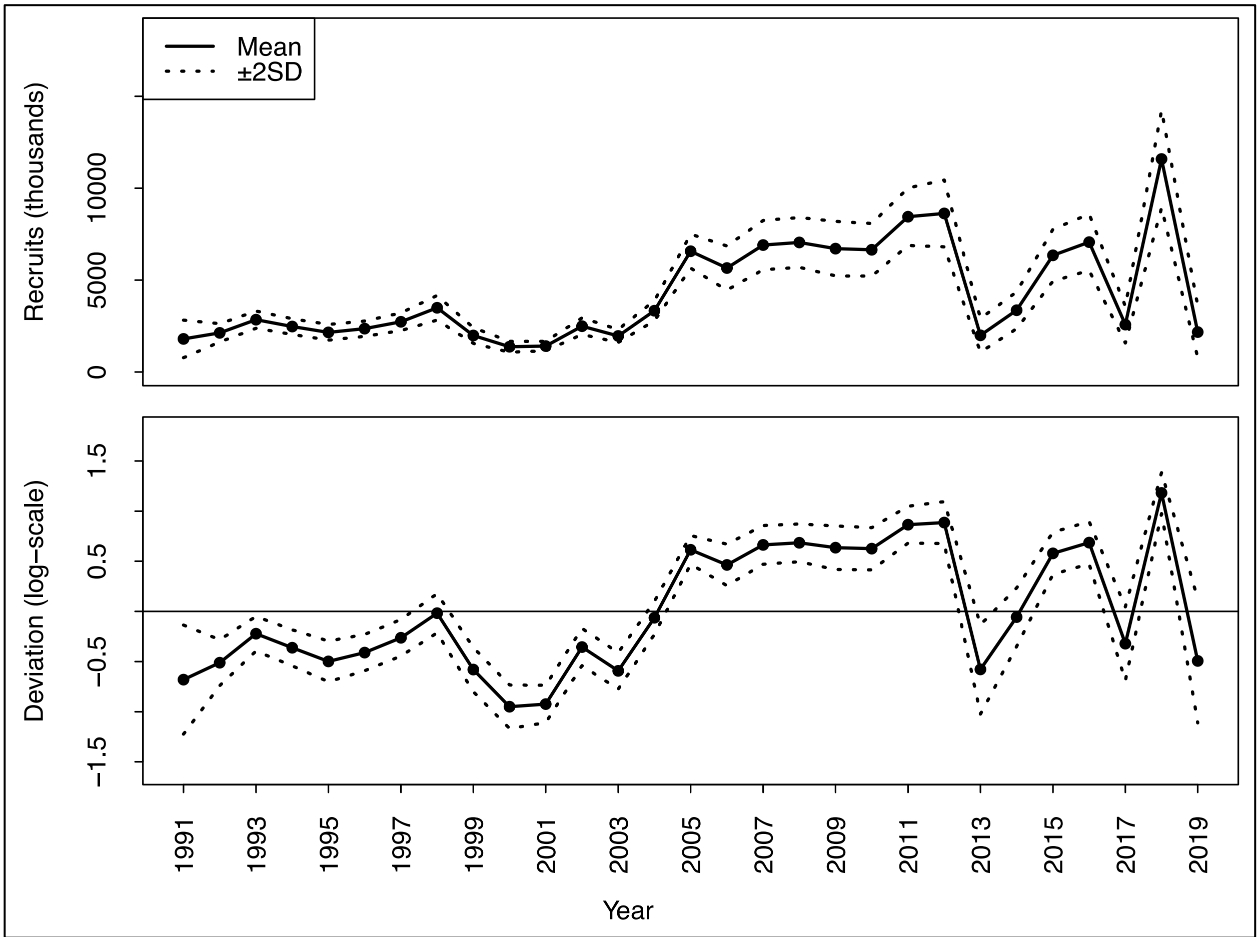


**Figure 3.24.** Predicted recruits (thousands of fish; top panel) and deviation (log-scale; bottom panel) from the base model of the stock assessment, 1991–2019.

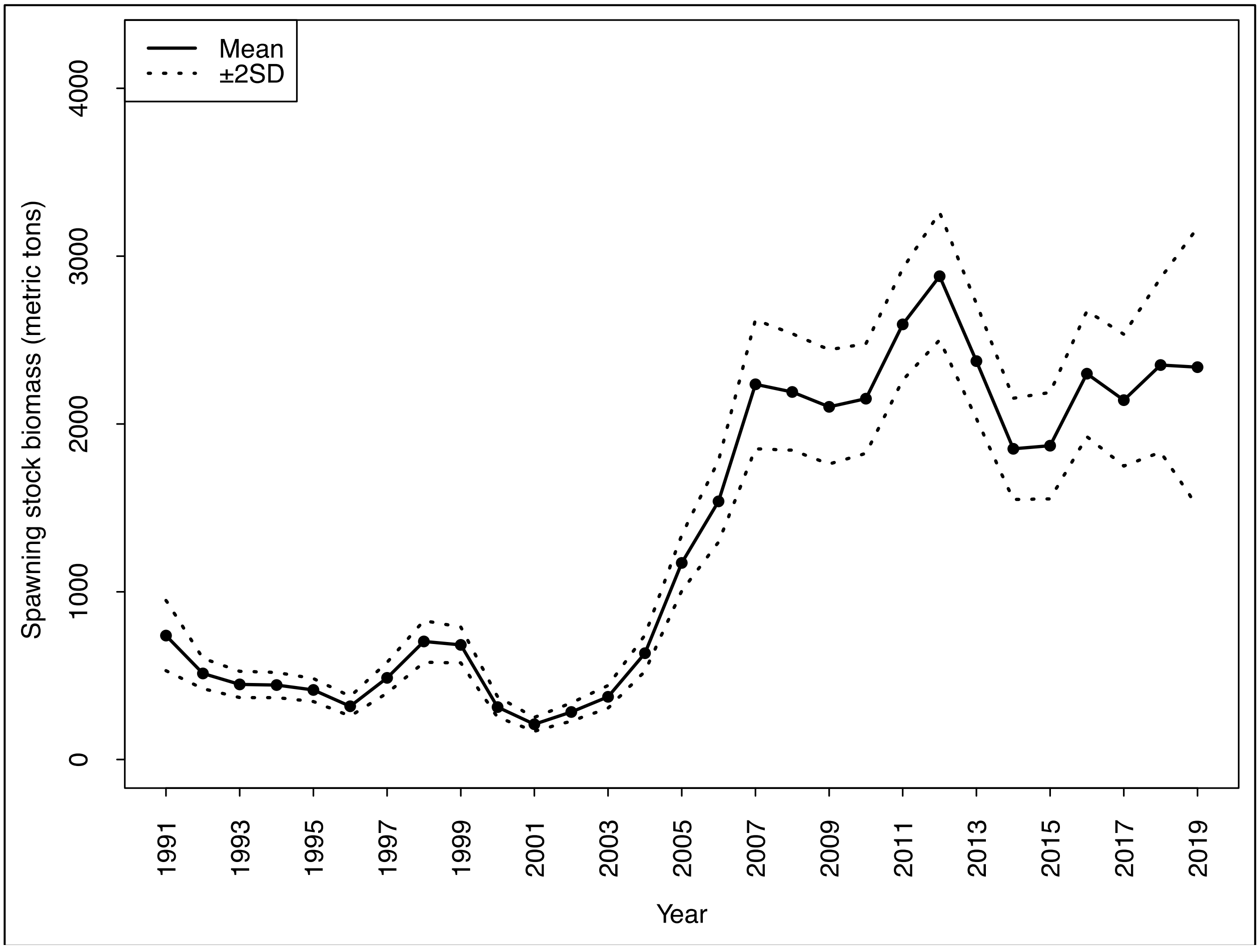


**Figure 3.25.** Predicted spawning stock biomass (metric tons) from the base model of the stock assessment, 1991–2019.

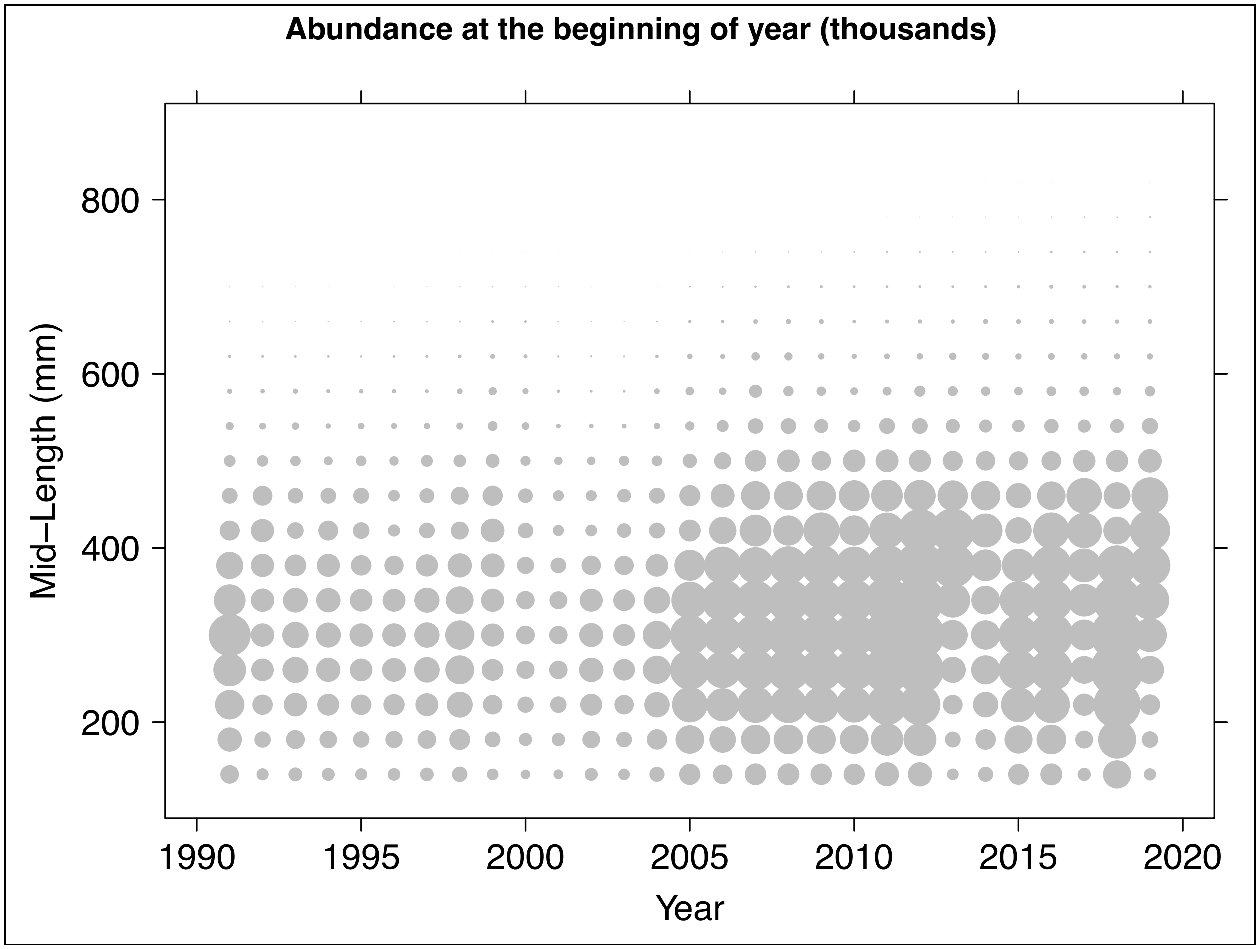


**Figure 3.26.** Predicted abundance at the beginning of year from the base model of the stock assessment, 1991–2019. The size of the bubble is proportional to the predicted abundance (thousands of fish).

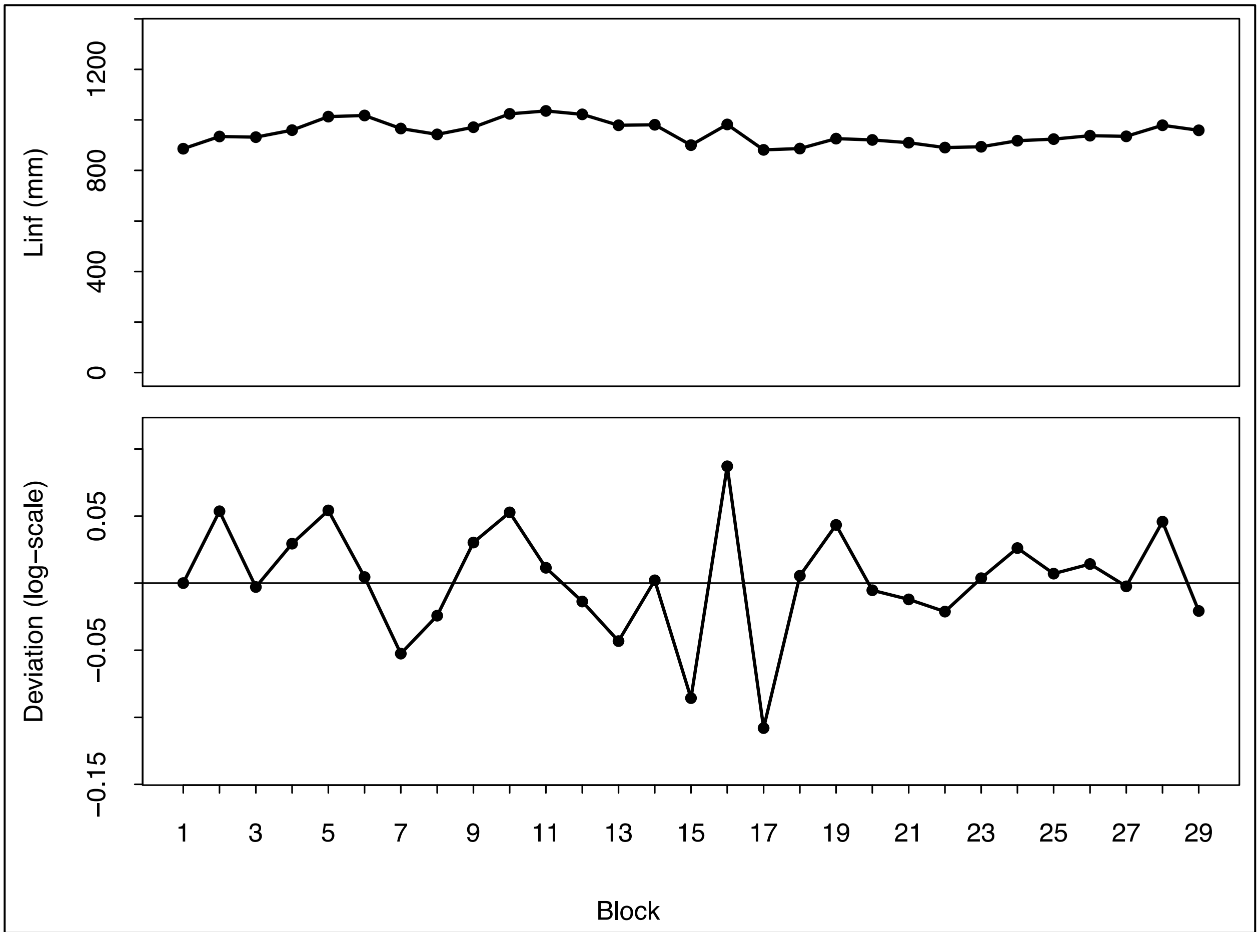


**Figure 3.27.** Predicted growth parameter $L_\infty$ (mm; top panel) and deviation (log-scale; bottom panel) from the base model of the stock assessment, 1991–2019. Block numbers 1–29 correspond to the year 1991–2019.

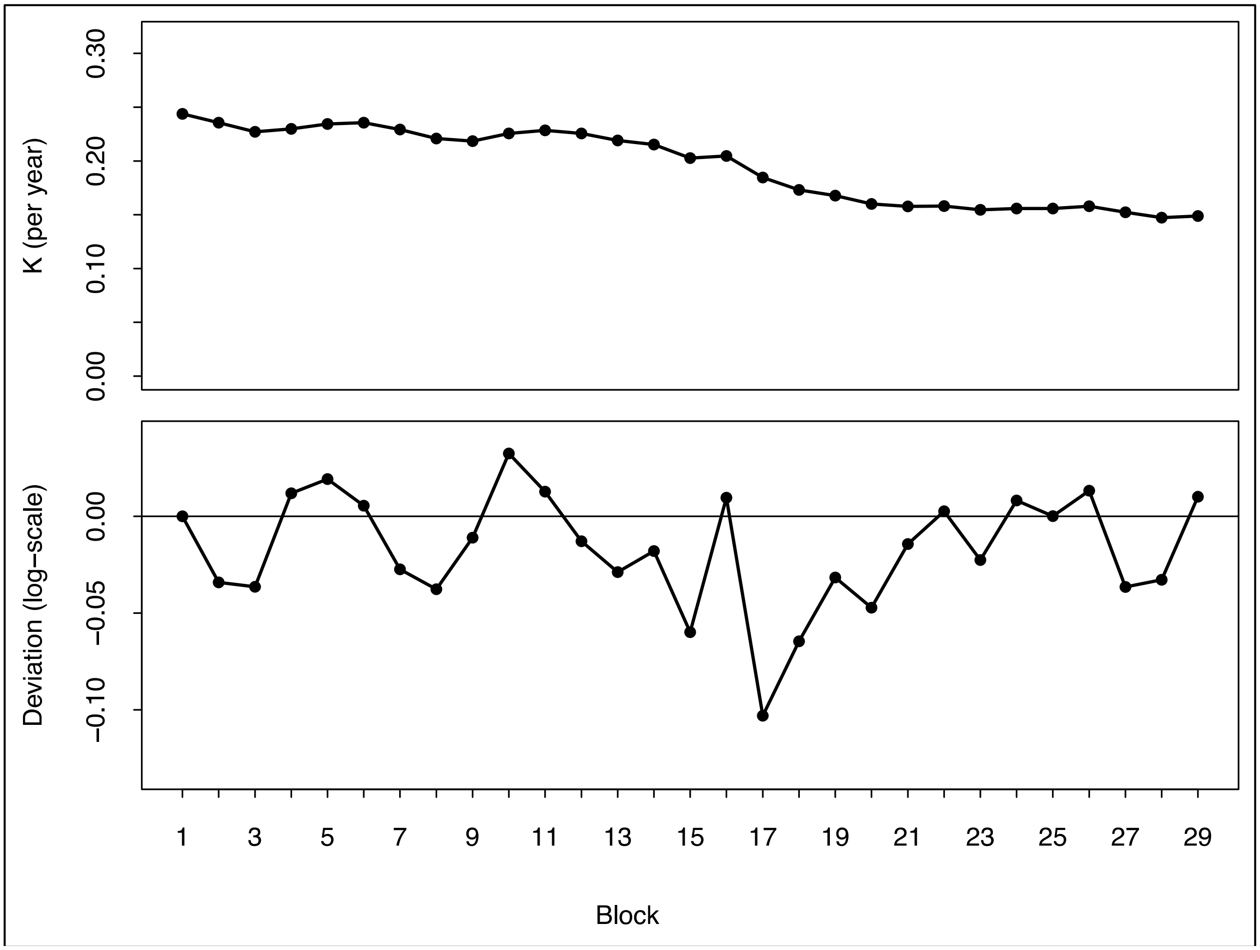


**Figure 3.28.** Predicted growth parameter *K* (per year; top panel) and deviation (log-scale; bottom panel) from the base model of the stock assessment, 1991–2019. Block numbers 1–29 correspond to the year 1991–2019.

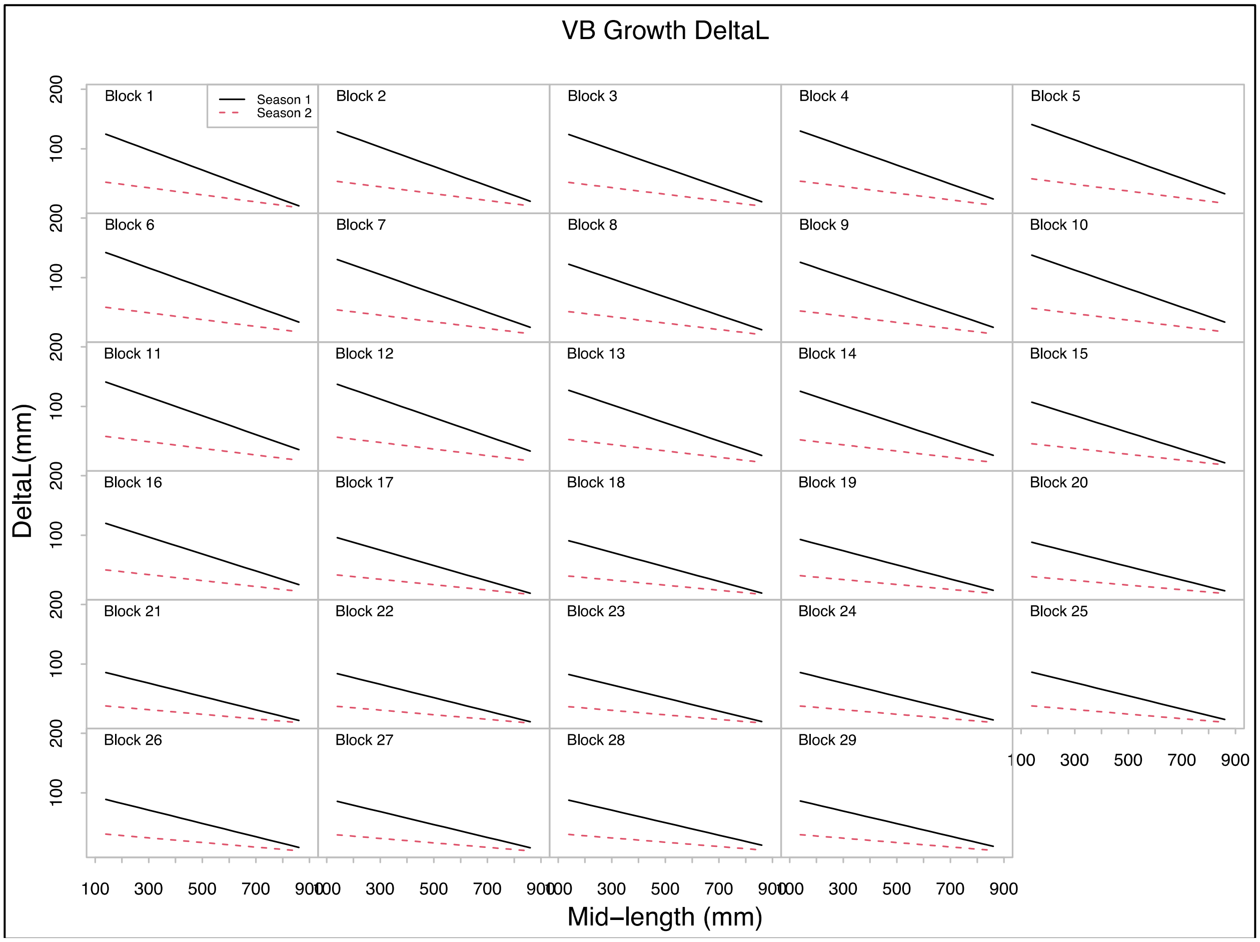


**Figure 3.29.** Predicted von Bertalanffy growth curve from the base model of the stock assessment, 1991-2019. Season 1—non-winter season, March–November; Season 2—winter season, December–February. Block numbers 1–29 correspond to the year 1991–2019.

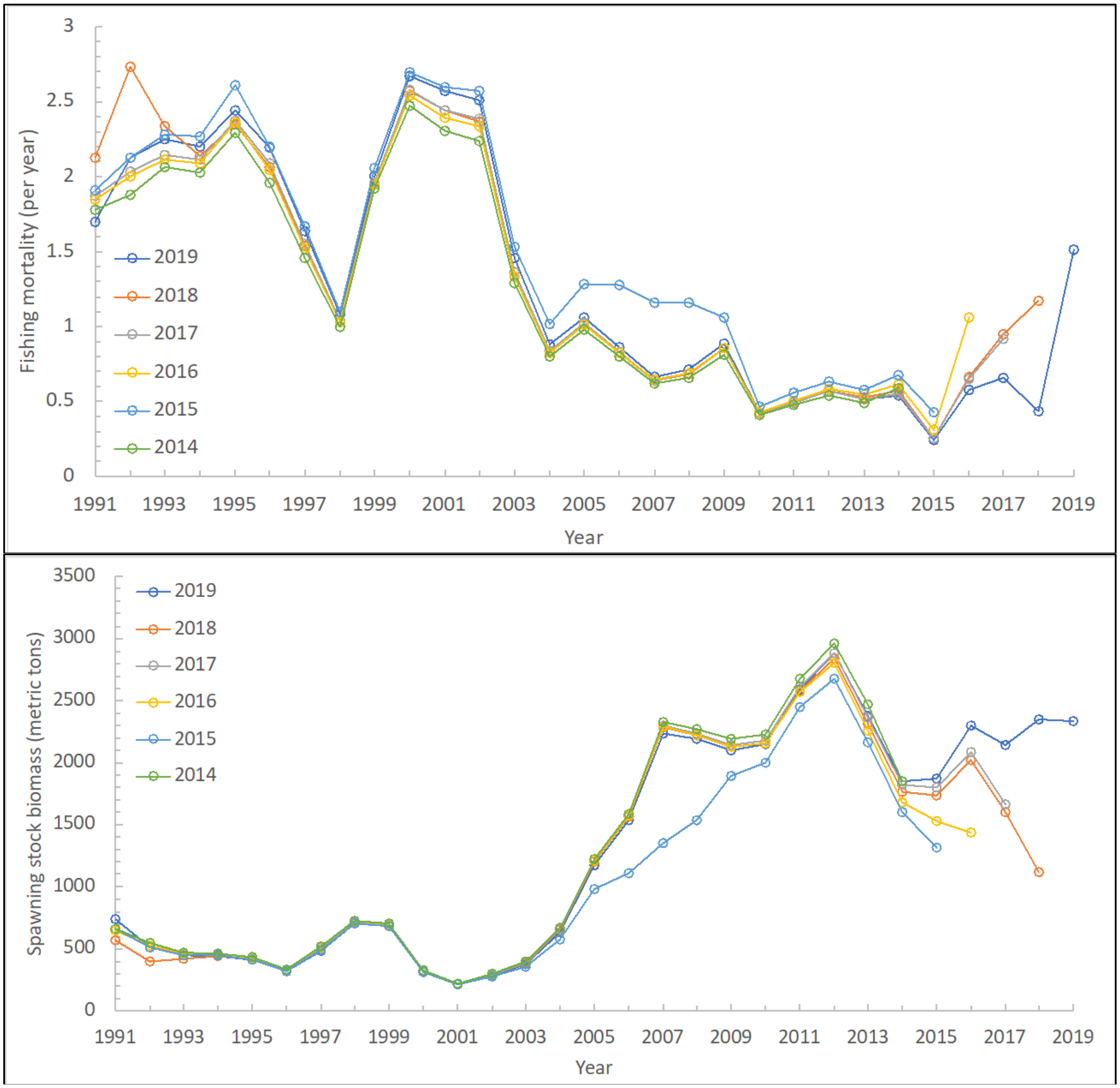


**Figure 3.30.** Predicted fishing mortality (per year; top panel) and spawning stock biomass (metric tons; bottom panel) from the retrospective analysis in which the model started with the data from 1991 to 2014, and added one additional year of data at a time up to 2019.

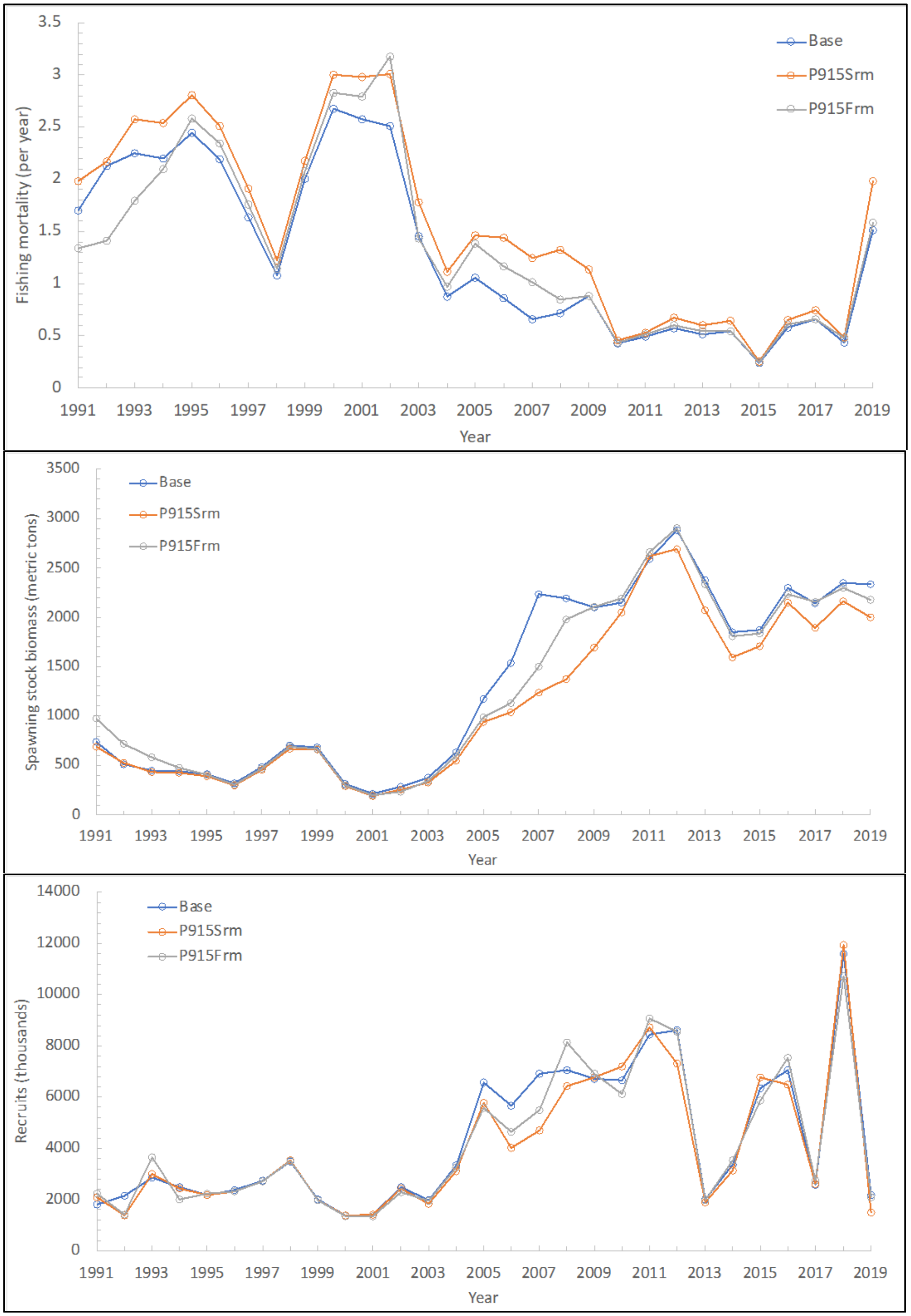


**Figure 3.31.** Sensitivity of predicted fishing mortality (per year; top panel), spawning stock biomass (metric tons; middle panel) and recruits (thousands of fish; bottom panel) to removal of different fishery-independent survey indices from the base model of the stock assessment, 1991–2019.

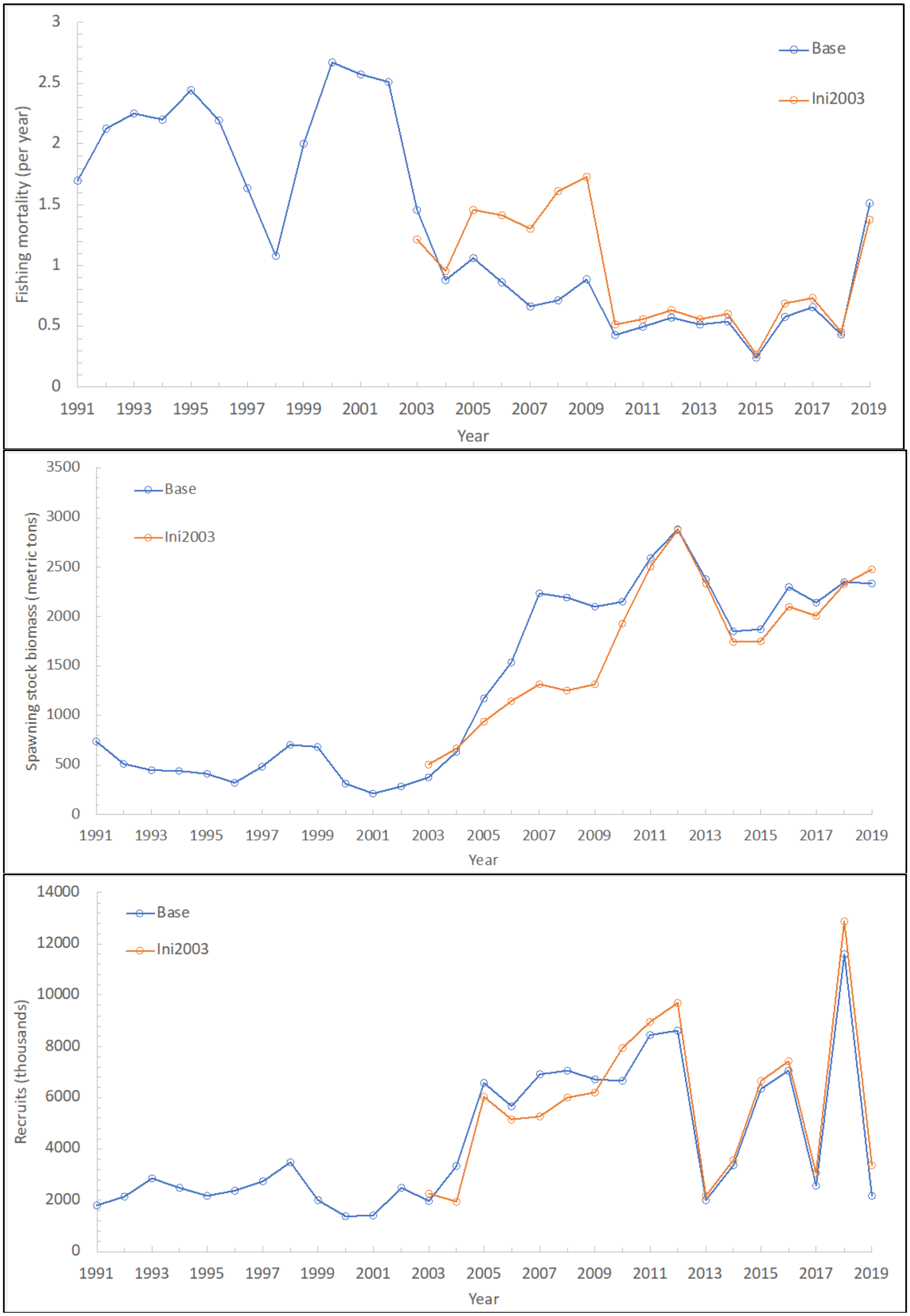


**Figure 3.32.** Sensitivity of predicted fishing mortality (per year; top panel), spawning stock biomass (metric tons; middle panel) and recruits (thousands of fish; bottom panel) to different initial years.

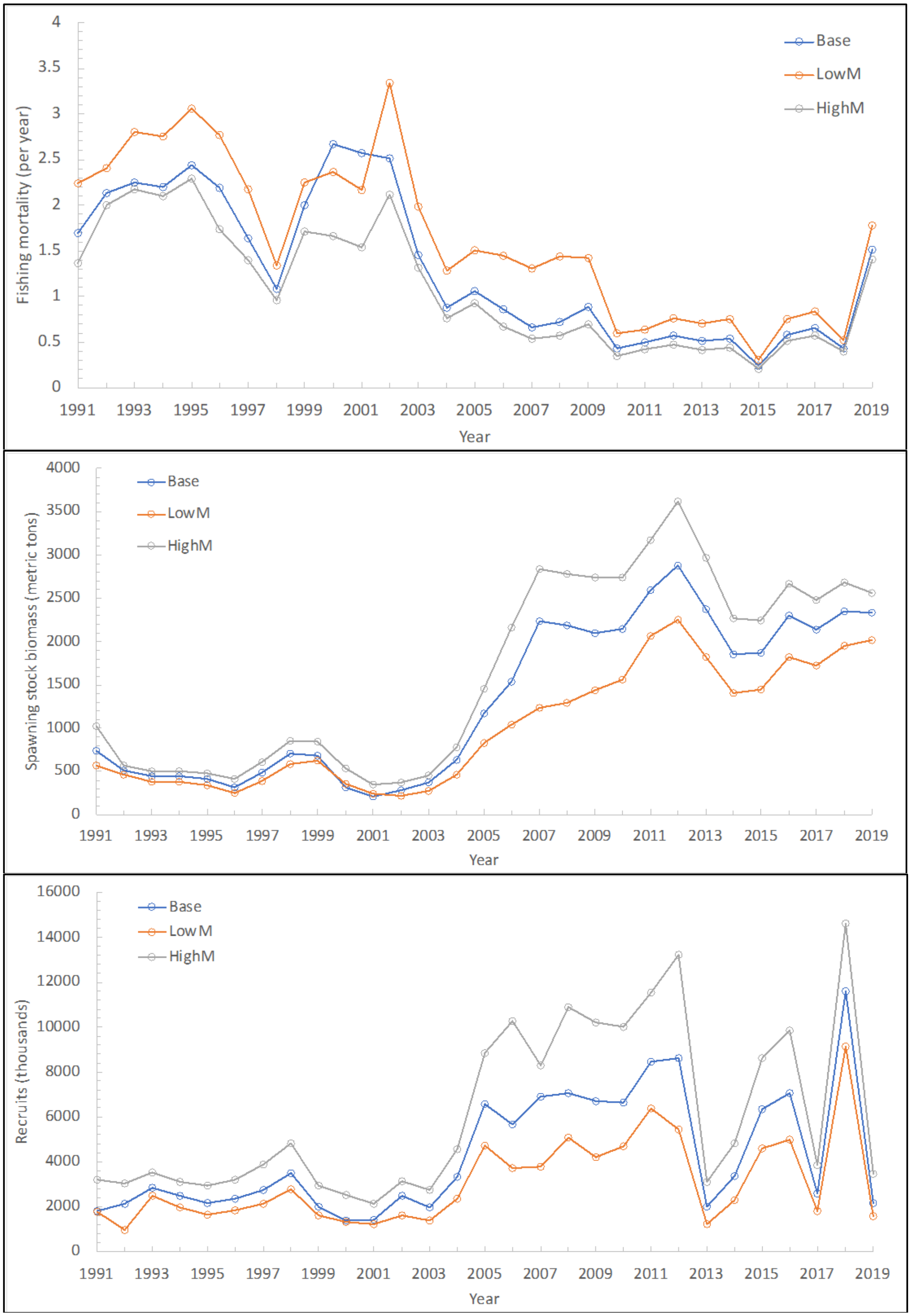


**Figure 3.33.** Sensitivity of predicted fishing mortality (per year; top panel), spawning stock biomass (metric tons; middle panel) and recruits (thousands of fish; bottom panel) to different annual natural mortality values.

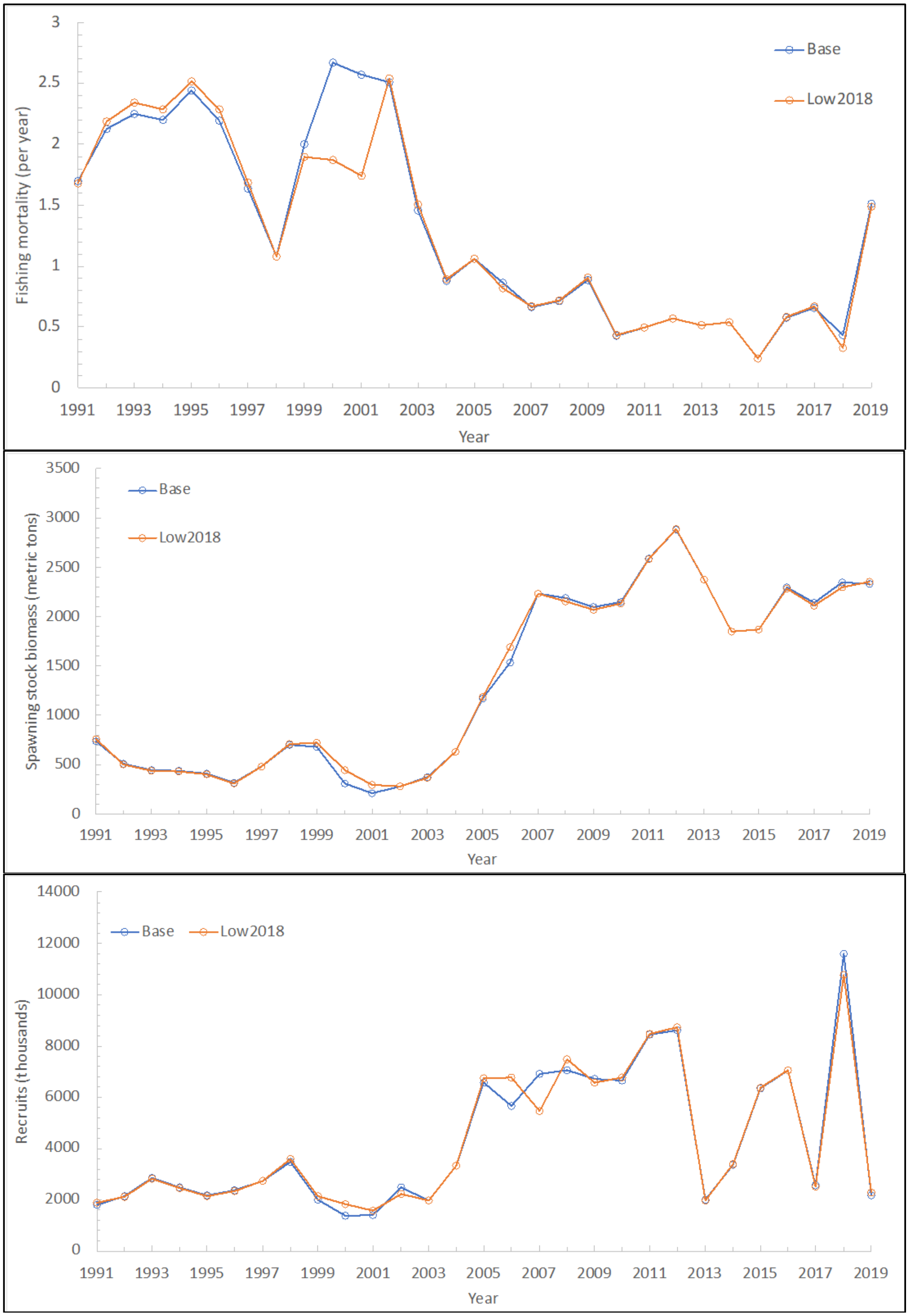


**Figure 3.34.** Sensitivity of predicted fishing mortality (per year; top panel), spawning stock biomass (metric tons; middle panel) and recruits (thousands of fish; bottom panel) to the 2018 non-winter season recreational discard input.

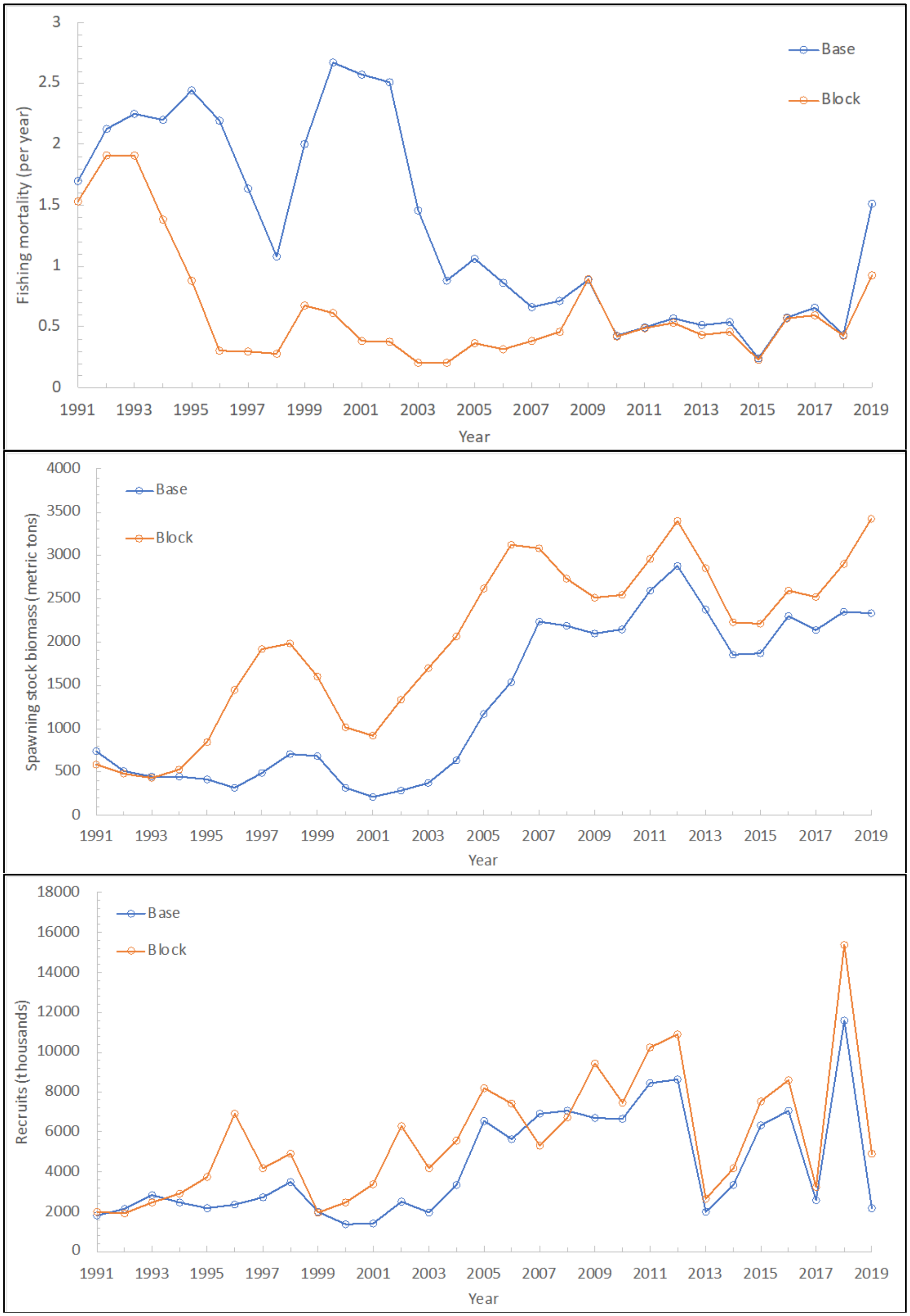


**Figure 3.35.** Sensitivity of predicted fishing mortality (per year; top panel), spawning stock biomass (metric tons; middle panel) and recruits (thousands of fish; bottom panel) to the assumption on fleet selectivity time block.

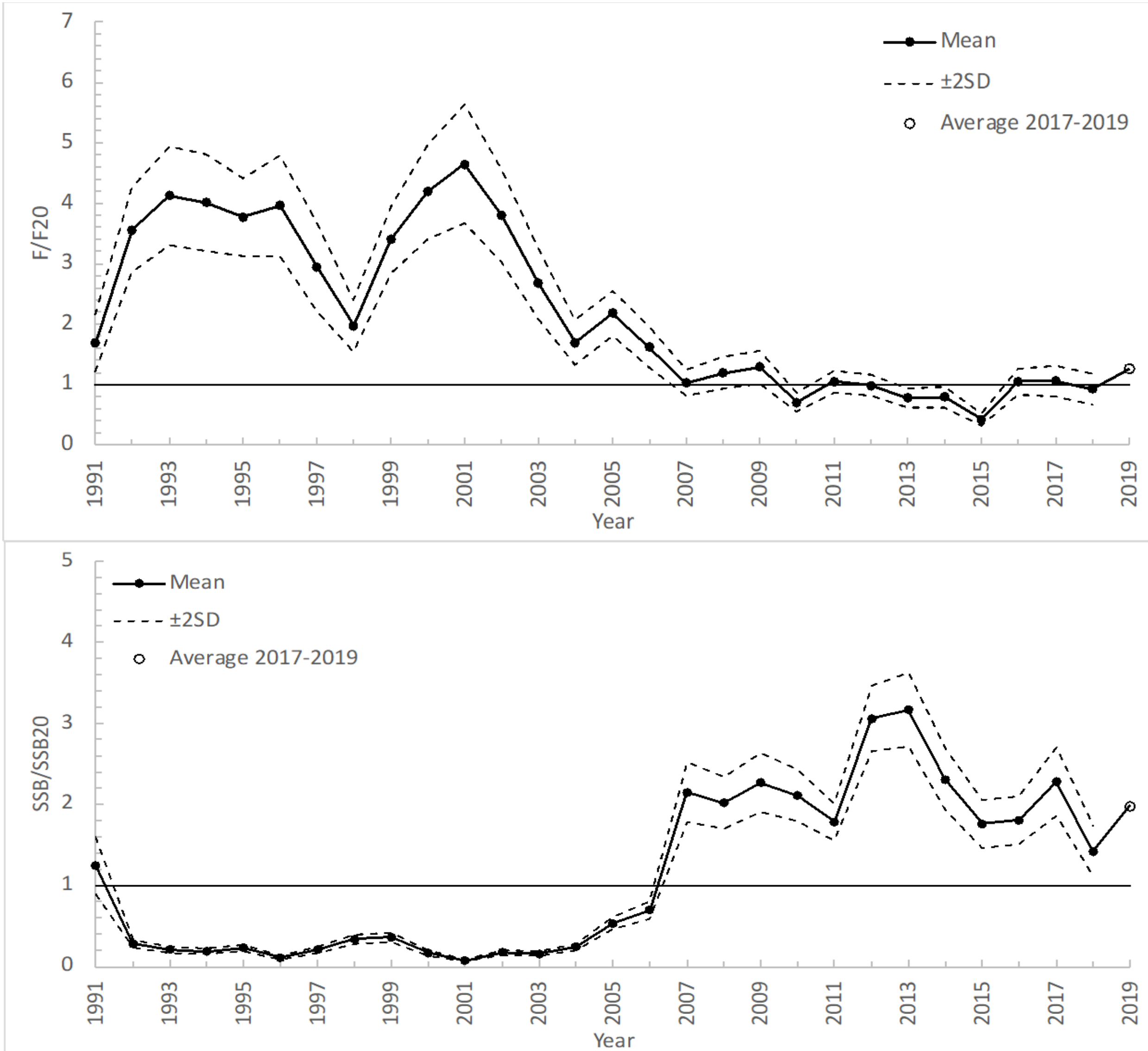


**Figure 4.1.** Predicted fishing mortality (per year) and spawning stock biomass (metric tons) relative to the fishing mortality threshold ($F/F_{20}$) and the spawning stock biomass threshold ($SSB/SSB_{20}$) from the base model of the stock assessment, 1991–2019. The horizontal black line shows a ratio of one. The terminal-year estimate is an average of the most recent three years weighted by the inverse CV values.

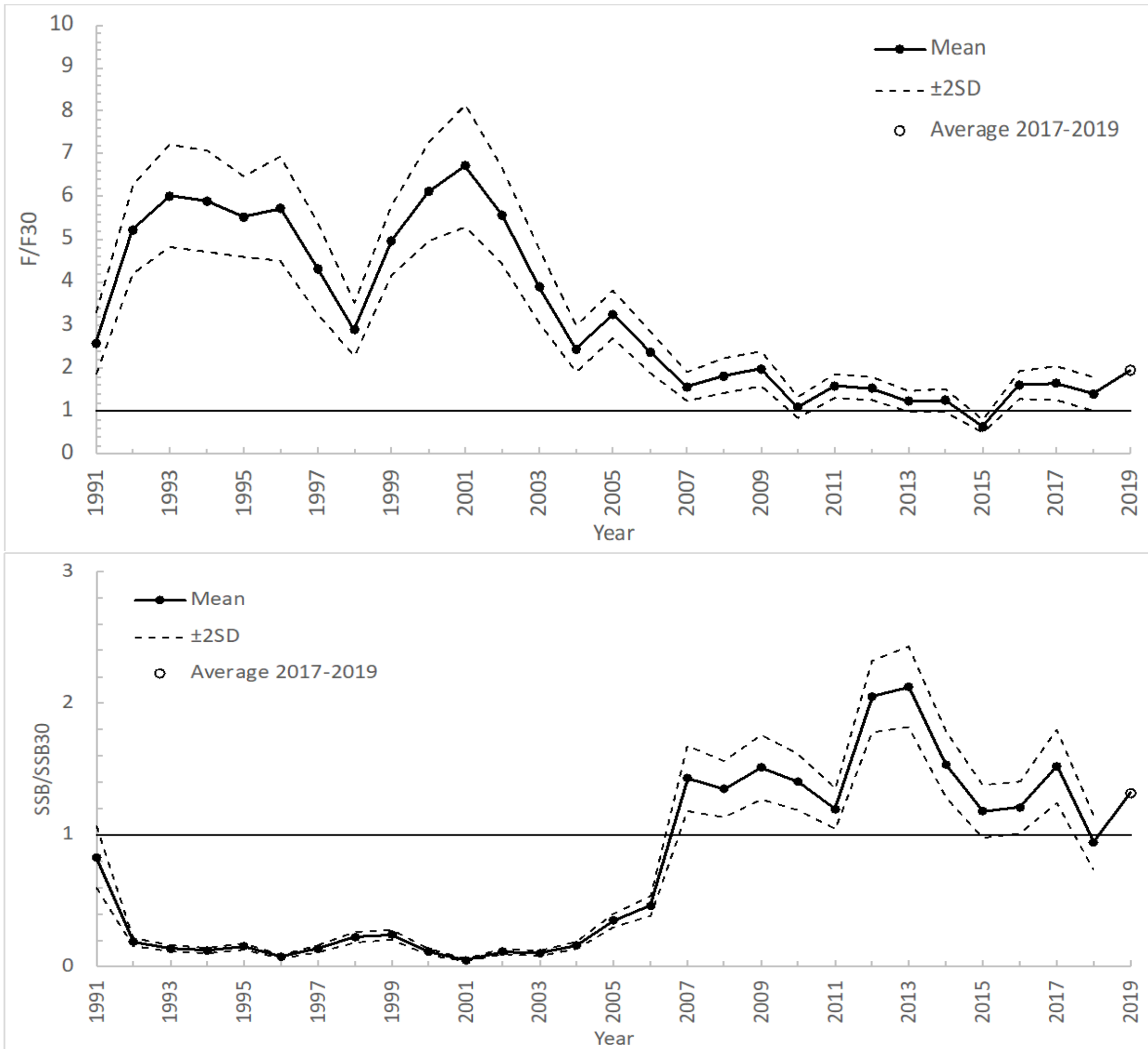


**Figure 4.2.** Predicted fishing mortality (per year) and spawning stock biomass (metric tons) relative to the fishing mortality target ($F/F_{30}$) and the spawning stock biomass target ($SSB/SSB_{30}$) from the base model of the stock assessment, 1991–2019. The horizontal black line shows a ratio of one. The terminal-year estimate is an average of the most recent three years weighted by the inverse CV values.

# External Peer Review Report
# for the
# 2022 Stock Assessment
# of
# Spotted Seatrout in Virginia and North Carolina


External Peer Review Panel

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September 2022

## EXECUTIVE SUMMARY

The Spotted Seatrout external Peer Review Panel met in Jacksonville, North Carolina from August 30 - September 1, 2022. Prior to the meeting, the agenda (below) was finalized on July 25, the Stock Assessment Report along with input/output files for the base assessment model were made available (August 1,2), the Terms of Reference for the review were provided to the Panel, and a conference call between the Panelists and the Assessment team was held on August 23. The conference call allowed the Panel to request additional analyses and ask for clarification about data and analyses contained in the Stock Assessment Report. During the meeting North Carolina staff provided presentations on the assessment history, fisheries, and fisheries management during the first day. The spatial and temporal extent of the stock assessment was described. A thorough review of the fishery dependent monitoring for lengths and ages and sex was given as was a presentation of all surveys available for monitoring spotted seatrout. The Panel retired early this day (3:30P) after completion of these presentations and a series of questions and answers. The Panel commends the Assessment team for their concise and comprehensive presentation of the data inputs used in the stock assessment.

On Wednesday the Panel was presented with a thorough description of the assessment model, data inputs and results. The base-run model fit the available data (1991-2019 fisheries landings and length composition, 2003-2019 survey index and length composition) quite well. A strong retrospective pattern was seen in the output suggesting that there could be upward bias in the recent estimates of F and downward bias in the estimated spawning stock biomass. Several alternate data summaries, additional analyses, and model sensitivities were requested and the timely responses greatly facilitated evaluation of the assessment model.

The Panel accepted the base model analyses of spotted seatrout population dynamics as the best scientific information available and suitable for management advice. However, the Panel felt that the terminal-year fishing mortality used in the status determination calculation should be modified to take into consideration the uncertainty inherent in the terminal year estimates. The Panel felt that the Assessment team should utilize an average (e.g., three-year, weighted by inverse of variance) as the best representation of the terminal-year SSB and F estimates.

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## 1 TERMS OF REFERENCE

The geographic scope of the spotted seatrout considered in the assessment was for fish from all waters of Virginia and North Carolina. Several tag/recapture studies and past genetics analyses indicate little mixing between South and North Carolina but more extensive seasonal movement to and from Virginia. More recent genetic analyses determined that there is a mixing zone between North and South Carolina in the Cape Fear area (O'Donnell *et al.* 2014). Given the infrequent movement of fish between North and South Carolina based on tag recaptures, the relatively small geographic area of mixing, and the relatively low level of spotted seatrout landings made from the mixing zone, the Panel accepted the stock boundaries as defined in the Assessment Report.

### 1.1 Evaluate the thoroughness of data evaluation and presentation including:

#### 1.1.1 Justification for inclusion or elimination of available data sources

The descriptions of the commercial and recreational fisheries, gears used and seasonality of activity along with fisheries management authority and the history of management actions directed at spotted seatrout in Virginia and North Carolina were adequately described to give context to changes seen in the fisheries over time.

The available recreational and commercial landings and discards data were described, and sources of bias were identified well in the report. The assessment model includes commercial harvest (in number) from VA and NC; commercial discards (relatively minor in magnitude) is only available for NC. Estimates of recreational harvest and discards are available for both Virginia and North Carolina. Recreational discards have increased dramatically in recent years, and estimated dead discards account for a significant fraction of removals. The Panel felt that these data were justified and the best available to account for fishing-induced mortalities. However, the recreational estimates are based on a survey that produces annual error estimates for both seen harvest (Type A) and live releases (Type B2). The Panel accepted the current configuration of the model which utilizes a constant error estimate over time for the recreational fishery harvest and discards but advised more complete use of the survey-estimated errors in the future. The Panel accepted the analyst's estimation schemes used to calculate the commercial live releases and dead discards for the gillnet fishery where direct samples were not available. This fishery is a very small component of the total fishery take.

There are several sampling programs that provide data on the length structure of spotted seatrout seen in the commercial landings and commercial discards. Additionally, the recreational survey (MRIP) provides length composition of landed and kept fish but not of live releases. This was a major data-deficiency for the size-structured assessment model, especially given the increased importance of live-release mortalities to the total fisheries catch in recent years. The Panel accepted the model-based estimation (through a meta-analysis-derived length selectivity function) of this length structure but recommended the future collection of these data through innovative volunteer programs already being initiated by NC staff. Recreational discards size structure and live-release mortality rates were available from proxy observations made from other studies, e.g., tagging. The Panel accepted the current treatment of these data realizing that they need improvement in the future.

The assessment model used spring and fall data from the NCDMF fishery-independent gillnet survey (Program 915, which uses a range of mesh sizes), beginning in 2003. Other surveys, some of which span the entire period of the assessment (1991-2019), either caught few spotted seatrout (NCDMF Program 195, Juvenile red drum survey; NEAMAP, CHESMAP) or catch only age-0 fish below the length range included in the model (NCDMF Program 120). The Panel requested a sensitivity assessment model run that included the Program 120 survey data, but the model was unable to capture the highly variable recruitment dynamics suggested by the trend in spotted seatrout recruit abundance in that survey. More effort should be made to try and incorporate this survey, with the need to possibly increase the amount of variability in recruitment accepted by the model (standard deviation of the recruit deviations).

Fishery-dependent indices were considered but were dropped out of hand over the concerns about the lack of experimental design as used for fishery-independent surveys and the potential for bias from changing catchability over time.

Several life history characteristics were calculated external to the assessment model. A large set (>24,000 fish) of available otolith-based annual age data (raw data) from both fisheries-dependent and fisheries-independent data sources in Virginia and North Carolina were used in an external analysis to provide estimates of von Bertalanffy growth parameters. The Panel judged these data and the analyses as adequate to calculate sex-averaged parameters for asymptotic length ($L_\infty$) and the Brody growth coefficient (K) as needed to estimate the expected mean growth increments for each size class in the initial March-November growth transition matrix.

Available biological data were also used to determine the female size-specific maturity schedule, the maximum age used to estimate a base annual natural mortality rate, and the weight-length relationships. The maturity and weight-length relations were used to calculate the female spawning stock biomass. The Panel questioned the assumed linear relation assumed between the spawning stock biomass and fecundity in this species but accepted it as a measure to be used in the status determination until further information became available from North Carolina. Additionally, the female maturity ogive showed an unusually high level of maturity in one smaller size class that the Panel felt should be checked. The Panel accepted the maturity schedule as estimated.

Habitat and ecological relations were described in a presentation and while pointing out potentials for habitat loss effecting the stock or its dynamics, the only consideration deemed important for inclusion in the assessment model were the changes in natural mortality ascribed to extreme cold events. Many tagging studies were examined to provide information on the variability of natural mortality, often associated with cold kills. This was largely the basis for the decision to use the current size-structure assessment model that can be used to estimate time-varying natural mortality. A base natural mortality was estimated given the observed 9-year maximum age and the cumulative lifetime mortality was distributed across lengths using a weight-based Lorenzen (1996) function. Overall annual estimates of natural mortality (M) were divided into warm (March-November) and cold (December-February) seasons assuming a 1:2 ratio with warm season's M held constant at 0.2. The cold season M was estimated in the model, though constrained through a standard deviation restriction. Assumptions are routinely needed in assessment models to define natural mortality. The Panel accepted the rationale used to define M as used in this assessment model.

### 1.1.2 Consideration of survey and data strengths and weaknesses (e.g., temporal and spatial scale, gear selectivities, sample size)

The harvest data are assumed to be precise as reflected by the small CVs (0.05, commercial; 0.10, recreational) used in the model. There is considerable (but unknown) uncertainty in the estimated dead recreational discards, obtained as an assumed constant live-release mortality rate (0.10) multiplied by the reported live discards. Discards were fitted using a higher CV (0.25 for both fisheries) to reflect uncertainties associated with those estimates.

The Multiple Panel Gill Net Survey (Program 915) was the sole source of relative abundance indices. These were split into spring (April-June) and fall (September through November) indices. This survey is spatially extensive (within NC) and covers all months except December-February. The spatial extent increased over time and the stock assessment uses a consistent subset of data from 2003 (Fall index) and 2004 (Spring index). Two weaknesses are that the survey covers only the most recent 17 of the 29 years covered by the assessment (1991-2019) and is not conducted in Virginia. The Panel agreed with the development of the standardized indices from these data. The Panel found that the Gillnet survey was well designed for measuring changes in spotted seatrout abundance although its temporal extent only back to 2003 limited its use in guiding the estimation of relative abundance for the entire time series used in the assessment (1991-2019).

### 1.1.3 Calculation and standardization of indices and other statistics

Generalized linear models were used to adjust for variables that might affect the indices (e.g., temperature or salinity on sampling dates). Nominal and standardized indices showed similar patterns, perhaps due to the relatively intensive and extensive design of the Program 915 survey. The Panel found these analyses to reflect operating standards currently in use in fisheries analyses.

### 1.2 Evaluate the adequacy, appropriateness, and application of data used in the assessment.

The complete set of available data needed to run the current assessment model and capture all the estimation variability will never be available. However, the Panel found that the available data and estimates were appropriately used and that any assumptions needed to complete the data needed for this analysis, while probably resulting in an underestimate of the overall uncertainty in its findings on fishing mortality and spawning stock biomass, were appropriate and adequate.

### 1.3 Evaluate the adequacy, appropriateness, and application of method(s) used to assess the stock.

The analysis was based on a size-structured model (Cao *et al*. 2017), modified to allow for time-varying natural mortality (as has been observed in Spotted Seatrout). The model was fitted using maximum likelihood methods and Automatic Differentiation Model Builder software (ADMB; Fournier *et al.* 2012; http://admb-foundation.org). The original size-structured model is peer-reviewed and supports management of northern shrimps (*Pandalus* spp.). Selectivity was estimated for commercial and recreational harvest but fixed at assumed values for discards. The shape of size selectivity was assumed to be logistic for harvest fleets and dome-shaped (double normal) for discards fleets. Natural mortality and growth are time-varying parameters. This provides flexibility to account for temporal changes including cold-stun mortality events.

Likelihood components (landings, discards, survey indices) were given equal weight (1.0). Model diagnostics used to assess fit included presence of estimated parameters at a bound, jitter analysis, evaluation of fits to commercial landings and survey indices, length composition of fisheries and surveys, and retrospective analysis. There were no obvious issues in fit of the base model, including fit to harvest, survey indices and length composition. The Spring survey was relatively uninformative (flat and variable) but precision was higher and the fit was improved for the Fall index. Jitter analysis provided evidence that a global solution had been obtained, but also suggested substantial uncertainty about the final fishing mortality estimate. Model fit showed a change in stock dynamics around the start of the survey data (e.g., fishing mortality: Assessment Report's Figure 3.21; recruitment: Figure 3.24); however, this was also approximately the start of increased recreational harvest.

Time-varying estimates of natural mortality showed some similarity to the temporal pattern from tag-return models, but tag-return models showed substantially higher estimates.

The model has a very large number of parameters (n=367), including time-varying growth and natural mortality. This provides the model with much flexibility but also the potential for overparameterization. Estimates of growth parameters suggested a relatively stable maximum size ($L_\infty$) but declining growth rate (K). An independent analysis of age and length data suggested that growth was stable over time (no trend in mean length-at-age). The Panel believes that this discrepancy warrants further investigation, to determine whether the time-varying growth model is overparameterized. Initial sensitivity runs using fixed or estimated time-independent growth parameters showed that estimates of F and spawning stock biomass were sensitive to the growth sub model structure. However, management guidance (F>threshold) was the same for the base run (time-varying) and sensitivity runs (Table 1).

Sensitivity runs were conducted by: (1) omitting one of the two surveys; (2) changing the start of the analysis to 2003 (start of survey data); (3) varying the assumed average natural mortality rate; (4) using a lower value for the (extreme) estimated number discarded in the non-winter season in 2018; and (5) using two selectivity eras for the recreational fishery (based on a 2009 change in minimum length). Results for the more recent period (the focus for management) were relatively insensitive to removal of either survey (suggesting a consistent signal for the two surveys) or changing the starting year of the assessment. Fishing mortality was similar but ending spawning stock varied when the assumed average natural mortality rate was varied. Changing the non-winter discards estimate for 2018 had a negligible effect on recent estimates. Using two selectivity periods to account for the regulation change had a negligible effect on fishing mortality but spawning stock was affected. For model changes that affect complexity (number of estimated parameters, e.g., one versus two selectivity eras), it might be possible to assess whether the increase in complexity was warranted by the improved fit.

There is a strong need for a continuity model to help evaluate how the change from age-structured models that were used in the past to the new size-structured framework has changed the findings. Allowing for cold season variability in natural mortality is a step forward in accurately analyzing spotted seatrout population dynamics in Virginia and North Carolina but it is important to identify other potential biases introduced in this model change.

The time block selectivity model appears to make a difference in early F estimates and stock status. The selectivity-blocked trend in total annual F appears to follow the pattern of total kill taken from the stock (Fig. 1) better than F estimates made from the single time block model. Both the base model and the 2-time-period sensitivity models appear to predict the sizes and number of fish landed, discarded dead, or live-release deaths just as well, thus this sensitivity configuration appeared to have support though with a slight increase in the number of parameters compared to the base model. However, a very strong retrospective pattern emerges from the time-blocked selectivity model results possibly indicating a strong misspecification in the model. The Panel felt that further consideration of this model configuration should be made in the future.

## 1.4 Reference points

### 1.4.1 Evaluate the adequacy and appropriateness of recommended stock status determination criteria.

The nonstationary use of M complicated reference point estimation. As currently used the threshold and target fishing mortality and spawning stock biomass are all based on the terminal year (2019) population dynamics. With changing M, accurate benchmark calculations cannot be made unless future natural mortality rates are known (Miller and Legault 2017). Calculations of year-specific benchmarks appear to show that the relative variability of natural mortality does not impart a high degree of variability in the threshold or target values of fishing mortality of spawning stock biomass (Fig. 2). The Panel felt a more important consideration for spotted seatrout is the method used to determine the current state of the fishery in terms of F and SSB and recommended a weighting scheme that considered the terminal-year estimates and their precision.

### 1.4.2 Evaluate the methods used to estimate values for stock status determination criteria.

The methods appear adequate except for the need to include the variability in the terminal-year dynamics in the calculation.

### 1.4.3 Comment on the appropriateness of comparing terminal year estimates to stock status determination criteria.

The jitter analysis shows high uncertainty in the terminal year F, as does the estimated variance (which underestimates uncertainty because of fixed parameters and assumptions in the model). The retrospective analysis shows a strong pattern of decreasing F as additional years of data are available. The high terminal-year F was due to very high recreational landings for 2019. The Program 915 survey was not conducted in 2020 and Spring of 2021. All these factors lead to uncertainty about recent status, and suggest a more measured approach (e.g., averaging last few years) to calculating status determination.

The Panel felt that the terminal-year F estimate's variability is large and that it should be incorporated into the calculation of the current stock dynamics, e.g., average last three year's estimates using inverse-variance weighted.

## 1.5 Do the results of the stock assessment provide a valid basis for management for at least the next five years given the available data and current knowledge of the species stock dynamics and fisheries? Please comment on response.

Yes, the Panel felt that the results adequately capture the recent dynamics of the spotted seatrout stock in North Carolina and Virginia. However, prior to about 2007, there is little information (surveys) to constrain the estimates of abundance or mortality. The sensitivity analyses generally pointed to some consistency in the model estimates of fishing mortality during the period of about 2007 through 2019. The earlier period was highly variable through the different sensitivities.

The sensitivity runs show that the thresholds and targets are highly sensitive to the form of the model, but management guidance (overfished/overfishing) is not sensitive (Table 1). There is however a notable sensitivity to the assessment structure (data, software, assumptions, analyst). Status of spotted seatrout has varied markedly from one assessment to the next, and we recommend against attaching too much significance to a single assessment. Gradual stable management (and regulation change) will be more consistent with the gradual pace of understanding stock dynamics.

The estimates of F from 1991 ~2003 are much higher than in the previous assessment. If accurate, then there should be few fish older than age 3 or 4 observed in the population during those years. The Panel recommends using representative age data from this period to calculate mortality rates that can be used to verify this high of an overall mortality rate.

The Panel recommends that the stock's status relative to threshold and target values calculated for fishing mortality and spawning stock abundance not rely only on the terminal year's estimates but use an average of recent estimates. The Panel believes this would be less likely to inflict wide changes in stock status based on poorly estimated terminal year parameters.

## 1.6 Evaluate appropriateness of research recommendations. Suggest additional recommendations warranted, clearly denoting research and monitoring needs that may appreciably improve the reliability of future assessments.

Given the large programs dedicated to gathering representative age- and sex-specific information from North Carolina's fisheries and surveys each year, the Panel recommends that there be an effort given to developing an age-structured model that can incorporate temporal changes in natural mortality. At the least, a component of the objective function within the current size-structured model should include a fit to age data.

The size structured model's current configuration did not incorporate estimated errors for the recreational landings and live releases. Though these are available, there was a hesitancy to use other than constant CV's for these data because the model was conditioned on catch and less stable when year/season -specific errors were included.

Re-evaluate the female maturity analysis with consideration of the extreme outlier used in the current assessment.

Spotted seatrout have a protracted spawning season, typically from April-October. A June index of juvenile recruitment will miss a large portion of the later spawn and is incomplete. As a research priority, NC should consider implementing a new fishery-independent juvenile survey, perhaps conducted year-round. It would also be useful for other species.

There is a large increase in the number of removals (all fleets combined) beginning in 2005 (Figure 1). This is a pivotal year for the model results, as well. It would be interesting to understand whether these increases were accompanied by an increase in recreational fishing effort in both Virginia and North Carolina. It is recommended that this be investigated as to whether design changes in the MRIP survey could be responsible for this change.

We suggest a lower emphasis on commercial monitoring for this species, because of the relatively minor impact of commercial fishing on the stock. Recreational discards should be the primary focus (and a high, rather than low, priority) because of the trend and magnitude of recreational catch-and-release. The planned expansion of a Citizen Science initiative to include spotted seatrout may be helpful, if biases related to participating angler reporting can be addressed.

We recommend testing and validating the model with known data sets. It has been used for northern shrimps (which lack age data) but not for fish with information about length and age. Testing can determine the extent to which length composition data can extract stock dynamics for longer-lived, multi-aged fish stocks, and can assess the best way to incorporate the available age data (fishery and survey).

Prior to expanding the Program 915 to winter months (that were initially sampled, then dropped for safety reasons), we recommend a detailed analysis of the existing data. This could determine the extent to which late fall and spring data provide insights into overwinter changes. This analysis could also provide insights into the magnitude of cold-stun events, which could explain differences in the effects observed in tagging and telemetry studies versus survey and fishery monitoring.

We recommend additional work to evaluate more fully the utility of the Program 120 survey, which spans the entire period used for the assessment. Including the recruitment index data may require a higher variance to accommodate the large fluctuations observed in the survey. Initial model results from a sensitivity run suggest that the model is sensitive to inclusion of recruitment data, at least for the early years prior to the start of the Program 915 survey.

We recommend that integration of tagging data be given high priority, given the dramatic difference in results regarding survival rate and natural mortality. Tagging provides an independent look at population dynamics and has different assumptions from analyses of harvest and survey data. Tag returns can also be used to investigate growth (growth increments) that could be compared to the size-based model inferences. An advantage of tagging studies is that key aspects can be tested using auxiliary studies (e.g., double tagging to address tag loss). There is a substantial data set of tags released (2008-2019 for NC; 1995-2018 for VA). Additional field or tank studies might be done to explore the possibility of chronic mortality associated with tagging and telemetry.

Age validation was suggested as a low priority. It is always a worthwhile endeavor but might be removed from the list until age data are being used in the assessment.

## 1.7 If applicable, recommend recruitment and fishing mortality/catch scenario(s) for projections

N/A

### 1.8 Recommend timing of next stock assessment for the species

We recommend maintaining the current approach of a five-year cycle. This provides enough additional data to warrant an update. There will be an information gap in the next assessment because of the cessation of sampling during the pandemic. A five-year delay will allow for enough new data to make updating worthwhile. Until the next assessment is done, real-time monitoring using the Program 915 survey and MRIP recreational catch-per-angler-hour could provide insights into the stock's status.

## 2 ADDITIONAL COMMENTS

## 3 LITERATURE CITED


Cao, J., Y. Chen, and R.A. Richards. 2017. Improving assessment of *Pandalus* stocks using a seasonal, size-structured assessment model with environmental variables. Part II: Model evaluation and simulation. Canadian Journal of Fisheries and Aquatic Sciences 74(3):1–14

Fournier, D.A., H.J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterised complex non-linear models. Optimisation Methods & Software 27:233–249

Jensen, C. C. 2009. Stock Status of Spotted Seatrout, *Cynoscion nebulosus*, in North Carolina, 1991-2008. North Carolina Division of Marine Fisheries, Morehead City, North Carolina.

Lorenzen, K. 1996. The relationship between body weight and natural mortality in juvenile and adult fish: a comparison of natural ecosystems and aquaculture. Journal of Fish Biology 49(4):627–647.

Miller, T.J. and C.M. Legault. 2017.Statistical behavior of retrospective patterns and their effects on estimation of stock and harvest status. Fisheries Research 186(1):109-120.

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## Spotted Seatrout Stock Assessment Peer Review Workshop
## 30 August–1 September 2022
## Jacksonville, North Carolina

## Final Agenda

**DAY 1: TUESDAY, 30 AUGUST 2022, 12:00 pm–5:00 pm**

***Day 1 Goals*:** Review purpose and expectations of peer review, gain understanding of fisheries and management history, gain understanding of species biology and ecology, and review and evaluate assessment input data

**Preliminaries**

- Welcome & introductions (*Steve Poland*)
- Purpose of review workshop & expected products (*Mike Murphy*)
- Review agenda & code of conduct (*Mike Murphy*)

**Background**

- Presentation: Assessment History (*Laura Lee*)
- Presentation: Fisheries & Management History (*David Behringer*)
- Presentation: Stock Structure & Species Life History (*Lucas Pensinger*)
- Review Panel Q & A

**Data**

- Presentation: Fisheries-Dependent Monitoring (*Alan Bianchi, Drew Cathey, & David Behringer*)
- Presentation: Fisheries-Independent Surveys (*David Behringer*)
- Review Panel Q & A

**DAY 2: WEDNESDAY, 31 AUGUST 2022, 9:00 am–5:00 pm**

***Day 2 Goals*:** Review and evaluate assessment model and results, review and evaluate method for estimating reference point values, review and evaluate current stock status, request additional analyses, and review and comment on research recommendations

**Seasonal, Size-Structured Model**

- Presentation: Model Data Input (*Yan Li*)
- Presentation: Model Structure & Parameterization (*Yan Li*)
- Presentation: Model Results (*Yan Li*)
- Review Panel Q & A
- Identify additional analytical requests

**Status Determination**

- Presentation: Reference Points & Stock Status (*Yan Li*)
- Review Panel Q & A

- Identify additional analytical requests

**Research Recommendations**

- Presentation: Research Recommendations (*Yan Li*)
- Review Panel Q & A

**DAY 3: THURSDAY, 1 SEPTEMBER 2022, 9:00 am–1:00 pm**

***Day 3 Goals*:** Recommend best model configuration for assessing stock, recommend best approach for estimating reference point values, recommend whether results provide a valid basis for management, complete draft version of peer review report, and identify any outstanding tasks

**Initial Summary**

- Review results of additional analytical requests
- Review Panel deliberations (closed session)
- Review Panel reviews initial conclusions with Working Group (closed session)
- Review Panel begins drafting report (closed session)/Working Group session addressing additional analytical requests

**Wrap-Up & Next Steps**

- Review results of additional analytical requests
- Review Panel deliberations (closed session)
- Review Panel reviews conclusions with Working Group (closed session)
- Review Panel session drafting report (closed session)
- Identify tasks to be completed & timeline

**ADDITIONAL INFORMATION**

There will be a one-hour break for lunch on Wednesday. Additional breaks will be given at the discretion of the chair.

The order and timing of agenda items is subject to change.

The goals listed for each day are intended for the peer review panel and chair.

During closed sessions, everyone except the peer review panel and chair will be asked to leave the room unless noted otherwise above.

Only the peer review panel and chair participate in the development of the peer review report. The report will not be available to the NCDMF staff, the public, or others until it is considered complete.

Table 1. Biological Reference Points for various sensitivity runs.

| Model | TerminalF | TerminalSSB | Fthresh | SSBthresh | Ftarget | SSBtarget |
|---|---|---|---|---|---|---|
| Base | 1.512 | 2337.974 | 0.691 | 832.344 | 0.437 | 1251.797 |
| P915Srm | 1.980 | 1997.854 | 0.671 | 764.102 | 0.422 | 1147.740 |
| P915Frm | 1.583 | 2181.306 | 0.667 | 834.094 | 0.422 | 1252.305 |
| Ini2003 | 1.376 | 2475.647 | 0.525 | 2701.429 | 0.359 | 4025.220 |
| LowM | 1.774 | 2016.808 | 0.359 | 1890.147 | 0.242 | 2812.434 |
| HighM | 1.404 | 2560.487 | 1.208 | 549.635 | 0.730 | 824.951 |
| Low2018 | 1.486 | 2356.872 | 0.676 | 850.583 | 0.427 | 1277.680 |
| Block | 0.925 | 3428.873 | 0.823 | 1234.601 | 0.510 | 1851.404 |
| P120noLag | 1.900 | 2028.298 | 0.681 | 795.909 | 0.432 | 1193.179 |
| P1201YrLag | 1.145 | 2814.201 | 0.676 | 784.001 | 0.427 | 1183.223 |
| constGLinfFix | 3.635 | 1125.937 | 0.549 | 2268.698 | 0.374 | 3429.834 |
| constGLinfKFix | 2.503 | 1577.664 | 0.559 | 1394.682 | 0.374 | 2094.259 |
| constGLinfKEst | 2.048 | 1936.712 | 0.500 | 1415.319 | 0.330 | 2127.802 |
| P120NoMissing | 0.726 | 4076.007 | 0.642 | 904.110 | 0.413 | 1347.701 |

Model configuration:
Base: default
P915Srm: omission of Program 915 spring gill-net data
P915Frm: omission of Program 915 fall gill-net data
Ini2003: start analysis in 2003
LowM: Annual average natural mortality set to 0.4, lower than the base model (0.6)
HighM: Annual average natural mortality set to 0.8, higher than the base model (0.6)
Low2018: March-November recreational discards set to the average of the previous five years, lower than the base model (1,863.527 thousands of fish)
Block: Two time blocks for fleet selectivity, 1991–2008 and 2009–2019
P120noLag: Inclusion of Program 120 survey data, with no lag
P1201YrLag: Inclusion of Program 120 survey data, with one-year lag
constGLinfFix: Modified growth sub-model with fixed $L_\infty$
constGLinfKFix: Modified growth sub-model with fixed $L_\infty$ and K
constGLinfKEst: Modified growth sub-model with constant but estimated $L_\infty$ and K
P120NoMissing: Inclusion of Program 120 survey data, with 0.01 added to dates with 0 catch

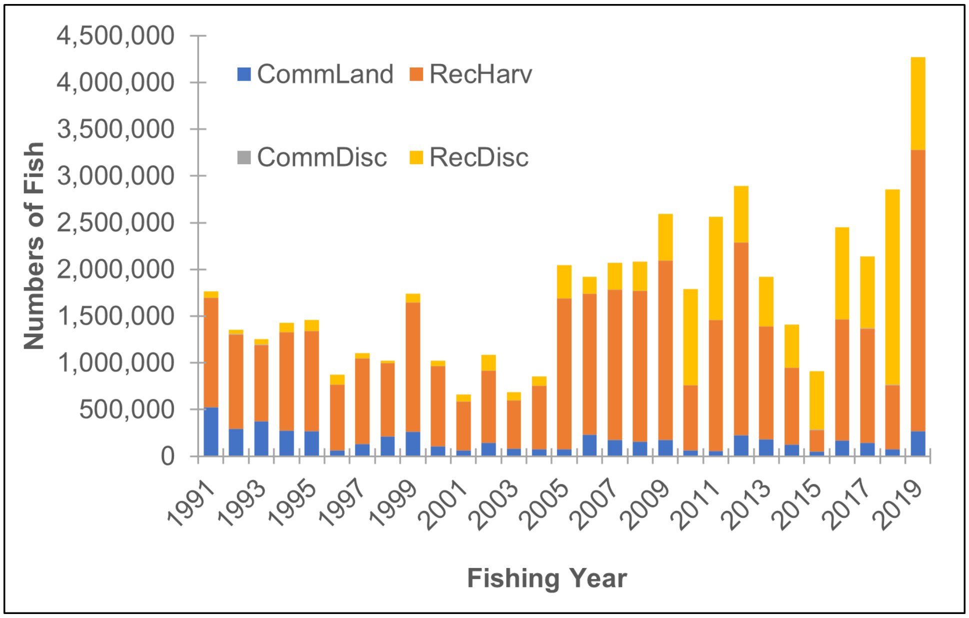



Figure 1. Total kill of spotted seatrout by fishery sector in North Carolina and Virginia during 1991-2019.

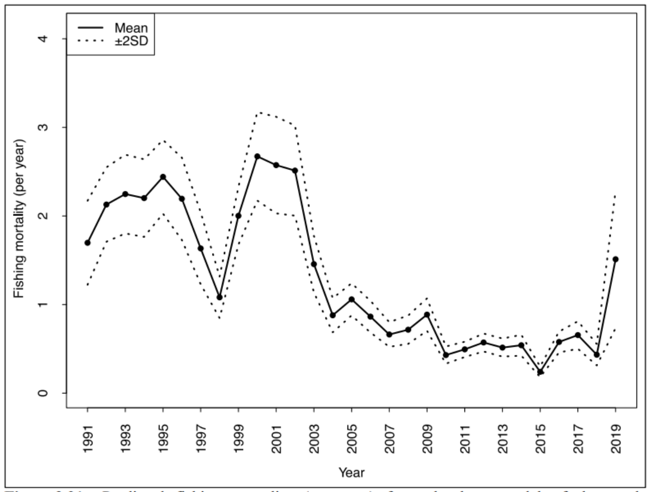



**Figure 3.21.** Predicted fishing mortality (per year) from the base model of the stock assessment, 1991–2019.

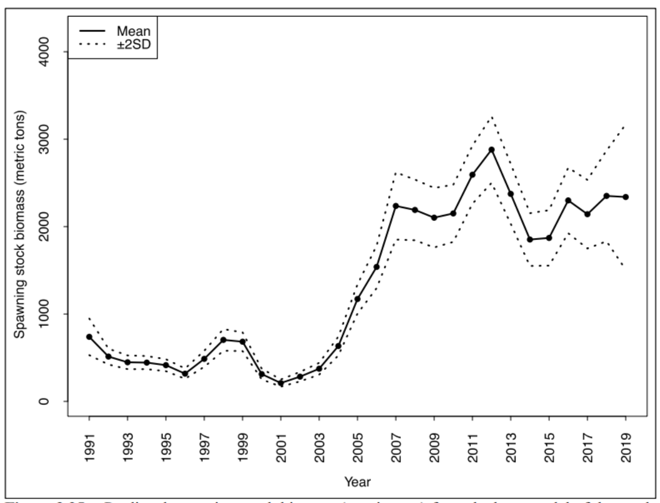



**Figure 3.25.** Predicted spawning stock biomass (metric tons) from the base model of the stock assessment, 1991–2019.

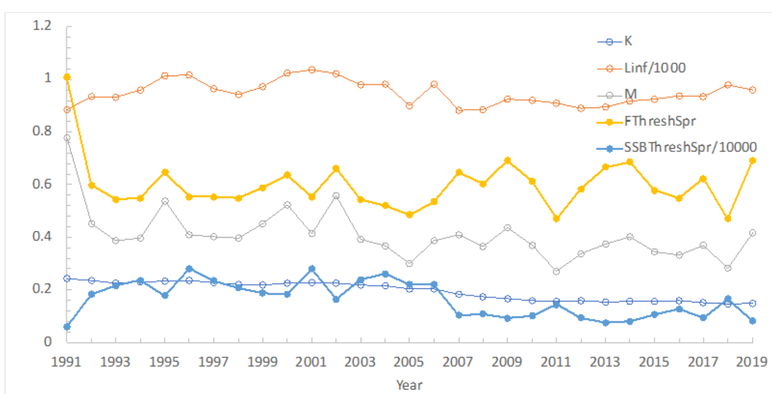



Figure 2. Base model estimates of annual F (Fig. 3.21), spawning stock biomass (Fig. 3.25) and associated estimation error (± 2SD's; dotted lines), and year-specific estimates of F and SSB at the threshold value of 20% spawning potential ratio. Year-to-year changes in thresholds are mostly associated with changes in estimates of annual M.

# Estuarine Striped Bass Fishery Management Plan Amendment 2 Decision Document

**August 2022**

**N.C. Division of Marine Fisheries**

**3441 Arendell Street**

**Morehead City, North Carolina 28557**

This Decision Document is a companion document to Amendment 2 to the Estuarine Striped Bass Fishery Management Plan. It provides a brief overview and context for the issues. The document also provides references to the full Amendment document where more detailed information and exact management option language is located. The Estuarine Striped Bass Fishery Management Plan Amendment 2 document is the plan under consideration and is the focus of all MFC action.

# Summary

During the August MFC business meeting the MFC will review departmental comments and vote on final adoption of draft Amendment 2 of the Estuarine Striped Bass Fishery Management Plan (Amendment 2) . If approved, the DMF, Marine Fisheries Commission (MFC) and Wildlife Resource Commission (WRC) will begin implementing the approved management.

The current stock assessment indicates the Albemarle-Roanoke Striped Bass Stock Assessment is overfished and overfishing is occurring. To address overfishing, the DMF implemented adaptive management approved under Amendment 1 of the Estuarine Striped Bass FMP. This significantly reduced the total allowable harvest for all fisheries to end overfishing. The management being considered in Amendment 2 will continue with this reduced total allowable harvest for all fisheries and the rebuilding process.

A stock status determination is not available for the Central Southern Management Area stocks of striped bass, however, based on evaluation of available data sustainable management are presented as part of Amendment 2.

# Amendment Timing

| | |
|---|---|
| November 2020 | Division holds public scoping period |
| February 2021 | MFC approves goal and objectives of FMP |
| October 2020 - September 2021 | Division drafts FMP |
| September - October 2021 | Division holds workshops to further develop draft FMP with Plan Advisory Committee |
| October 2021 - January 2022 | Division updates draft plan |
| February 2022 | MFC votes to send draft FMP for public and AC review |
| March 2022 | MFC Advisory Committees meet to review draft FMP and receive public comment |
| May 2022 | MFC selects preferred management options |
| June - July 2022 | DEQ Secretary and Legislative review of draft FMP |
| **August 2022** | **MFC votes on final adoption of FMP** |
| TBD | DMF, WRC and MFC implement management strategies |

# FMP Goal and Objectives

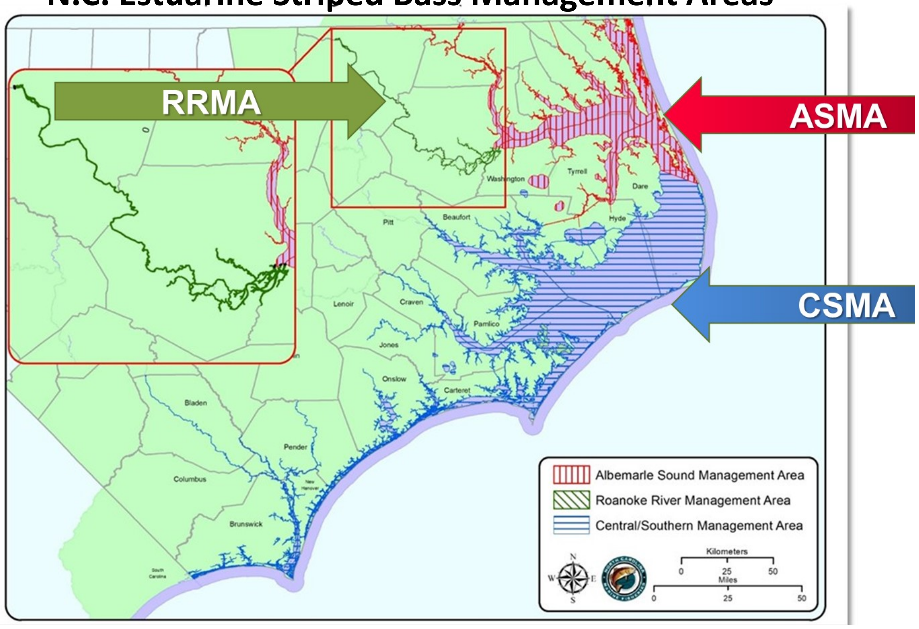
The goal of Amendment 2 is to manage the estuarine striped bass fisheries to achieve self-sustaining populations that provide sustainable harvest based on science-based decision-making processes. If biological and/or environmental factors prevent a self-sustaining population, then alternate management strategies will be implemented that provide protection for and access to the resource. The following objectives will be used to achieve this goal.

- Implement management strategies within North Carolina and encourage interjurisdictional management strategies that maintain and/or restore spawning stock with adequate age structure and abundance to maintain recruitment potential and to prevent overfishing.
- Restore, enhance, and protect critical habitat and environmental quality in a manner consistent with the Coastal Habitat Protection Plan, to maintain or increase growth, survival, and reproduction of the striped bass stocks.
- Use biological, social, economic, fishery, habitat, and environmental data to effectively monitor and manage the fisheries and their ecosystem impacts.
- Promote stewardship of the resource through public outreach and interjurisdictional cooperation regarding the status and management of the North Carolina striped bass stocks, including practices that minimize bycatch and discard mortality.

# Background

There are two estuarine striped bass management units and four stocks in North Carolina. The Northern management unit includes the Albemarle Sound Management Area (ASMA) and Roanoke River Management Area (RRMA). The striped bass stock in these two harvest management areas is referred to as the Albemarle– Roanoke (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 MFC. Within the RRMA, commercial regulations are the responsibility of the MFC while recreational regulations are the responsibility of the WRC. The A-R stock is also included in the management unit of Amendment 7 to the Atlantic States Marine Fisheries Commission (ASMFC) Interstate FMP for Atlantic Striped Bass. The Southern management unit is the Central Southern Management Area (CSMA) and includes the Tar-Pamlico, Neuse, and the Cape Fear rivers stocks.

**N.C. Estuarine Striped Bass Management Areas**




The most recent A-R striped bass stock assessment was completed and approved for management use in 2020. The assessment indicated the resource is overfished and is experiencing overfishing. The North Carolina Fisheries Re-form Act and Amendment 7 to the ASMFC Interstate FMP for Atlantic Striped Bass require management measures to be implemented to end overfishing in 1-year and end the overfished status in 10-years. Adaptive management described in Amendment 1 was triggered by the assessment and the November 2020 Revision to Amendment 1 to the North Carolina Estuarine Striped Bass FMP reduced the striped bass total allowable landings (TAL) from 275,000 pounds to 51,216 pounds in the ASMA and RRMA. This reduction in TAL is expected to end overfishing in one year. This adaptive management action maintains compliance with Amendment 1 to the North Carolina Estua-rine Striped Bass FMP and ASMFC Addendum IV to Amendment 6 to the Interstate FMP for Atlantic Striped Bass. The new TAL was effective January 1, 2021. The commercial and recreational fisheries are set at a 50/50 allocation. Recreational allocation is split evenly between the ASMA and RRMA.

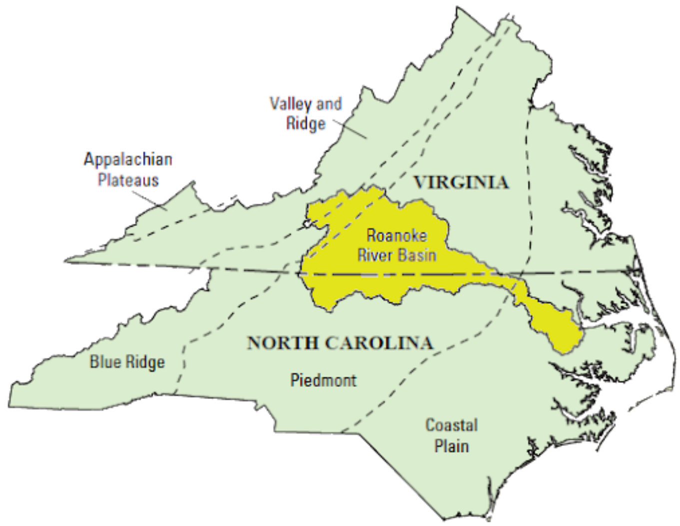
The CSMA Estuarine Striped Bass Stocks report completed in 2020, is a collection of (1) all data that have been collected, (2) all management effort, and (3) all major analyses that have been completed for CSMA stocks to serve as an aid in development of Amendment 2. While this report does not yield a stock status, it does indicate that sustainability of Tar-Pamlico and Neuse rivers stocks is unlikely at any level of fishing mortality. It also indicates that natural recruitment is the primary limiting factor. The report concludes that without stocking, abundance will decline. In the Cape Fear River, abundance declined even with no possession measures in place. No-possession measures were implemented in the Cape Fear River in 2008 and the Tar-Pamlico and Neuse rivers in 2019. The overall goal of the no-possession measures is to increase the age structure and abundance of fish in these systems to move towards sustainable stocks.

## River Flow

Striped bass are broadcast spawners, producing eggs that must remain suspended in the water column to develop and hatch. Proper river flow is a critical environmental factor influencing year class strength. In the RRMA, extended periods of high water flow from May to June negatively impact eggs and fry. Recruitment failures since 2001 are thought to be due to spring flooding.

There are three dams on the Roanoke River above Weldon. The Federal Energy Regulatory Commission does limit activities, such as hydropeaking, to limit dam impacts. However, rainfall in the river basin impacts the ability to regulate river flow while limiting flooding. The Roanoke River is impacted by rain north of Winston-Salem, NC and into southern Virginia.

A cooperative agreement with the US Army Corp. of Engineers strives to maintain Roanoke River flow rates within specified ranges to allow for striped bass spawning success. Flow rates that strive to benefit striped bass spawning are negotiated. Spawning success is measured by the annual juvenile abundance index (JAI). In 2005, the flow was ideal for spawning and the JAI was high. In 2013, the flow rate was too high for half of the spawning period. The resulting JAI was low. Poor recruitment is a major factor causing population declines. Inter-agency work continues to address these environmental concerns.




**Roanoke River Basin USGS Report 2012-5101**

## Stocking

In the late 19th century, the Weldon Hatchery began growing striped bass to release into the wild. Since then striped bass have been stocked in the Albemarle Sound, Tar-Pamlico, Neuse, and Cape Fear rivers. An interagency cooperative agreement (See Appendix 1A, p. 51) between the US Fish and Wildlife Service, DMF, and WRC was established in 1986 to oversee the North Carolina Coastal Striped Bass Stocking Program. An annual workplan establishes stocking goals by river system.

Historically, Roanoke River broodstock were used when stocking the rivers of North Carolina. This has resulted in genetically similar fish stocks across the state. Broodstock are now retrieved from the different river systems; however, the fish are genetically from the same stock.


Stocking is necessary to maintain the Tar-Pamlico, Neuse, and Cape Fear stocks. Data collection efforts continue to evaluate if self-sustaining stocks are achievable in these systems. If not, alternative management may be considered, such as hatchery supported fisheries. More on the history of stocking and an assessment of the state stocking program is provided in Appendix 1 of the FMP document (p. 31) . This information informs the three sustainable harvest issue papers.

# MFC Preferred Management Measures

In May 2022, the North Carolina MFC reviewed the input from the WRC, MFC Advisory Committees, and the public for draft Amendment 2 and selected its preferred management options listed below. The MFC selected the options recommended by the DMF which are listed below. In addition, the MFC passed a motion continuing the current prohibition of gill nets above the ferry lines in the Tar-Pamlico and Neuse Rivers. The DMF is to study the effects of the gill net closure and reevaluate the decision based on the study outcome during the next full amendment review. Amendment 2 was jointly developed by the Division of Marine Fisheries (DMF) staff and Wildlife Resources Commission (WRC) staff, with recommendations provided by the WRC and DMF.

## Measures to Achieve Sustainable Harvest for the Albemarle Sound-Roanoke River Stock *(Appendix 2)*

- Continue to use stock assessments and projections to determine the Total Allowable Landings (TAL) that achieve sustainable harvest
- Continue managing the ASMA commercial fishery as a bycatch fishery
- Modify accountability measures: if landings in any fishery exceeds their allocation, all landings in excess will be deducted from that fisheries TAL the next calendar year or until the overage is paid back
- In the ASMA, implement a harvest slot of a minimum size of 18-inches TL to not greater than 25 inches TL in the commercial and recreational sectors
- In the RRMA, maintain current harvest slot limit of a minimum size of 18-inches TL to not greater than 22-inches TL with no harvest allowed on fish greater than 22 inches.
- Allow commercial harvest of striped bass with gill nets in joint and coastal waters of the ASMA and continue recreational harvest and catch-and-release fishing in the ASMA and RRMA. Implement a requirement to use non-offset barbless circle hooks when fishing with live or natural bait in the inland waters of the Roanoke River upstream of the Hwy 258 bridge from May 1 through June 30. The requirement from April 1 through June 30, only a single barbless hook or lure with single barbless hook (or hook with barb bent down) may be used in the inland waters of the Roanoke River upstream of U.S. Highway 258 Bridge will remain in effect.
- Adopt adaptive management framework that will allow for future adjustments of the TAL based on results of updated stock assessments and provide the Director the flexibility to modify daily possession limits, harvest seasons, and gear requirements to manage harvest to the TAL and reduce discards.

## Measures to Achieve Sustainable Harvest for the Tar-Pamlico and Neuse Rivers Stocks *(Appendix 3)*

- Continue the no-possession measure.
- Continue gill net closure above the ferry lines and the 3-foot tie-downs below the ferry lines.
- In 2025, review data through 2024 to determine if populations are self-sustaining and if sustainable harvest can be determined.

## Measures to Achieve Sustainable Harvest for the Cape Fear River Stock *(Appendix 4)*

- Continue Cape Fear River harvest moratorium.
- Adaptive management based on young of year surveys and parentage-based tagging analysis to evaluate if the levels of natural reproduction in the system further warrant a harvest moratorium and allow the Director the flexibility to allow harvest after consultation with the Finfish Advisory Committee

## Measures for the Use of Hook and Line as a Commercial Gear *(Appendix 5)*

- Continue to manage the use of hook and line gear in the commercial fishery as an adaptive management option across the fishery. Commercial harvest of stiped bass from hook and line gear is not authorized at this time.

# DRAFT
# North Carolina Estuarine Striped Bass Fishery Management Plan Amendment 2

By

North Carolina Division of Marine Fisheries

and

North Carolina Wildlife Resources Commission

August 2022


North Carolina Department of Environmental Quality
North Carolina Division of Marine Fisheries
3441 Arendell Street
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**DRAFT – SUBJECT TO CHANGE**

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**Disclaimer:** Data in this Fishery Management Plan may have changed since publication based on updates to source documents.

## ACKNOWLEDGEMENTS

Amendment 2 to the North Carolina (NC) Estuarine Striped Bass Fishery Management Plan (FMP) was developed jointly by the NC Department of Environmental Quality (DEQ), NC Division of Marine Fisheries (DMF) and the NC Wildlife Resources Commission (WRC) under the auspices of the NC Marine Fisheries Commission (MFC) with the advice of the Estuarine Striped Bass FMP Advisory Committee (AC). Deserving special recognition are the members of the Estuarine Striped Bass FMP AC and the DMF Plan Development Team who contributed their time and knowledge to this effort.

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Daniel Ipock
Laura Lee
Yan Li
Brian Long
Justin Lott
Todd Mathes (Co-lead)
Jeremy McCargo
Lee Paramore
Jason Peters
Katy Potoka
Kyle Rachels
Ben Ricks
Jason Rock
Kirk Rundle
Christopher Smith
Scott Smith
Chris Stewart
Thomas Teears
Chad Thomas
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## EXECUTIVE SUMMARY

The North Carolina (NC) Estuarine Striped Bass Fishery Management Plan (FMP) is jointly developed by the NC Division of Marine Fisheries (DMF) and NC Wildlife Resources Commission (WRC). Striped bass fisheries that occur in the sounds and coastal rivers of NC are managed under this FMP, while striped bass fisheries that occur in the Atlantic Ocean are managed through the Atlantic States Marine Fisheries Commission (ASMFC) Interstate FMP for Atlantic Striped Bass. There are four estuarine striped bass stocks managed under two management units in NC. The northern management unit includes the Albemarle Sound (ASMA) and Roanoke River Management Areas (RRMA) while the remainder of the states estuarine waters comprise the CentralSouthern Management Area (CSMA).

The 2020 stock assessment of the Albemarle Sound-Roanoke River striped bass indicated the stock is overfished and undergoing overfishing. The ASMFC requires an end to overfishing within one year, which was addressed through the November 2020 Revision to Amendment 1. This meets the NC standard requiring management action end overfishing in two years. NC law also requires management action to recover from the overfished status within 10 years. Stock status is not available for the other NC stocks due to continuous stocking efforts. However, modeling indicates that these stocks are depressed to an extent sustainability is unlikely under any fishing mortality.

The goal of Amendment 2 is to manage the estuarine striped bass fisheries to achieve self-sustaining populations that provide sustainable harvest based on science-based decision-making processes. If biological and/or environmental factors prevent a self-sustaining population, then alternate management strategies will be implemented that provide protection for and access to the resource. The objectives to achieve this goal include: implement management strategies within NC and encourage interjurisdictional management strategies that maintain and/or restore spawning stock with adequate age structure and abundance to maintain recruitment potential and to prevent overfishing; restore, enhance, and protect critical habitat and environmental quality in a manner consistent with the Coastal Habitat Protection Plan (CHPP), to maintain or increase growth, survival, and reproduction of the striped bass stocks; use biological, social, economic, fishery, habitat, and environmental data to effectively monitor and manage the fisheries and their ecosystem impacts; promote stewardship of the resource through public outreach and interjurisdictional cooperation regarding the status and management of the NC striped bass stocks, including practices that minimize bycatch and discard mortality.

To meet statutory requirements to achieve self-sustaining striped bass stocks, sustainable harvest is addressed in the FMP. An additional issue addresses the use of hook and line as a commercial gear. Specific recommendations for each issue are as follows:

Sustainable harvest: Albemarle Sound-Roanoke River Stock *(Appendix 2)*:

- Use stock assessments and projections to determine the Total Allowable Landings (TAL) that achieve sustainable harvest.
- If fishing mortality ($F$) exceeds the $F_{\text{Target}}$, reduce the TAL to achieve the $F_{\text{Target}}$ in one year through a Revision.
- Continue managing the ASMA commercial fishery as a bycatch fishery.

- Accountability measures to address total allowable landing (TAL) overages: if landings in any fishery exceeds their TAL, all landings in excess will be deducted from that fisheries TAL the next calendar year or until the overage is paid back.
- In the ASMA, implement a harvest slot of a minimum size of 18-inches TL to not greater than 25-inches TL in the commercial and recreational sectors.
- In the RRMA, maintain current harvest slot limit of a minimum size of 18-inches TL to not greater than 22-inches TL with no harvest allowed on fish greater than 22-inches.
- Allow commercial harvest of striped bass with gill nets in joint and coastal waters of the ASMA and continue recreational harvest and catch-and-release fishing in the ASMA and RRMA. Implement a requirement to use non-offset barbless circle hooks when fishing with live or natural bait in the inland waters of the Roanoke River upstream of the Hwy 258 bridge from May 1 through June 30.
- Adopt adaptive management framework that will allow for future adjustments of the TAL based on results of updated stock assessments and provide the Director the flexibility to modify daily possession limits, harvest seasons, and gear requirements to manage harvest to the TAL and reduce striped bass discards.

Sustainable harvest: Tar-Pamlico, and Neuse rivers stocks *(Appendix 3):*

- Continue the no-possession measure in Supplement A to Amendment 1.
- Maintain gill net closure above the ferry lines and maintain the 3-foot tie-downs below the ferry lines.
- In 2025, review data through 2024 to determine if populations are self-sustaining and if sustainable harvest can be determined.

Sustainable harvest: Cape Fear River stock *(Appendix 4):*

- Maintain Cape Fear River harvest moratorium.
- Adaptive management based on young-of-year surveys and parentage-based tagging analysis to evaluate if the levels of natural reproduction in the system further warrant a harvest moratorium and provide the Director the flexibility to allow harvest after consultation with the Finfish Advisory Committee.

Hook and line as a commercial gear *(Appendix 5):*

- Continue to manage the use of hook and line gear in the commercial fishery as an adaptive management option across the fishery. Commercial harvest of stiped bass from hook and line gear is not authorized at this time.

## INTRODUCTION

This is Amendment 2 to the NC Estuarine Striped Bass FMP. By law, each FMP must be reviewed at least once every five years in accordance with N.C.G.S. section 113-182.1. The NC DMF reviews each FMP annually and a comprehensive review is undertaken about every five years. The last comprehensive review of the plan (Amendment 1) was approved by the NC Marine Fisheries Commission (MFC) in 2013. FMPs are the ultimate product that brings all information and management considerations into one document. The DMF prepares FMPs for adoption by the MFC for all commercially and recreationally significant species or fisheries that comprise state marine or estuarine resources. The goal of these plans is to ensure long-term viability of these fisheries.

In NC striped bass (*Morone saxatilis*) stocks are managed among four areas: (1) Albemarle Sound Management Area (ASMA), (2) Roanoke River Management Area (RRMA), (3) Central/Southern Management Area (CSMA), and (4) Atlantic Ocean. The MFC adopts rules and policies and with DMF implements management measures for the estuarine striped bass fishery in Coastal Fishing Waters in accordance with N.C.G.S. section 113-182.1. The Estuarine Striped Bass FMP is jointly developed with the NC WRC. The migratory Atlantic Ocean stock is managed by the ASMFC. The ASMA and RRMA are also subject to compliance requirements of the ASMFC Interstate FMP for Atlantic Striped Bass.

## FISHERY MANAGEMENT PLAN HISTORY

| | |
|---|---|
| Original FMP Adoption: | November 1993 |
| | May 2004 |
| Amendments: | Amendment 1 – May 2013 |
| Revisions: | November 2014 Revision to Amendment 1 |
| | November 2020 Revision to Amendment 1 |
| Supplements: | Supplement A – February 2019 |
| Information Updates: | None |
| Schedule Changes: | August 2016 |
| Comprehensive Review: | At least five years after Amendment 2 adoption |

Past versions of the Estuarine Striped Bass FMP, Revisions, Amendment, and Supplement (NCDMF 2004, 2013, 2014, 2019, and 2020) are available on the DMF website.

## MANAGEMENT UNIT

There are two geographic striped bass management units in NC (Figure 1). The northern management unit is comprised of two harvest management areas: the RRMA and the ASMA. These two management areas form the geographical area of the Albemarle-Roanoke (A-R) stock of striped bass. Commercial regulations in the RRMA are the responsibility of the MFC, while recreational regulations are the responsibility of the WRC. Recreational and commercial striped bass regulations within the ASMA are the responsibility of the MFC. The RRMA and ASMA are also subject to the [ASMFC Interstate FMP for Atlantic Striped Bass]. To ensure compliance with the ASMFC Interstate FMP, the A-R stock is additionally managed under the NC FMP for Interjurisdictional Fisheries.

The southern geographic management unit is the CSMA that is comprised of the Tar-Pamlico, Neuse, and Cape Fear rivers and the Pamlico Sound. Management of striped bass within the CSMA is the sole responsibility of NC through the MFC and the WRC.

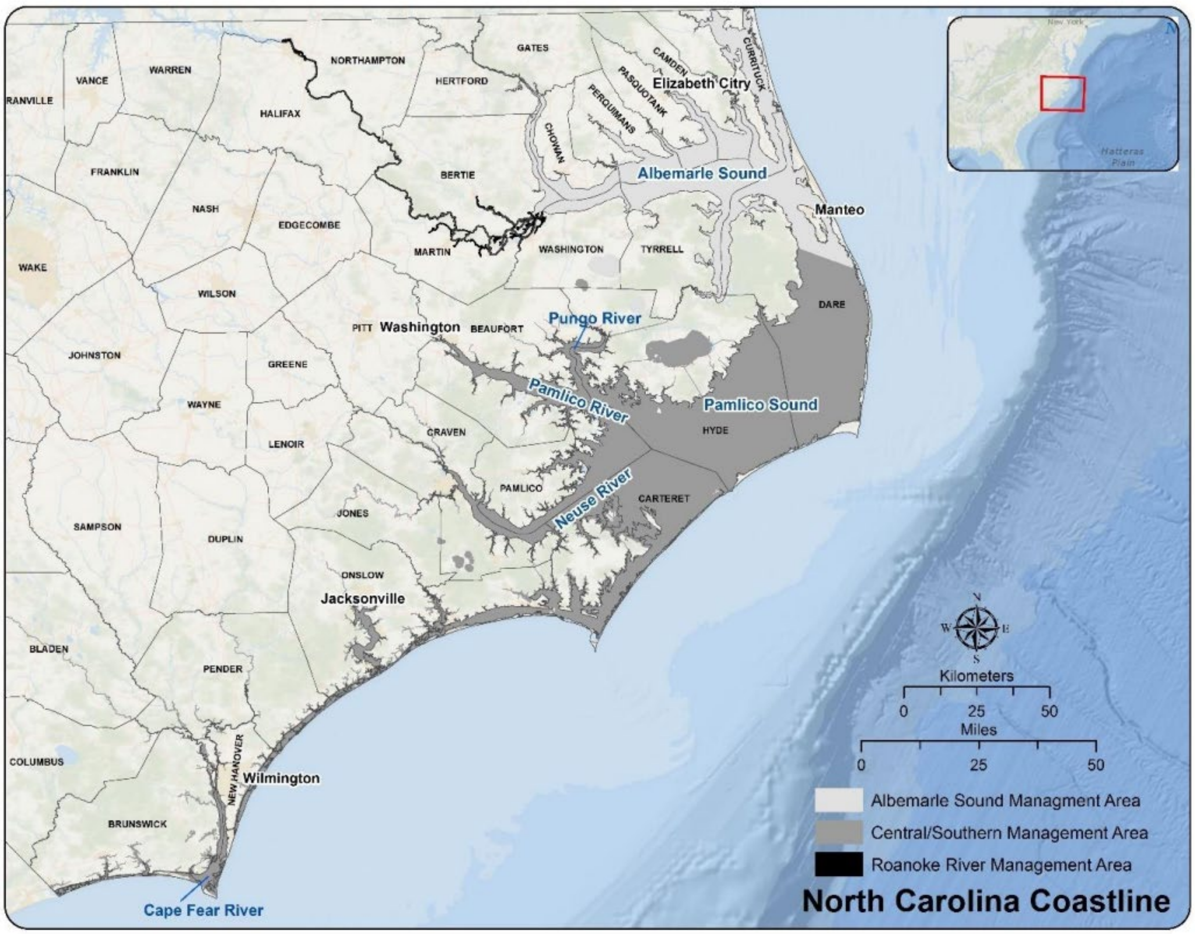


Figure 1. Boundary lines defining the Albemarle Sound Management Area, Central/Southern Management Area, and the Roanoke River Management Area.

## GOAL AND OBJECTIVES

The goal of Amendment 2 is to manage the estuarine striped bass fisheries to achieve self-sustaining populations that provide sustainable harvest based on science-based decision-making processes. If biological and/or environmental factors prevent a self-sustaining population, then alternate management strategies will be implemented that provide protection for and access to the resource. The following objectives will be used to achieve this goal.

- Implement management strategies within North Carolina and encourage interjurisdictional management strategies that maintain and/or restore spawning stock with adequate age structure and abundance to maintain recruitment potential and to prevent overfishing.
- Restore, enhance, and protect critical habitat and environmental quality in a manner consistent with the Coastal Habitat Protection Plan, to maintain or increase growth, survival, and reproduction of the striped bass stocks.
- Use biological, social, economic, fishery, habitat, and environmental data to effectively monitor and manage the fisheries and their ecosystem impacts.
- Promote stewardship of the resource through public outreach and interjurisdictional cooperation regarding the status and management of the North Carolina striped bass stocks, including practices that minimize bycatch and discard mortality.

## DESCRIPTION OF THE STOCK

### BIOLOGICAL PROFILE

Striped bass is an estuarine dependent species found from the lower St. Lawrence River in Canada to the west coast of Florida, through the northern Gulf of Mexico to Texas. In NC, the species is also known as striper, rockfish, or rock. Stocks from Maine to the A-R in NC are migratory, spending most of their adult life in the estuaries and ocean before moving into fresh water to spawn in the spring. The large, A-R stock striped bass leave the Roanoke River system after spawning and migrate north, to ocean waters from New Jersey to Massachusetts. In the fall, these fish migrate south to ocean waters off Virginia and NC, before entering the Albemarle Sound and Roanoke River again in the spring (Callihan et al. 2015). Southern stocks, including the stocks of the CSMA, are riverine, spending their entire life in the estuary and river systems (Setzler et al. 1980; Rulifson et al. 1982; Callihan 2012).

Striped bass migrate far distances to spawning grounds located in freshwater portions of coastal rivers. Spawning grounds for the A-R stock are concentrated at the fall line, where the coastal plain meets the piedmont, 137 miles up the Roanoke River near Weldon, NC. Spawning grounds in the CSMA rivers are not as clearly defined. On the Tar-Pamlico River, striped bass spawning is suspected to occur from the Rocky Mount Mills Dam,125 miles upstream of Washington, NC, to Tarboro, NC (Smith and Rulifson 2015). Neuse River spawning grounds are centered between Smithfield and Clayton, NC, but range from Kinston river mile (rm) 130 to Raleigh (rm 236). On the Cape Fear River, historic striped bass spawning grounds are located at the fall line near Smiley's Falls (rm 165) in Lillington, NC, but access to this spawning habitat is restricted by a series of three lock and dam systems. In the Northeast Cape Fear River, adult striped bass have been captured and acoustically tagged during the spawning season between White Stocking, NC (rm 73) and Chinquapin, NC (rm 104), with potential spawning occurring as far upstream as Hallsville, NC (rm 114; Rock et al. 2018).

Striped bass are relatively long-lived and can reach 50–60 pounds. Females grow larger than males, with a reported maximum total length of 60 inches. The oldest observed striped bass in the A-R stock was 31 years old, while within the CSMA the maximum age was 17 years. The largest recorded striped bass, which weighed 125 pounds, was caught in the early 1900s in the Albemarle Sound. Females in the A-R stock are 97% mature at age-4 (Boyd 2011), while females in the Tar-Pamlico and Neuse rivers are 98% mature by age-3 (Knight 2015). In the Tar-Pamlico and Neuse rivers, fecundity (number of eggs a female produces) ranges from 223,110 eggs for an age-3 female to 3,273,206 eggs for an age-10 female (Knight 2015).

Streamflow and water temperature are important environmental conditions that influence the success of annual striped bass reproduction and recruitment (number of juveniles produced). Striped bass require flowing, freshwater that allows eggs to remain suspended until they hatch and fry to be transported to nursery areas. Female striped bass produce large quantities of eggs that are broadcast into riverine spawning areas and fertilized by mature males. Fertilized eggs drift with downstream currents and hatch in 1.5–3 days depending on water temperature (Mansueti 1958). Spawning in NC can occur from late March until early June. Peak spawning activity for the A-R stock occurs when water temperature reaches 62–67 degrees Fahrenheit on the spawning grounds.

Striped bass form large schools, feeding on available fishes and invertebrates. Oily fish such as Atlantic menhaden (*Brevoortia tyrannus*), herrings (*Clupea* spp.), and shads (*Alosa* spp.) are common prey, but spot (*Leiostomus xanthurus*), mullet (*Mugil* spp.), Atlantic croaker (*Micropogonias undulatus*), American eel (*Anguilla rostrata*), and blue crabs (*Callinectes sapidus*) are also consumed.

STOCK UNIT

There are four striped bass stocks in NC: Albemarle-Roanoke (A-R), Tar-Pamlico, Neuse, and Cape Fear stocks.

ASSESSMENT METHODOLOGY

The A-R stock was assessed using Stock Synthesis through a forward-projecting statistical catch-at-age model which was applied to data characterizing landings/harvest, discards, fishery-independent indices, and biological data collected during 1991–2017 (Lee et. al 2020).

Traditional stock assessment techniques could not be applied to CSMA stocks because of high hatchery contribution and lack of natural recruitment in these systems. A demographic matrix model was developed to evaluate stocking and management measures for striped bass in all three CSMA river systems. In addition, a tagging model was developed to estimate striped bass abundance in the Cape Fear River.

STOCK STATUS

A-R Stock

The 2020 A-R striped bass stock assessment indicates the stock is overfished and overfishing is occurring (Lee et. al 2020). The estimate of fishing mortality (*F*) in the terminal year of the assessment (2017) was 0.27, greater than the $F_{35\%SPR\ Threshold}$ of 0.18 (Figure 2). The estimate of spawning stock biomass (SSB) was 78,576 pounds, less than the $SSB_{35\%SPR\ Threshold}$ of 267,390 pounds (Figure 3). The stock had a period of strong recruitment from 1993 to 2000, then a period of low recruitment from 2001 to 2017. The complete stock assessment can be reviewed on the division Fishery Management Plans website.

The 2020 stock assessment is used to establish sustainable harvest in the A-R stock fisheries. This is done by calculating the Total Allowable Landings (TAL) that can be removed annually from the stock. The TAL is currently allocated with a 50/50 split to the recreational and commercial fisheries. The ASMA commercial fishery receives 50% of the TAL with the RRMA recreational and the ASMA recreational fisheries each receiving a 25% allocation of the TAL.

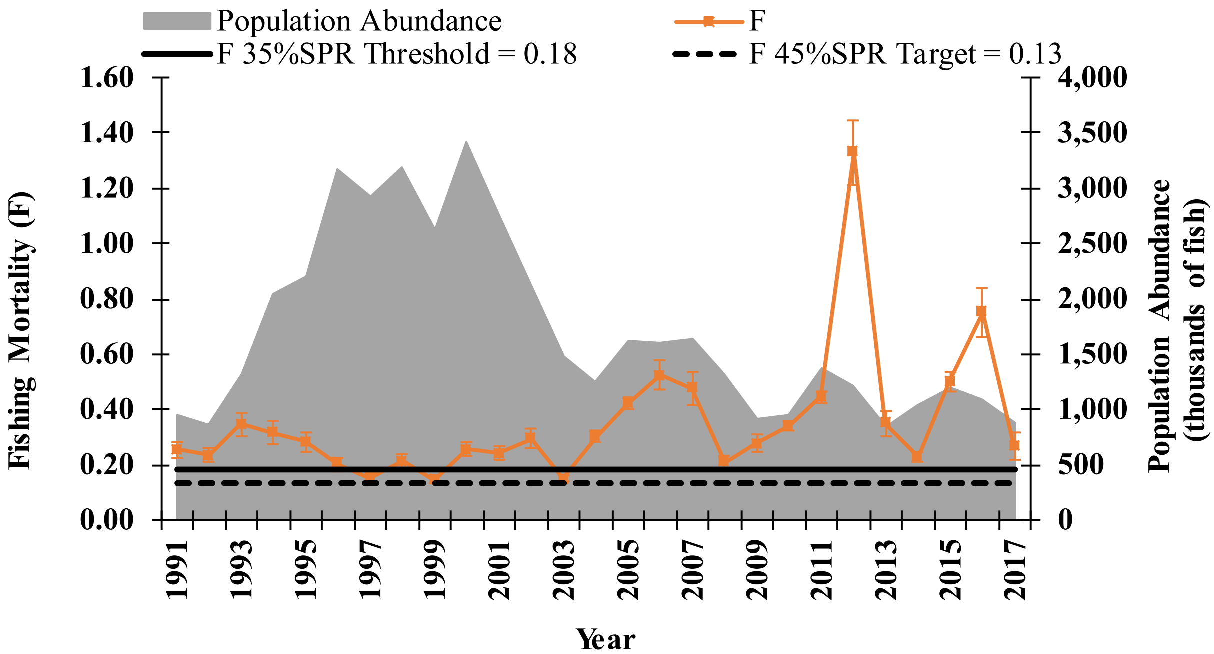


Figure 2. Estimates of fishing mortality (F) and population abundance for the Albemarle-Roanoke striped bass stock, 1991–2017. Error bars represent ± two standard errors. Source: Lee et al. 2020.

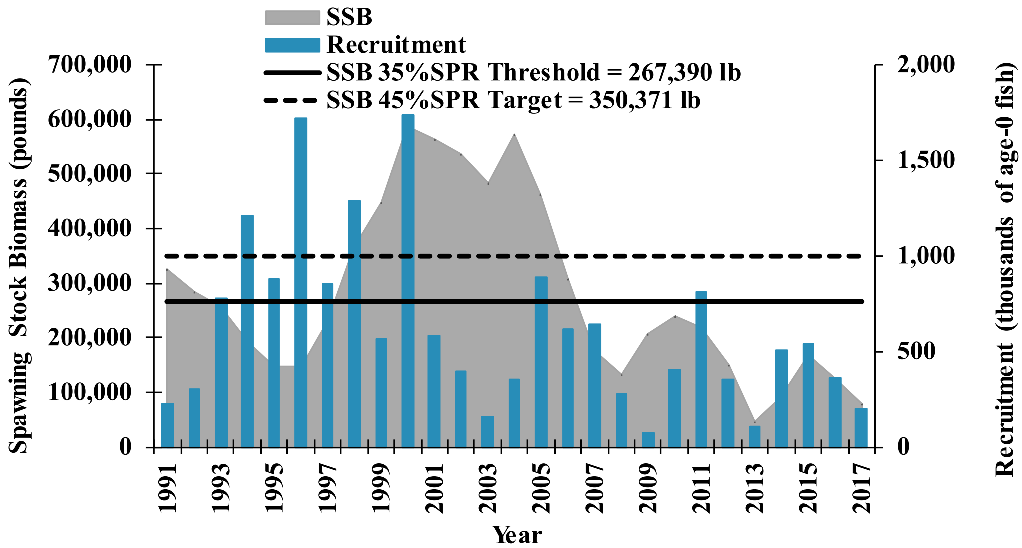


Figure 3. Estimates of spawning stock biomass (SSB) and recruitment of age-0 fish coming into the population each year for the Albemarle-Roanoke striped bass stock, 1991–2017. Source: Lee et al. 2020

CSMA Stocks

The demographic matrix model indicates the striped bass populations in the CSMA are depressed to an extent that sustainability is unlikely at any level of fishing mortality. The model suggests insufficient natural recruitment is the primary factor limiting population abundance of Tar-Pamlico and Neuse stocks and suggests the populations would decline without stocking (Mathes et al. 2020). Tagging model results indicate a consistent decline in abundance estimates for striped bass in the Cape Fear River (2012–2018). Even with a no-possession provision for the Cape Fear River since 2008, 2018 abundance was less than 20% of the 2012 abundance. 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 (O'Donnell and Farrae 2017). For more information on stocking see Appendix 1: Striped Bass Stocking in Coastal North Carolina. The complete stock assessment report can be reviewed on the division Fishery Management Plans website.

## DESCRIPTION OF THE FISHERIES

Additional in-depth analyses and discussion of NC's commercial and recreational striped bass fisheries can be found in earlier versions of the Estuarine Striped Bass FMP, Revisions, Amendment 1, and Supplement A (NCDMF 2004, 2013, 2014, 2019, and 2020); all FMP documents are available on the DMF Fishery Management Plans website and commercial and recreational landings can be found in the License and Statistics Annual Report (NCDMF 2020) produced by the DMF which can be found on the DMF Fisheries Statistics page, including a report entitled North Carolina Striped Bass (*Morone saxatilis*) Commercial Fishery (Gambill and Bianchi 2019).

COMMERCIAL FISHERIES

ASMA

Under Amendment 1, the ASMA commercial striped bass fishery is a bycatch fishery, striped bass harvest occurs while targeting other finfish species. Striped bass cannot be greater than 50% by weight of all other finfish species landed per trip. Daily landing limits of 5–25 striped bass further deter fishers from targeting striped bass and aim to ensure striped bass quota is available when multispecies gill net fisheries are operating. Most striped bass harvest occurs with the American shad (*Alosa sapidissima*) anchored gill net fishery in the spring, followed by the southern flounder (*Paralichthys lethostigma*) anchored gill net fishery in the fall. Since 2015, as a commercial fishery for invasive blue catfish (*Ictalurus furcatus*) has developed, more striped bass landings have occurred in this strike net fishery. Strike nets are fished by locating a school of fish, encircling the school with a gill net, then immediately retrieving the net. Harvest from pound nets is the second leading harvest gear with an average of 20% of the total harvest since 2010.

Commercial landings in the ASMA have been limited by an annual TAL since 1991. Due to gill net mesh size regulations and minimum striped bass size limits since 1993, most harvest consists of fish 4–6 years of age. During 1990–1997 the commercial TAL was set at 98,000 pounds because the A-R stock was at historically low levels of abundance and required rebuilding. The stock was declared recovered in 1997 and the commercial 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.

Beginning in 2004, commercial landings no longer reached the annual TAL, even with increases in the number of harvest days and daily possession limits. From 2005 to 2009, landings steadily declined averaging 150,000 pounds annually (Figure 4).

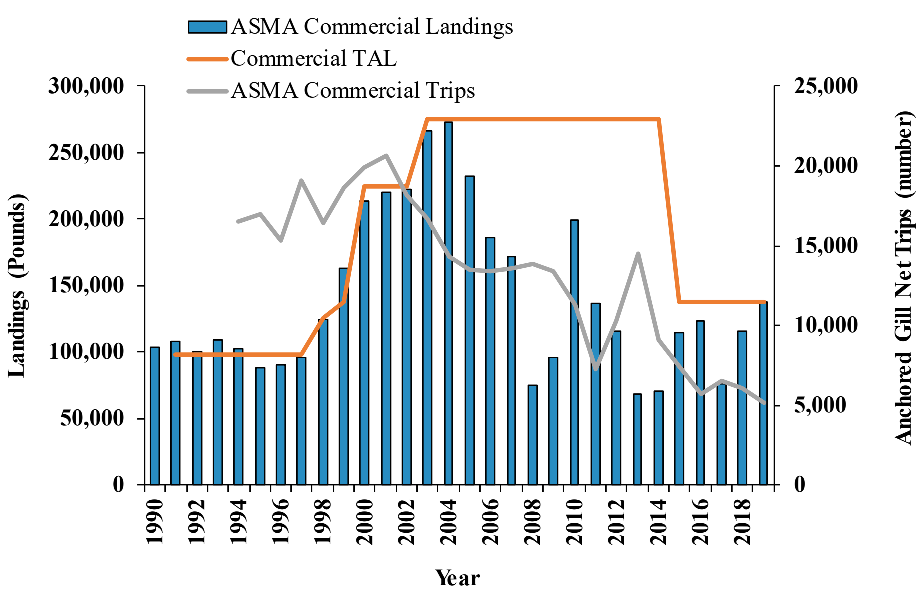


Figure 4. Commercial striped bass landings and the number of all anchored gill net trips in the Albemarle Sound Management Area (ASMA), 1991–2019.

The decline in landings in years 2005–2009 was due to poor year classes produced during 2001–2004. An increase in landings in 2010 was due to the strong 2005-year class. Since 2013, landings have declined in part because of a shortened American shad season. In 2021, the commercial TAL was reduced to 25,608 pounds to meet requirements of adaptive management measures in Amendment 1 to the Striped Bass FMP to end overfishing in one year of stock assessment results indicated the stock was undergoing overfishing (NCDMF 2020).

CSMA

Supplement A (NCDMF 2019) closed the CSMA commercial striped bass fishery to protect important year classes of striped bass. From 1994 to 2018 commercial landings in the CSMA were limited by a 25,000 lb annual TAL. From 1994 to 2018 striped bass commercial landings in the CSMA averaged 26,132 lb (Figure 5). Most commercial landings are from the Tar-Pamlico, Pungo, Neuse, and Bay rivers (Figure 6). From 2004 to 2018, there was only a spring harvest season, opening March 1 and closing when the annual TAL was reached.

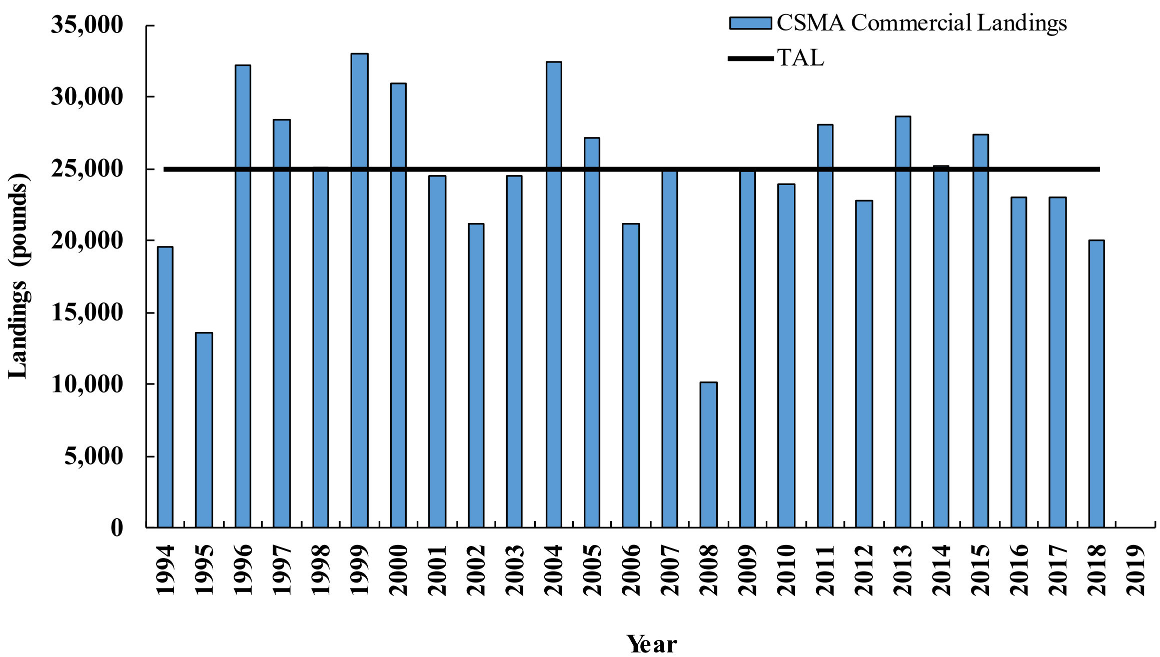


Figure 5. Annual commercial CSMA striped bass harvest and TAL in pounds, 1994–2019. Since 2019 the commercial season has been closed.

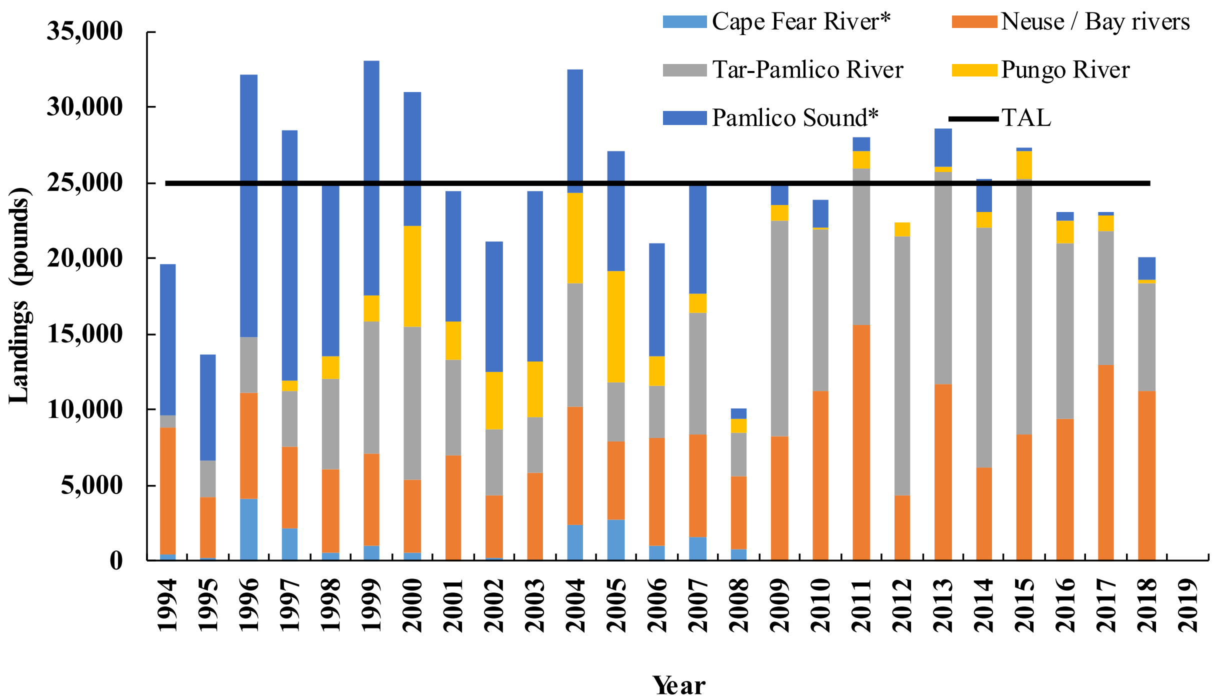


Figure 6. Commercial striped bass harvest by system, and the TAL in the CSMA, 2004–2019. There has been a harvest moratorium in the Cape Fear River since 2008, and a closed season in the CSMA since 2019. *Landings data for the Cape Fear River in 2001 and the Pamlico Sound in 2012 are confidential.

## RECREATIONAL FISHERIES

### ASMA

In the initial 1993 FMP, effective January 1, 1994, the MFC and WRC approved management to split the TAL evenly between the commercial and recreational sectors when the stock recovered (NCDMF 1993). In 1997 the stock was declared recovered and in 1998 the MFC allocated the TAL 50/50 between the commercial and recreational sectors through incremental steps. The ASMA receives 25% of the recreational allocation. The ASMA recreational TAL increased from 29,400 pounds in 1997 to 137,500 pounds in 2003. Adaptive management to address the overfished status in 2021 reduced the ASMA recreational TAL to 12,804 pounds (NCDMF 2020). Recreational landings peaked in 2001 at 118,506 pounds (Figure 7). Recreational landings in the ASMA primarily consist of fish age 3–5.

Beginning in fall 2005, harvest was allowed seven days a week in the ASMA. Additionally, in fall 2006 possession limits were increased from two to three fish. Despite the increases in bag limits and days recreational fishery was open, harvest continued to decline. Several poor year classes produced since 2001 may have contributed to 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. Recreational harvest from 1991 to 2019 averaged 42,466 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 24,051 fish (Table 1).

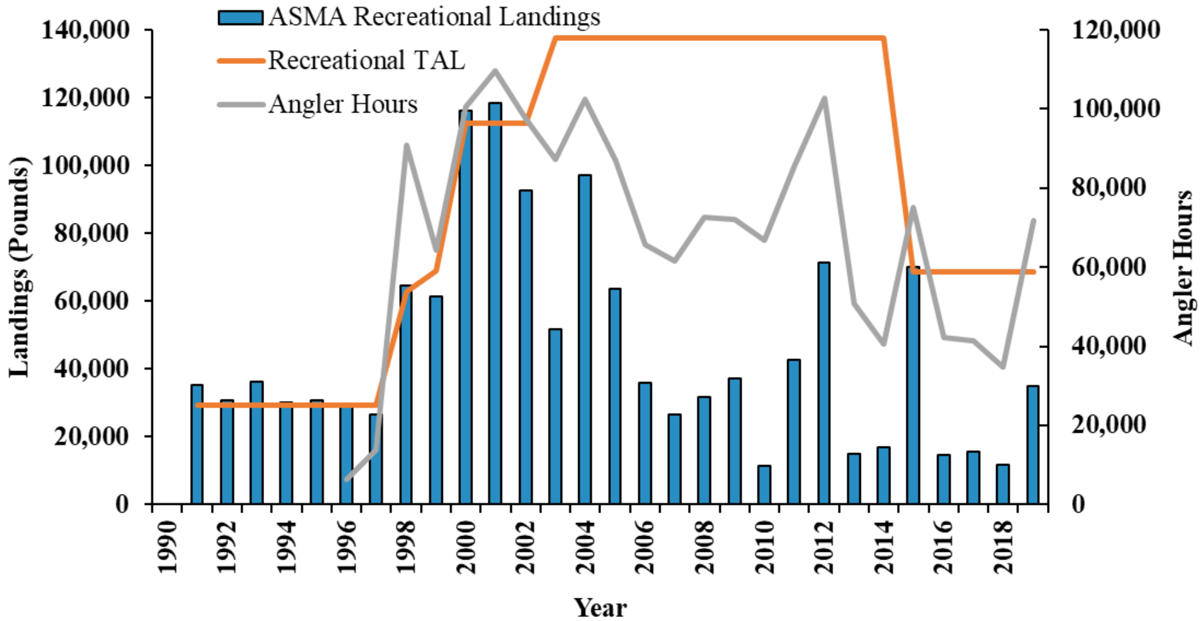


Figure 7. Recreational striped bass landings and the hours of striped bass fishing effort in the Albemarle Sound Management Area (ASMA) 1991–2019.

RRMA

Harvest from 1982 through 2019 averaged 54,103 pounds in the RRMA (Table 2; Figure 8). Discards outnumber landings annually, especially in the RRMA where concentrations of fish on the spawning grounds can be dense. Annual releases from 2005 through 2019 in the RRMA averaged 80,821 fish.

From 2003 to 2016, landings averaged 64,389 pounds, with a few noticeably low years (Figure 8). Adaptive management measures implemented in 2021 reduced the RRMA recreational TAL to 12,804 pounds (NCDMF 2020). Recreational landings in the RRMA are dominated by age-3 to age-5 fish, primarily due to a no possession rule of fish between 22 and 27-inches total length (TL) and general angling techniques. Few fish over age 9 are observed in the creel survey because most anglers do not use the large artificial lures or natural bait needed to effectively target striped bass over 28-inches TL.

Table 1. Estimates of striped bass angling effort, harvest, and numbers caught and released from the Albemarle Sound Management Area, 1991–2019. Cells with a dash indicate estimates were not generated in that year. Estimates of discards are not available for the post-harvest period.

| Year | Striped Bass Trips | Angler Hours | Number of fish harvested | Total pounds harvested | Striped Bass Discard (#over-creel) | Striped Bass Discard (#under-sized) | Striped Bass Discard (#legal-sized) | Total number of fish released |
|---|---|---|---|---|---|---|---|---|
| 1991 | | | 14,395 | 35,344 | | | | 23,540 |
| 1992 | | | 10,542 | 30,758 | | | | 19,981 |
| 1993 | | | 11,404 | 36,049 | | | | 13,241 |
| 1994 | | | 8,591 | 30,217 | | | | |
| 1995 | | | 7,343 | 30,564 | | | | |
| 1996 | | 6,349 | 7,433 | 29,186 | | | | |
| 1997 | | 13,656 | 6,901 | 26,724 | | | | 30,771 |
| 1998 | | 90,820 | 19,566 | 64,761 | | | | 91,888 |
| 1999 | | 64,442 | 16,967 | 61,447 | | | | 40,321 |
| 2000 | | 100,425 | 38,085 | 116,414 | | | | 78,941 |
| 2001 | | 109,687 | 40,127 | 118,645 | | | | 61,418 |
| 2002 | | 97,480 | 27,896 | 92,649 | | | | 51,555 |
| 2003 | | 87,292 | 15,124 | 51,794 | | | | 25,281 |
| 2004 | | 102,505 | 28,004 | 97,097 | 9,877 | 28,859 | 2,305 | 41,041 |
| 2005 | 13,735 | 86,943 | 17,954 | 63,477 | 11,333 | 7,032 | 2,855 | 21,220 |
| 2006 | 10,707 | 65,757 | 10,711 | 35,985 | 2,490 | 6,339 | 626 | 9,455 |
| 2007 | 9,629 | 61,679 | 7,143 | 26,633 | 1,148 | 12,259 | 192 | 13,599 |
| 2008 | 11,793 | 72,673 | 10,048 | 31,628 | 391 | 36,324 | 260 | 36,975 |
| 2009 | 11,326 | 72,021 | 12,069 | 37,313 | 20 | 38,683 | 1,860 | 40,563 |
| 2010 | 9,660 | 66,893 | 3,504 | 11,470 | 569 | 15,398 | 233 | 16,200 |
| 2011 | 13,114 | 85,325 | 13,341 | 42,536 | 317 | 20,114 | 1,141 | 21,572 |
| 2012 | 14,490 | 102,787 | 22,345 | 71,456 | 1,024 | 19,977 | 3,970 | 24,971 |
| 2013 | 7,053 | 50,643 | 4,299 | 14,897 | 31 | 16,034 | 316 | 16,381 |
| 2014 | 7,264 | 40,478 | 5,529 | 16,867 | 18 | 22,558 | 510 | 23,086 |
| 2015 | 11,132 | 75,009 | 23,240 | 70,008 | 1,573 | 45,559 | 2,402 | 49,534 |
| 2016 | 7,023 | 42,276 | 4,794 | 14,486 | 252 | 8,822 | 1,278 | 10,352 |
| 2017 | 7,658 | 41,371 | 4,215 | 15,480 | 56 | 24,004 | 600 | 24,660 |
| 2018 | 9,057 | 34,764 | 3,465 | 11,762 | 281 | 21,337 | 3,970 | 25,588 |
| 2019 | 19,864 | 61,645 | 8,502 | 34,968 | 2,301 | 34,452 | 1,625 | 38,378 |

# DRAFT – SUBJECT TO CHANGE

Table 2. Estimates of striped bass angling effort, harvest, and numbers caught and released from the Roanoke River Management Area, 1988–2019. Blank cells indicate data was not collected in that year. **For 1989–2009 number of trips was calculated by dividing the angler hours by 4.75 (assumes each trip was 4.75 hours long). Since 2010, number of trips were estimated based on creel survey data sampling probabilities.

| | Open Season (Harvest estimates) | | | | Post-Harvest Period (Catch and Release Only) | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Number Harvested | Weight (lb) | Effort (angler-hours) | Trips** | Number released | Number released | Effort (angler-hours) | Trips** |
| 1988 | | 74,639 | | | | | | |
| 1989 | 8,753 | 32,107 | 46,566 | 9,803 | | | | |
| 1990 | 15,694 | 42,204 | 56,169 | 11,825 | | | | |
| 1991 | 26,934 | 72,529 | 74,596 | 15,704 | | | | |
| 1992 | 13,372 | 36,016 | 49,277 | 10,374 | | | | |
| 1993 | 14,325 | 45,145 | 52,932 | 11,144 | | | | |
| 1994 | 8,284 | 28,089 | 44,693 | 9,409 | | | | |
| 1995 | 7,471 | 28,883 | 56,456 | 11,885 | | 52,698 | 20,639 | 4,345 |
| 1996 | 8,367 | 28,178 | 46,164 | 9,719 | | 148,222 | 32,743 | 6,893 |
| 1997 | 9,364 | 29,997 | 23,139 | 4,871 | | 271,328 | 47,001 | 9,895 |
| 1998 | 23,109 | 73,541 | 72,410 | 15,244 | | 102,299 | 26,367 | 5,551 |
| 1999 | 22,479 | 72,967 | 72,717 | 15,309 | | 113,394 | 30,633 | 6,449 |
| 2000 | 38,206 | 120,091 | 95,622 | 20,131 | | | | |
| 2001 | 35,231 | 112,805 | 100,119 | 21,078 | | | | |
| 2002 | 36,422 | 112,698 | 122,584 | 25,807 | | | | |
| 2003 | 11,157 | 39,170 | 77,863 | 16,392 | | | | |
| 2004 | 26,506 | 90,191 | 145,782 | 30,691 | | | | |
| 2005 | 34,122 | 107,530 | 130,755 | 27,527 | | 68,147 | 24,146 | 5,083 |
| 2006 | 25,355 | 84,521 | 120,621 | 25,394 | | 24,719 | 15,235 | 3,207 |
| 2007 | 19,305 | 62,492 | 141,874 | 29,868 | | 11,622 | 9,254 | 1,948 |
| 2008 | 10,541 | 32,725 | 110,608 | 23,286 | | 47,992 | 17,764 | 3,740 |
| 2009 | 23,248 | 69,581 | 120,675 | 25,405 | | | | |
| 2010 | 22,445 | 72,037 | 125,495 | 24,347 | 77,882 | 46,028 | 31,281 | 5,111 |
| 2011 | 22,102 | 71,561 | 122,876 | 27,311 | 80,828 | 26,865 | 15,110 | 2,707 |
| 2012 | 28,847 | 88,539 | 110,982 | 27,151 | 40,772 | 22,246 | 8,935 | 1,881 |
| 2013 | 7,718 | 25,197 | 100,391 | 19,539 | 49,148 | 25,074 | 12,423 | 2,246 |
| 2014 | 11,058 | 33,717 | 80,256 | 15,960 | 93,471 | 72,068 | 17,542 | 2,972 |
| 2015 | 20,031 | 58,962 | 111,419 | 22,827 | 78,401 | 29,839 | 12,229 | 2,207 |
| 2016 | 21,260 | 65,218 | 129,132 | 25,036 | 34,753 | 17,891 | 11,291 | 2,087 |
| 2017 | 9,899 | 32,569 | 101,565 | 19,688 | 68,693 | 9,754 | 7,446 | 1,317 |
| 2018 | 8,741 | 26,797 | 95,447 | 18,280 | 121,969 | 65,245 | 14,499 | 2,462 |
| 2019 | 16,582 | 53,379 | 99,259 | 20,633 | 117,550 | 69,642 | 26,867 | 5,283 |

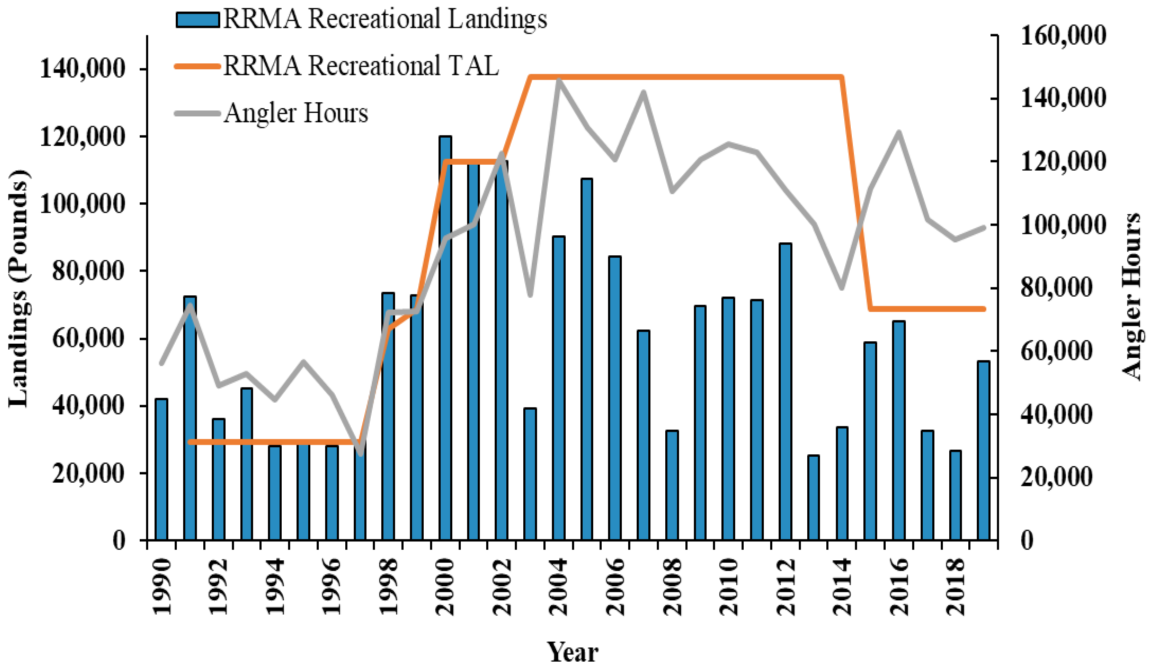


Figure 8. Recreational striped bass landings and the hours of striped bass fishing effort in the Roanoke River Management Area (RRMA) 1991–2019.

CSMA

The DMF began collecting recreational striped bass data in the major rivers of the CSMA in 2004. In 2013, due to low recreational striped bass catch in the Cape Fear River, creel survey methodology was adjusted to target American and hickory shad (*Alosa mediocris)* effort. The Supplement A recreational no possession measure approved in February 2019 limited recreational harvest in 2019. Recreational landings fluctuated between 2004 and 2019 (Table 3; Figure 9).

From 2004 to 2007 most recreational harvest occurred in the Neuse River, but since 2008 harvest has generally been split between the Tar-Pamlico and Neuse rivers (Figure 10). In 2016 and 2017, the number of trips and hours spent targeting striped bass in the CSMA increased substantially compared to other years (Table 3). Within the CSMA there is a significant catch-and-release fishery, averaging 47,309 releases from 2010 to 2019 (Table 3). Undersized discards peaked in 2017 but declined through 2019.

Table 3. Recreational striped bass effort, harvest and discards from the CSMA, 2004–2019. The 2019 season was January 1–March 19, 2019.

| Year | Fishing Trips | Effort Hours | Number Harvested | Pounds Harvested | Total Discards |
|---|---|---|---|---|---|
| 2004 | 12,782 | 63,791 | 6,141 | 22,958 | 13,557 |
| 2005 | 16,414 | 69,370 | 3,832 | 14,965 | 16,854 |
| 2006 | 10,611 | 42,066 | 2,481 | 7,352 | 14,895 |
| 2007 | 10,971 | 46,655 | 3,597 | 10,794 | 23,527 |
| 2008 | 6,621 | 28,413 | 843 | 2,990 | 17,966 |
| 2009 | 5,642 | 26,611 | 895 | 3,061 | 6,965 |
| 2010 | 6,559 | 25,354 | 1,757 | 5,537 | 7,990 |
| 2011 | 12,606 | 51,540 | 2,728 | 9,474 | 24,188 |
| 2012 | 18,338 | 71,964 | 3,922 | 15,240 | 43,313 |
| 2013 | 20,394 | 86,918 | 5,467 | 19,537 | 32,816 |
| 2014 | 15,682 | 70,316 | 3,301 | 13,368 | 30,209 |
| 2015 | 18,159 | 79,398 | 3,934 | 14,269 | 31,353 |
| 2016 | 23,675 | 110,453 | 6,697 | 25,260 | 75,461 |
| 2017 | 26,125 | 119,680 | 7,334 | 26,973 | 131,129 |
| 2018 | 16,393 | 69,917 | 3371 | 10,884 | 49,122 |
| 2019 | 8,820 | 40,580 | 959 | 3,562 | 37,039 |
| Average | 14,362 | 62,689 | 3,579 | 12,889 | 34,774 |

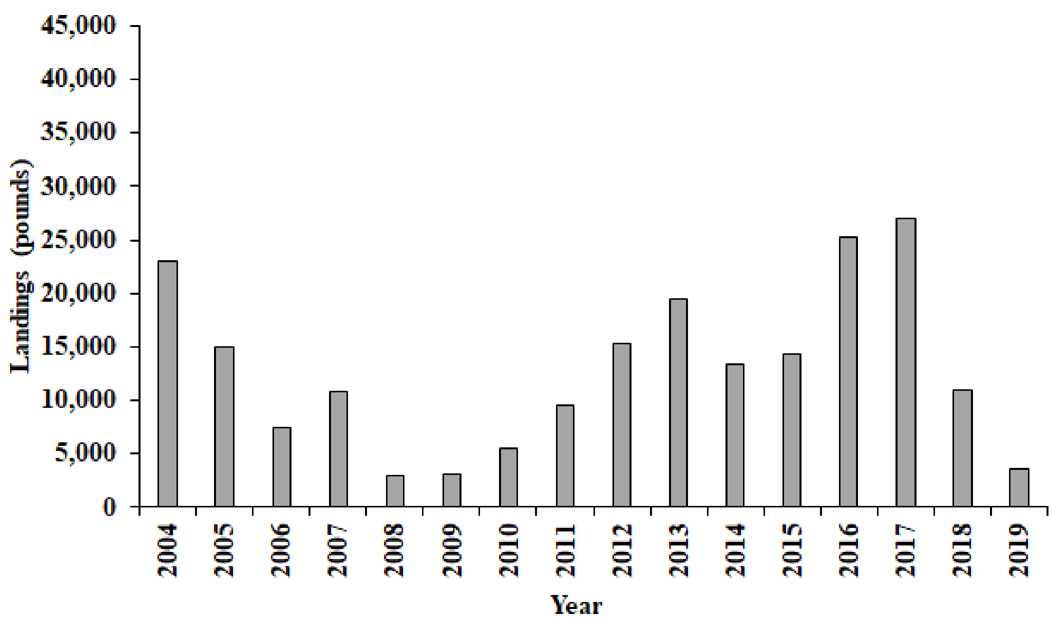


Figure 9. Annual recreational CSMA striped bass landings in pounds, 2004–2019. The 2019 season was January 1–March 19, 2019.

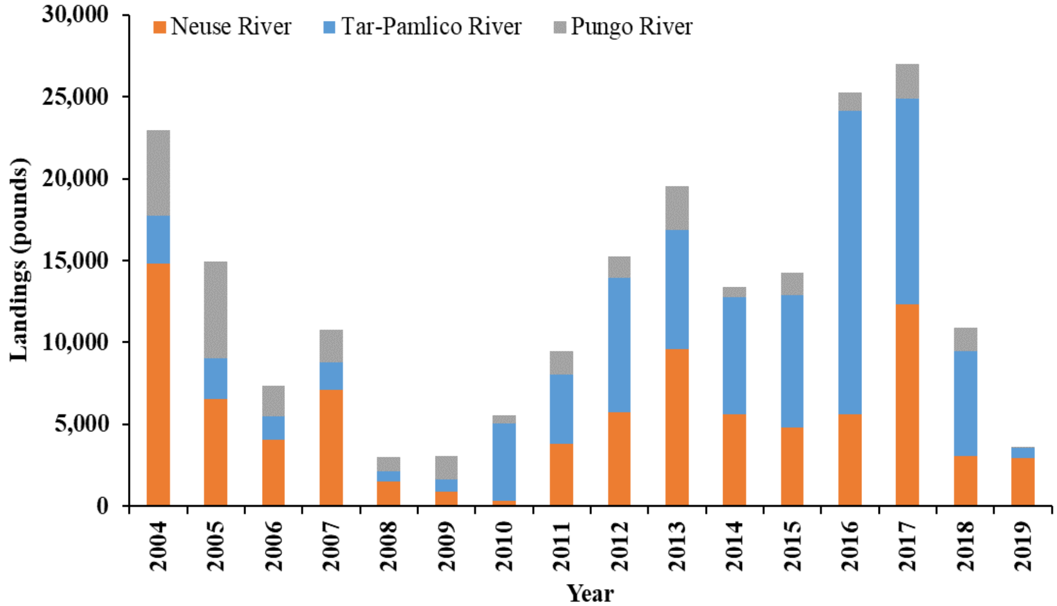


Figure 10. Recreational striped bass harvest in the Tar-Pamlico, Pungo, and Neuse rivers, 2004–2019. The 2019 season was January 1–March 19, 2019.

## SUMMARY OF ECONOMIC IMPACTS OF STRIPED BASS FISHING

Modeling software, IMPLAN, is used to estimate the economic impacts of an industry to the state at-large, accounting for revenues and participation. For a detailed explanation of the methodology used to estimate the economic impacts please refer to DMF's License and Statistics Section Annual Report on the Fisheries Statistics page. For further information on overall trends, economics, and characteristics of the commercial fishery see the report entitled North Carolina Striped Bass (*Morone saxatilis*) Commercial Fishery (Gambill and Bianchi 2019).

### Commercial

Commercial landings and effort data collected through the DMF trip ticket program are used to estimate the economic impact of the commercial fishing industry. For commercial fishing output, total impacts are derived by incorporating modifiers from NOAA's Fisheries Economics of the United States report (National Marine Fisheries Service 2018), which account for proportional expenditures and spillover impacts from related industries. By assuming striped bass fisheries contribute to the expenditure categories at a proportion equal to their contribution to total commercial ex-vessel values, we can generate an estimate of the total economic impact of striped bass harvest in the CSMA and ASMA. This same indirect impact methodology is applied to the aggregate landings of other species harvested during a striped bass trip. Economic impacts of the striped bass fishery and alternative species cannot be combined. As these landings occurred during the same trips with the same participants, much of the economic impact of striped bass harvest is also reflected in the economic impact of harvest of other species. These two impact categories have been separated to demonstrate how commercial striped bass fishing in the CSMA and ASMA impacts the state economy outside of direct landings, and how that effect could change if commercial striped bass effort were eliminated or reduced.

ASMA

Commercial effort and output in the ASMA are greater than in the CSMA. The number of striped bass commercial fishery participants in the ASMA is roughly two to three times higher than in the CSMA. More effort, and historically higher TAL in the ASMA compared to the CSMA leads to increased harvest of striped bass. Average annual landings of striped bass are roughly 100,000 pounds in the ASMA, with average ex-vessel values of $300,000 (Figure 11). Both values are approximately five times greater than annual values in the CSMA.

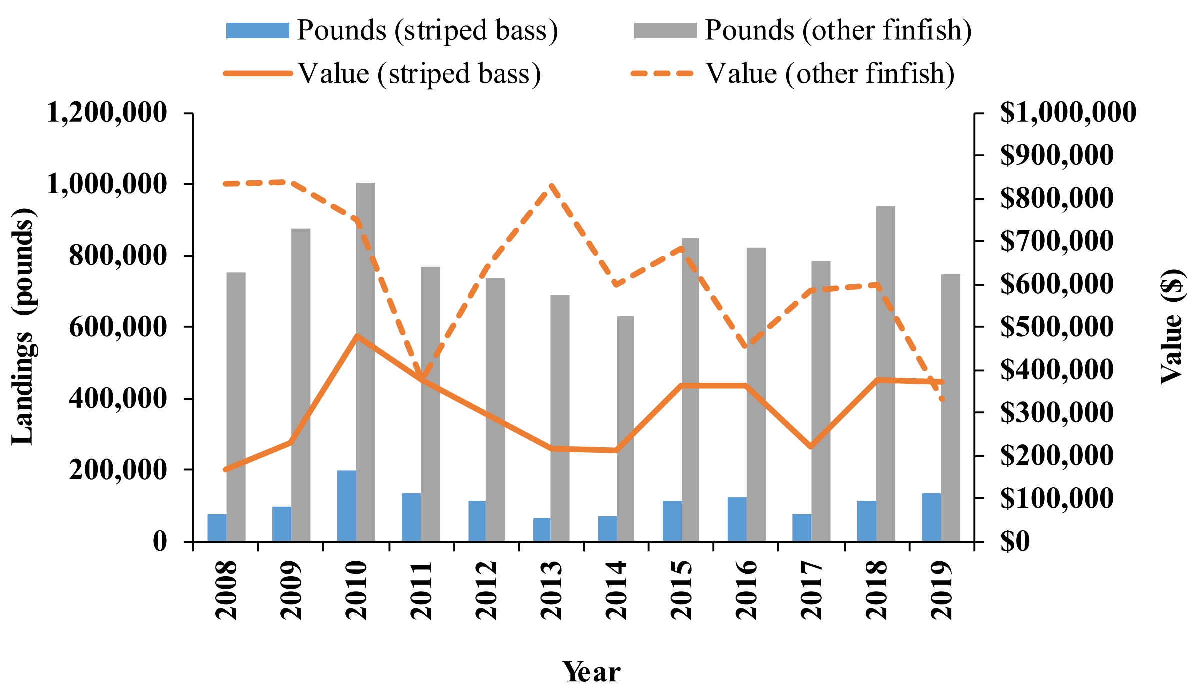


Figure 11. Annual commercial striped bass effort and ex-vessel value data for the ASMA, 2008–2019.

From 2008 to 2019 striped bass landings in the ASMA averaged 110,691 pounds (Table 4). During the same period harvest of all other species during trips which had striped bass as bycatch in the ASMA averaged 799,570 pounds (Table 5). Dockside value of other species landed in nets that also caught striped bass varies annually although the highest value species are often a mixture of catfishes, American shad, white perch (*M. Americana*), striped mullet (*M. cephalus*), spotted seatrout (*Cynoscion nebulosus*), and southern flounder.

As the total value of striped bass and other products harvested annually in the ASMA is significantly greater, so are the economic impacts to the state (Tables 4 and 5). Annual sales impacts of striped bass harvest average over $1 million annually, with the impacts from the harvest of other species valued between $1 million and nearly $4 million. In general, these estimates demonstrate that the ASMA striped bass commercial fishery produces a greater overall economic impact to the state than in the CSMA.

Table 4. Annual commercial striped bass effort data and estimates of annual economic impact to the state of North Carolina from striped bass harvest for the ASMA, 2008–2019.

| Year | Pounds Landed | Ex-Vessel Value | Total Participants | Total Trips | Job Impacts | Income Impacts | Value-added Impacts | Sales Impacts |
|---|---|---|---|---|---|---|---|---|
| 2008 | 74,921 | $167,750 | 278 | 2,857 | 287 | $311,255 | $583,523 | $756,264 |
| 2009 | 95,794 | $231,914 | 279 | 3,495 | 291 | $430,176 | $813,040 | $1,033,704 |
| 2010 | 199,829 | $479,648 | 327 | 6,116 | 353 | $847,691 | $1,586,334 | $2,043,151 |
| 2011 | 136,266 | $378,577 | 276 | 4,212 | 296 | $671,721 | $1,256,856 | $1,618,695 |
| 2012 | 115,605 | $298,162 | 264 | 3,612 | 280 | $524,276 | $978,808 | $1,258,901 |
| 2013 | 68,338 | $218,662 | 268 | 2,864 | 280 | $372,105 | $692,894 | $893,139 |
| 2014 | 70,989 | $214,143 | 236 | 2,834 | 248 | $359,952 | $668,554 | $864,931 |
| 2015 | 114,488 | $365,505 | 237 | 4,043 | 257 | $633,013 | $1,183,400 | $1,515,359 |
| 2016 | 123,111 | $362,759 | 197 | 4,245 | 215 | $633,119 | $1,177,209 | $1,477,691 |
| 2017 | 75,991 | $222,854 | 178 | 2,717 | 189 | $374,107 | $696,497 | $887,232 |
| 2018 | 116,144 | $377,668 | 193 | 3,621 | 215 | $683,207 | $1,239,287 | $1,614,420 |
| 2019 | 136,820 | $370,278 | 192 | 3,309 | 212 | $636,930 | $1,167,901 | $1,507,707 |
| Average | 110,691 | $307,327 | 244 | 3,660 | 260 | $539,796 | $1,003,692 | $1,289,266 |

Table 5. Annual effort data and estimates of annual economic impact to the state of North Carolina from harvest of all other species caught during trips when striped bass landings occurred in the ASMA, 2008–2019.

| Year | Pounds Landed | Ex-Vessel Value | Total Participants | Total Trips | Job Impacts | Income Impacts | Value-added Impacts | Sales Impacts |
|---|---|---|---|---|---|---|---|---|
| 2008 | 752,788 | $833,879 | 271 | 2,826 | 317 | $1,547,237 | $2,900,673 | $3,759,363 |
| 2009 | 875,110 | $838,842 | 276 | 3,423 | 321 | $1,555,961 | $2,940,795 | $3,738,946 |
| 2010 | 1,004,196 | $751,024 | 314 | 5,896 | 354 | $1,327,298 | $2,483,852 | $3,199,126 |
| 2011 | 769,786 | $376,144 | 262 | 4,012 | 282 | $667,404 | $1,248,778 | $1,608,292 |
| 2012 | 734,894 | $639,535 | 260 | 3,536 | 294 | $1,124,534 | $2,099,472 | $2,700,252 |
| 2013 | 690,471 | $828,539 | 265 | 2,840 | 310 | $1,409,953 | $2,625,466 | $3,384,216 |
| 2014 | 628,430 | $598,214 | 236 | 2,818 | 268 | $1,005,535 | $1,867,623 | $2,416,208 |
| 2015 | 847,805 | $682,205 | 236 | 3,958 | 273 | $1,181,502 | $2,208,785 | $2,828,378 |
| 2016 | 823,328 | $453,967 | 194 | 4,217 | 217 | $792,302 | $1,473,192 | $1,849,224 |
| 2017 | 784,689 | $587,458 | 177 | 2,712 | 207 | $986,166 | $1,836,006 | $2,338,796 |
| 2018 | 937,616 | $599,714 | 193 | 3,590 | 228 | $1,084,890 | $1,967,910 | $2,563,599 |
| 2019 | 745,726 | $333,321 | 192 | 3,295 | 210 | $573,358 | $1,051,334 | $1,357,223 |
| Average | 799,570 | $626,904 | 240 | 3,594 | 273 | $1,104,678 | $2,058,657 | $2,645,302 |

Beyond the high-level relationship between commercial striped bass effort and statewide economic impacts, there is also a range of smaller-scale factors in this fishery that could affect its overall contribution to the state economy. A notable example is the difference in management between the CSMA and ASMA. Historically, the CSMA was allocated a smaller striped bass TAL and operated over a shorter season than the ASMA. Additionally, The ASMA striped bass fishery is regulated under a bycatch requirement, in which striped bass cannot be harvested unless it is with other finfish species.

While the exact economic costs and benefits of these differences in regulations cannot be quantified, it is likely the overall economic impact differs greatly between management areas.

CSMA

Prior to the 2019 closure, striped bass commercial effort in the CSMA was low. Roughly 100 participants engaged in less than 1,000 striped bass trips annually (Table 6), with the total harvest never exceeding 30,000 pounds or $85,000 (Table 6; Figure 12). Because of the TAL, striped bass harvest was consistent year-over-year except for 2008, which produced notably low striped bass landings. Landings of other species from the striped bass fishery are more variable than striped bass landings. Although landings of other species from striped bass trips generally produced a larger total amount of product, these species generally sold for lower overall prices. As a result, despite higher landings, annual ex-vessel values of other species are comparable to striped bass.

Table 6. Annual commercial striped bass effort data and estimates of annual economic impact to the state of North Carolina from striped bass harvest for the CSMA, 2008–2019. Commercial and recreational harvest of striped bass was closed in the CSMA in March of 2019, with no observed effort for all of 2019.

| Year | Pounds Landed | Ex-Vessel Value | Total Participants | Total Trips | Job Impacts | Income Impacts | Value-added Impacts | Sales Impacts |
|---|---|---|---|---|---|---|---|---|
| 2008 | 10,115 | $20,906 | 110 | 706 | 111 | $38,790 | $72,722 | $94,249 |
| 2009 | 24,847 | $56,616 | 103 | 915 | 106 | $105,016 | $198,482 | $252,352 |
| 2010 | 23,888 | $55,678 | 103 | 680 | 106 | $98,401 | $184,143 | $237,170 |
| 2011 | 28,054 | $72,452 | 80 | 661 | 84 | $128,553 | $240,536 | $309,785 |
| 2012 | 22,725 | $51,958 | 69 | 571 | 72 | $91,360 | $170,567 | $219,376 |
| 2013 | 28,597 | $84,824 | 97 | 784 | 102 | $144,348 | $268,790 | $346,469 |
| 2014 | 25,245 | $69,098 | 125 | 826 | 129 | $116,147 | $215,725 | $279,091 |
| 2015 | 27,336 | $84,703 | 104 | 809 | 109 | $146,697 | $274,246 | $351,175 |
| 2016 | 23,041 | $69,271 | 94 | 685 | 98 | $120,898 | $224,795 | $201,506 |
| 2017 | 23,018 | $66,033 | 100 | 808 | 103 | $110,850 | $206,376 | $237,914 |
| 2018 | 19,903 | $61,477 | 90 | 776 | 94 | $111,213 | $201,732 | $233,959 |
| 2019 | | | | | | | | |
| Average | 23,343 | $63,001 | 98 | 747 | 101 | $110,207 | $205,283 | $251,186 |

When effort data are extended to generate state-wide economic impacts, the same patterns hold. The striped bass fishery produces roughly a quarter of one million dollars in sales impacts annually (Table 6). As the annual ex-vessel values and number of participants are comparable with other species harvested during striped bass trips, the economic impact of striped bass and other species is similar, but the economic impact of alternative species varies more year to year (Table 7).

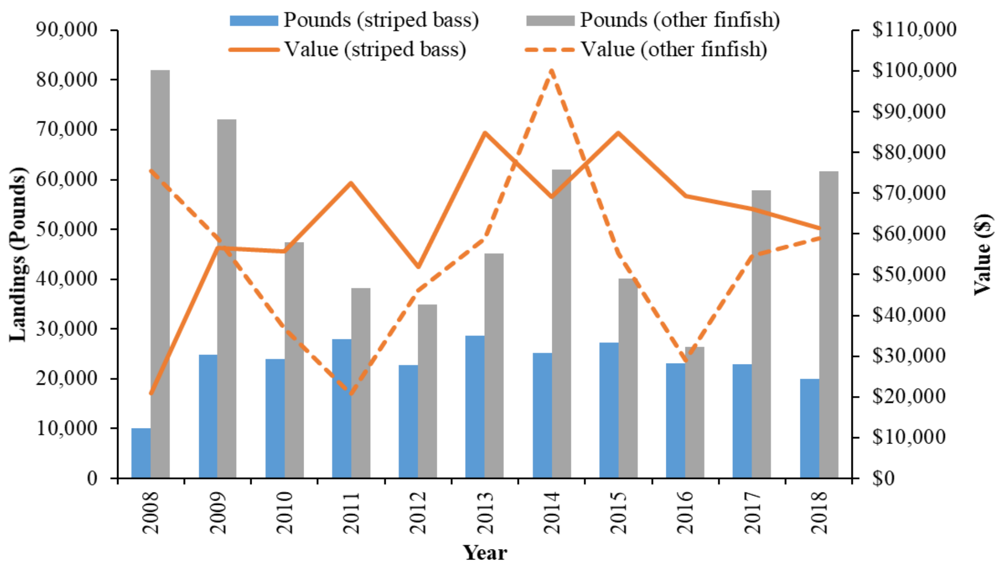


Figure 12. Annual Striped Bass effort and ex-vessel value data for the CSMA, 2008–2019.

Table 7. Annual effort data and estimates of annual economic impact to the state of North Carolina from harvest of all other species caught during trips when striped bass landings occurred in the CSMA, 2008–2019. Commercial and recreational harvest of striped bass was closed in the CSMA in March of 2019, with no observed effort for all of 2019.

| Year | Pounds Landed | Ex- Vessel Value | Total Participants | Total Trips | Job Impacts | Income Impacts | Value-added Impacts | Sales Impacts |
|---|---|---|---|---|---|---|---|---|
| 2008 | 81,922 | $75,381 | 109 | 664 | 113 | $139,867 | $262,214 | $339,839 |
| 2009 | 72,125 | $58,882 | 90 | 824 | 93 | $109,221 | $206,429 | $262,455 |
| 2010 | 47,382 | $36,904 | 97 | 521 | 99 | $65,220 | $122,051 | $157,198 |
| 2011 | 38,189 | $20,637 | 71 | 472 | 72 | $36,617 | $68,514 | $88,239 |
| 2012 | 34,855 | $46,172 | 60 | 429 | 62 | $81,186 | $151,573 | $194,947 |
| 2013 | 45,107 | $58,914 | 91 | 668 | 94 | $100,255 | $186,685 | $240,637 |
| 2014 | 62,013 | $100,115 | 114 | 504 | 119 | $168,283 | $312,559 | $404,368 |
| 2015 | 40,056 | $55,244 | 89 | 574 | 92 | $95,677 | $178,866 | $229,039 |
| 2016 | 26,374 | $28,877 | 85 | 548 | 86 | $50,398 | $93,710 | $117,629 |
| 2017 | 57,812 | $54,695 | 105 | 712 | 108 | $91,817 | $170,941 | $197,062 |
| 2018 | 61,723 | $58,959 | 97 | 688 | 100 | $106,658 | $193,469 | $224,373 |
| 2019 | | | | | | | | |
| Average | 51,596 | $54,071 | 92 | 600 | 94 | $95,018 | $177,001 | $223,253 |

Recreational

Creel surveys provide data on recreational angler effort and expenditures to measure state-wide economic impacts of the fishery. The creel surveys collect information on target species, angler hours, and expenditures across six categories: lodging, food, ice, bait and tackle, vehicle fuel, and boat fuel. Combined, these data allow for an assessment of direct trip expenditures, as well as spillover impacts using IMPLAN statistical software.

ASMA

Annual ASMA effort estimates are combined with per-trip expenditure estimates from the CSMA creel survey, as these values are not tracked in the ASMA. Trip expenditure estimates are only provided using DMF survey data, combined with ASMA effort data. The ASMA maintains the same definition of a striped bass trip as the CSMA, in which striped bass is the angler's primary target, secondary target, or was caught.

In terms of trips and angling hours, the ASMA has the lowest striped bass angling effort among the three management areas (Table 8). Generally, the ASMA produces the lowest overall economic impact to the state of these management areas. As with the RRMA, this analysis extrapolates impact values from CSMA expenditure estimates and does not present impact estimates that are fully reflective of the ASMA system.

Table 8. Annual recreational striped bass effort estimates and state-level economic impacts of recreational striped bass angling in the Albemarle Sound Management Area. For this analysis, a striped bass trip is as a primary or secondary directed trip for striped bass, or a trip where striped bass was caught.

| Year | Estimated Total ASMA Striped Bass Trips | Estimated Total ASMA Striped Bass Angling Hours | Estimated Sales Impacts | Estimated Income Impacts | Estimated Value-Added Impacts | Estimated Job Impacts | Total Expenditures Using DMF Inshore Vessel Trip Costs |
|---|---|---|---|---|---|---|---|
| 2008 | 11,793 | 72,673 | $378,011 | $135,019 | $204,838 | 3.44 | $1,834,428 |
| 2009 | 11,326 | 72,021 | $421,153 | $152,375 | $299,096 | 3.91 | $1,755,517 |
| 2010 | 9,660 | 66,893 | $1,466,355 | $551,802 | $802,439 | 11.82 | $1,521,849 |
| 2011 | 13,114 | 85,325 | $1,067,875 | $377,870 | $601,856 | 9.15 | $2,131,210 |
| 2012 | 14,490 | 102,787 | $836,596 | $291,843 | $477,153 | 6.99 | $2,403,561 |
| 2013 | 7,053 | 50,643 | $494,936 | $172,553 | $283,706 | 4.1 | $1,187,069 |
| 2014 | 7,264 | 40,478 | $830,858 | $288,344 | $476,395 | 6.81 | $1,242,414 |
| 2015 | 11,132 | 75,009 | $937,967 | $326,264 | $535,776 | 7.72 | $1,906,246 |
| 2016 | 7,023 | 42,276 | $312,791 | $109,274 | $176,394 | 2.63 | $1,217,791 |
| 2017 | 7,658 | 41,371 | $1,098,641 | $382,203 | $632,422 | 9 | $1,356,190 |
| 2018 | 9,057 | 34,764 | $510,289 | $177,879 | $289,450 | 4.22 | $1,643,121 |
| 2019 | 19,864 | 61,645 | $1,528,169 | $532,055 | $873,914 | 12.63 | $3,475,633 |
| Average | 10,786 | 62,157 | $823,637 | $291,457 | $471,120 | 6.87 | $1,806,252 |

While angler effort, participation, and overall expenditures drive the economic impact of recreational estuarine striped bass angling in the state, the valuation can also be affected by smaller-scale factors specific to the fishery. Several social, regulatory, or environmental factors could affect the total economic impact of any fishery, though these are often difficult to quantify due to lack of data and clear causality. A notable component that may impact expenditures, and therefore economic impacts to the state, across management areas is variability in slot limits.

Each management area operates under different recreational harvest limits, including season length and size restrictions. For example, the ASMA is open for harvest from October to April with an 18-inch minimum TL size limit and the RRMA allows harvest from March to April and includes an 18-inch minimum TL size limit and a 22–27-inch TL no harvest protective slot. Varying restrictions could affect angler expenditures and total economic impact across management areas. Longer harvest seasons with less restrictive size limits could increase angler effort and expenditures in the ASMA compared to the RRMA, and likely lead to greater economic impacts to the recreational fishing industry.

RRMA

The RRMA creel survey does not collect reliable angler expenditure data annually, although Dockendorf et al. 2015 does provide an estimate of angler expenditures for the 2015 fishing year. Therefore, this analysis incorporates CSMA angler expenditure data instead, using the assumption that angler expenditures would be comparable across water bodies annually. Given that on-site expenditure values are not available, the only annual total expenditure estimates are those using RRMA effort data and DMF recreational angler expenditure survey data. In addition, the RRMA creel survey does not specifically include secondary targeting as part of its directed trip definition, but all striped bass trips, whether anglers target striped bass by itself or in combination with other species, are included in the estimates.

The state-wide economic impacts of the RRMA recreational fishery are higher than the ASMA and the CSMA because of higher overall effort and less year-to-year variability (Table 9). However, while it is assumed that CSMA expenditure values are a valid proxy for the RRMA, annual variability of the CSMA values impact the RRMA estimates. Therefore, while these are valid estimates of overall impact, they may not be perfectly reflective as they rely on indirect expenditure data.

CSMA

Recreational striped bass effort in the CSMA has generally increased over time, with corresponding increases in state-wide economic impacts. However, striped bass effort in 2019 dropped to its lowest levels in 10 years, with corresponding decreases in economic impact to the state (Table 10). The large increase in value of the fishery in 2017 is most directly attributed to higher lodging estimates from that year’s creel survey, which can significantly impact model outputs.

Table 9. Annual recreational striped bass effort estimates and state-level economic impacts of recreational striped bass angling in the Roanoke River Management Area. For this analysis, a striped bass trip is as a directed trip for striped bass or a trip where striped bass was caught.

| Year | Estimated Total RRMA Striped Bass Trips | Estimated Total RRMA Striped Bass Angling Hours | Estimated Sales Impacts | Estimated Income Impacts | Estimated Value-Added Impacts | Estimated Job Impacts | Total Expenditures Using DMF Inshore Vessel Trip Costs |
|---|---|---|---|---|---|---|---|
| 2008 | 23,286 | 110,608 | $746,409 | $266,604 | $404,467 | 6.79 | $3,622,190 |
| 2009 | 25,405 | 120,675 | $944,680 | $341,790 | $513,880 | 8.77 | $3,937,746 |
| 2010 | 24,347 | 125,495 | $3,695,792 | $1,390,759 | $2,022,463 | 29.79 | $3,835,657 |
| 2011 | 27,311 | 122,876 | $2,223,940 | $786,945 | $1,253,414 | 19.16 | $4,438,423 |
| 2012 | 27,151 | 119,917 | $1,567,592 | $546,849 | $894,076 | 13.1 | $4,503,733 |
| 2013 | 19,539 | 112,814 | $1,371,146 | $478,033 | $785,967 | 11.35 | $3,288,550 |
| 2014 | 18,932 | 97,798 | $2,165,449 | $751,506 | $1,241,620 | 17.74 | $3,238,077 |
| 2015 | 25,034 | 123,648 | $2,109,331 | $733,712 | $1,204,871 | 17.36 | $4,286,828 |
| 2016 | 27,123 | 140,423 | $1,208,006 | $422,018 | $681,239 | 10.14 | $4,703,140 |
| 2017 | 21,004 | 109,011 | $3,013,303 | $1,048,289 | $1,740,066 | 24.67 | $3,719,693 |
| 2018 | 20,742 | 109,947 | $1,168,648 | $407,372 | $662,889 | 9.67 | $3,763,013 |
| 2019 | 20,633 | 99,259 | $1,674,227 | $582,907 | $957,440 | 13.84 | $3,811,110 |
| Average | 23,376 | 116,039 | $1,824,044 | $646,399 | $1,030,199 | 15.20 | $3,929,013 |

Table 10. Annual recreational striped bass effort estimates and state-level economic impacts of recreational striped bass angling in the Central-Southern Management Area. For this analysis, a striped bass trip is defined as any trip in which striped bass was an angler's primary target species, secondary target, or was caught.

| Year | Estimated Total CSMA Striped Bass Trips | Estimated Total CMSA Striped Bass Angling Hours | Estimated Sales Impacts | Estimated Income Impacts | Estimated Value-Added Impacts | Estimated Job Impacts |
|---|---|---|---|---|---|---|
| 2008 | 6,620 | 28,415 | $212,196 | $75,793 | $114,986 | 1.93 |
| 2009 | 5,640 | 26,607 | $209,725 | $75,879 | $114,085 | 1.95 |
| 2010 | 6,889 | 25,355 | $995,635 | $374,666 | $544,846 | 8.03 |
| 2011 | 12,608 | 51,540 | $1,026,671 | $363,289 | $578,633 | 8.8 |
| 2012 | 18,338 | 71,964 | $1,058,786 | $369,354 | $603,879 | 8.85 |
| 2013 | 20,394 | 86,918 | $1,431,103 | $498,937 | $820,335 | 11.85 |
| 2014 | 15,682 | 70,316 | $1,793,659 | $622,479 | $1,028,444 | 14.69 |
| 2015 | 18,159 | 79,398 | $1,530,041 | $532,211 | $873,974 | 12.59 |
| 2016 | 23,675 | 110,453 | $1,054,420 | $368,363 | $594,627 | 8.85 |
| 2017 | 26,125 | 119,680 | $3,748,044 | $1,303,895 | $2,164,350 | 30.69 |
| 2018 | 16,394 | 69,917 | $923,651 | $321,970 | $523,920 | 7.64 |
| 2019 | 8,820 | 40,580 | $715,654 | $249,466 | $409,261 | 5.92 |
| Average | 14,945 | 65,095 | $1,224,965 | $429,692 | $697,612 | 10.15 |

## ECOSYSTEM PROTECTION AND IMPACTS

As an anadromous species, one that migrates from the ocean or estuary upriver to spawn, habitat requirements for striped bass are specific to life stage. Striped bass are commonly found in habitats identified by the NC Coastal Habitat Protection Plan (CHPP) as priority habitats. These include the water column, wetlands, submerged aquatic vegetation (SAV), soft bottom, hard bottom, and shell bottom (NCDEQ 2016). These habitats provide appropriate conditions necessary for different life stages of striped bass.

### COASTAL HABITAT PROTECTION PLAN

The Fisheries Reform Act statutes require that a CHPP be drafted by the DEQ and reviewed every five years (G.S. 143B 279.8). The CHPP is intended as a resource and guide compiled by DEQ staff to assist the department, MFC, NC Environmental Management Commission (EMC), and NC Coastal Resources Commission (CRC) for the protection and enhancement of fishery habitats of NC. The CHPP ensures consistent actions between commissions as well as their supporting DEQ divisions. The three commissions adopt rules to implement the CHPP in accordance with Chapter 150B of the General Statutes. Habitat recommendations related to fishery management can be addressed directly by the MFC. Habitat recommendations not under MFC authority (e.g., water quality management, shoreline development) can be addressed by the EMC and the CRC through the CHPP process.

The CHPP Source Document summarizes the economic and ecological value of coastal habitats to NC, their status, and the potential threats to their sustainability (NCDEQ 2016). The Coastal Habitat Protection Plans and Source Document can be viewed and downloaded from: http://portal.ncdenr.org/web/mf/habitat/chpp/07-2020-chpp.

The CHPP completed the five-year review, producing the 2021 Amendment. The Amendment includes two priority issues, "Submerged Aquatic Vegetation (SAV) Protection and Restoration, with Focus on Water Quality Improvements" and "Wetland Protection and Restoration with a Focus on Nature-based Methods", which may have implications for striped bass in NC. The presence of SAV is often used as a bio-indicator of water quality, as it is sensitive to specific conditions. One goal addressed in the CHPP is to modify water quality criteria to improve light penetration to the seafloor, one of the most important factors affecting SAV growth. Water quality improvements that benefit SAV will also benefit the species that use SAV habitat, like striped bass. As noted below, wetlands provide striped bass with a variety of habitat functions. The wetlands issue paper provides significant justification regarding nature-based methods of restoration and shoreline protection. Therefore, improvements to wetlands through the recommendations of the wetlands paper can have direct benefits to striped bass by increasing available habitat that can be used by striped bass.

### THREATS AND ALTERATIONS

Striped bass use nearly all the environmentally and economically valuable habitat types that are listed in the 2016 CHPP during one or more life stages. Each habitat type provides environmental conditions critical to the enhancement and sustainability of striped bass populations in NC. Water quality impacts the habitats required by striped bass at various life stages (i.e., wetlands, submerged aquatic vegetation, shell bottom, and soft bottom). The primary human threats to these habitats include coastal development, industrial/wastewater discharges, and runoff. These threats often alter water chemistry, causing shifts in salinity, temperature, dissolved oxygen (DO), suspended solids, nutrients, pH, velocity, depth, flow, and clarity.

Wetlands, submerged aquatic vegetation, shell bottom, and soft bottom are of particular importance for striped bass as they function as nursery habitat, refuge, foraging grounds, and movement corridors. As anadromous fish, striped bass migrate from one system to another. Therefore, barriers to migration have the potential to significantly affect striped bass populations. Dams across rivers can cause segmentation in waterways and prevent striped bass from accessing historical spawning grounds. Additionally, coastal development that alters or removes migration corridors can further restrict the quantity and quality of habitat. The placement of large structures, such as breakwaters, groins, and jetties, can cause alterations in water flow patterns. For larval striped bass, this can result in altered migration patterns and force larval fish into areas where they are susceptible to predation.

Potential environmental influences on the striped bass stock include both dissolved oxygen and blue-green algae blooms. Hurricanes, increases in rainwater runoff, and blue-green algae blooms can lead to decreases in DO that can increase stress on fish and lead to fish kills (fish kills can be reported to the hotline at 1-800-858-0368 or online). For additional information on blue-green algae please see: the DEQ Algal Blooms Page, Albemarle-Pamlico National Estuarine Partnership Blue-green Algae Fact Sheet, and the North Carolina CHPP.

Another area of potential influence on the striped bass stock is the prevalence of the non-native blue catfish and flathead catfish (*Pylodictis olivaris*). Both species have been present in the Tar-Pamlico, Neuse, and Cape Fear river basins for decades, and while flathead catfish are not currently found in the Albemarle Sound basin, the population of blue catfish in the Roanoke River and Albemarle Sound and tributaries has increased dramatically in recent years (Darsee et al. 2019; NCDMF 2019). Striped bass made up only a small fraction of the overall diet of blue catfish in the James River of Chesapeake Bay (Schmitt et al. 2016), but non-native catfishes including flathead catfish and blue catfish were suggested to play a large role in structuring native fish communities and to delay recovery of anadromous fish populations in the Cape Fear River (Belkoski et al. 2021). Predation by non-native catfishes could potentially impact recruitment of striped bass directly or could influence food resources for striped bass through competition (e.g., Pine et al. 2005). The WRC published the 2019 Catfish Management Plan which details goals, strategies, and recommendations for developing and implementing management strategies for invasive catfish. Additional information about blue catfish in NC can be found in the APNEP Aquatic Nuisance Species Management Plan.

Manmade barriers also act as impediments to spawning for striped bass stocks in NC. On the Roanoke River spawning migrations have been impeded since the construction of the initial dam at Roanoke Rapids around 1900 (NMFS and USFWS 2016). In the CSMA, dams on the Tar-Pamlico, Neuse, and Cape Fear rivers obstruct migration and alter the flow regime. The Cape Fear River may provide the best opportunity for remediation of migration impediments. The U.S. Army Corps of Engineers (USACE) owns three locks and dams on the Cape Fear River that are currently not operational. These locks and dams have severely reduced access to historic spawning areas near the fall line. Various unsuccessful forms of passage have been attempted to restore spawning stocks, but recent alterations to fish passage may allow higher passage efficiency over the first lock and dam. Further details regarding fish passage on the Cape Fear River can be found in the Cape Fear River Sustainable Harvest Issue Paper Appendix 4.

FLOW

Striped bass are broadcast spawners, producing eggs that must remain in the water column to develop and hatch (Bain and Bain 1982). Appropriate river flow is critical before and after the spawning period (Hassler et al. 1981) and is the most important factor influencing year class strength. Striped bass require relatively high streamflow to encourage upstream migration prior to the peak of spawning, whereas low to moderate flows are necessary for spawning success and downstream transport of early life stages. Extremely low flows will result in eggs settling on the river bottom where they can be covered in sediment and die (Albrecht 1964), and extended periods of high water from May to June negatively impact reproduction by stranding eggs and larvae in the floodplain where dissolved oxygen is low. Recruitment failures in the ASMA since 2001 are thought to be due to extended spring flooding events.

ASMA/RRMA

Streamflow in the lower Roanoke River is regulated by John H. Kerr Dam, which is operated by the USACE for flood control, hydropower, and recreational uses. Two additional hydropower dams owned and operated by Dominion Energy, Gaston Dam and Roanoke Rapids Dam, are located downstream of Kerr Dam and further regulate streamflow in the Roanoke River. Operation of Kerr Dam is guided by a Water Control Plan (USACE 2016), which is the result of years of environmental studies and collaboration with numerous resource agencies and stakeholders. Gaston and Roanoke Rapids dams are operated by Dominion under conditions of a license received from the Federal Energy Regulatory Commission in 2005 (FERC 2005). Both the USACE Water Control Plan and Dominion's FERC license stipulate flow regimes and restrictions intended to facilitate successful striped bass spawning in the Roanoke River. Staff from the WRC and DMF as well as other resource agencies including DEQ and U.S. Fish and Wildlife Service (USFWS) advise the USACE and Dominion Energy on a weekly basis during the striped bass spawning season to inform streamflow decisions within the constraints of the Water Control Plan and FERC license.

Appropriate flow regimes for successful striped bass reproduction in the Roanoke River have been a concern since Kerr Dam was constructed in 1953. Adequate minimum flows were first addressed in 1957 when the USACE agreed to a 2-feet increase in the guide curve to provide sufficient flows during the striped bass spawning season. The increased storage and changes to the guide curve during the spring spawning season are maintained in the current version of the Water Control Plan. The USACE along with federal and state resource agencies developed and tested a recommended flow regime during the striped bass spawning season beginning in 1989 to identify beneficial flows for successful reproduction. After testing the flow regime for four years, the USACE implemented the negotiated flow regime (Table 11), which specifies high flows in April and low to moderate flows in May and June, on a permanent basis in 1995, and they incorporated the same spawning flow targets in the 2016 revision of their Water Control Plan. Additionally, Dominion is prohibited from conducting hydropeaking operations (large daily variations in streamflow) during the striped bass spawning in April through June 15. This FERC license requirement dictates that Dominion consistently adheres to the USACE weekly flow declaration from Kerr Reservoir. Prior to each spawning season, USACE, WRC, and USFWS staff discuss an overall plan of operation based on Water Management forecasts of available storage and inflows during the upcoming spawning season, and the USACE attempts to meet the weekly target flow regime depending on water availability or the need for flood control.

Table 11. U.S. Army Corps of Engineers guidelines for providing Roanoke River striped bass spawning flows from John H. Kerr Dam.

| Dates | Lower Target Flow (cfs) | Median Target Flow (cfs) | Upper Target Flow (cfs) |
|---|---|---|---|
| April 1–15 | 6,600 | 8,500 | 13,700 |
| April 16–30 | 5,800 | 7,800 | 11,000 |
| May 1–15 | 4,700 | 6,500 | 9,500 |
| May 16–31 | 4,400 | 5,900 | 9,500 |
| June 1–15 | 4,000 | 5,300 | 9,500 |

The negotiated spawning flow regime strives to maintain Roanoke River flow rates within the range of 6,000–8,000 $ft^3/s$, which was identified as optimum levels for striped bass spawning by Hassler (1981) and Rulifson and Manooch (1990). However, recent analysis indicates that streamflow conditions within the optimum ranges did not always produce strong year classes; rather, the analysis of year-class strength and flows since 1955 showed that poor year classes were produced when flows were above 20,000 $ft^3/s$ during May but did not find a relationship between target-level streamflow and successful recruitment (NCDMF 2021). Flood control is the primary objective of John H. Kerr Dam (USACE 2016), and the reservoir is designed to temporarily store flood waters until they can be released later at the maximum rate possible without causing significant damaging flows downstream. When heavy rainfall causes high inflows into the reservoir, the USACE enters into flood control operations and flows will typically exceed the negotiated flow regime. The Water Control Plan allows for flood releases up to 35,000 $ft^3/s$ when lake levels are between 300 and 320 ft (NGVD29), but flows are generally based on weekly average inflows into the reservoir. At higher lake elevations, flood releases can exceed 35,000 $ft^3/s$ to prevent damage to the dam itself, but, to date, flows from Kerr Dam have never exceeded 35,000 $ft^3/s$. Between 2016 and 2020, monthly reservoir inflows during the spawning timeframe were above average and some months recorded some of the highest inflows on record (Figure 13). These high-inflow years caused the need for high streamflow and flood control operations during the striped bass spawning season (Tony Young, USACE, personal communication), which has, in turn, resulted in reduced recruitment for the Albemarle-Roanoke striped bass stock.

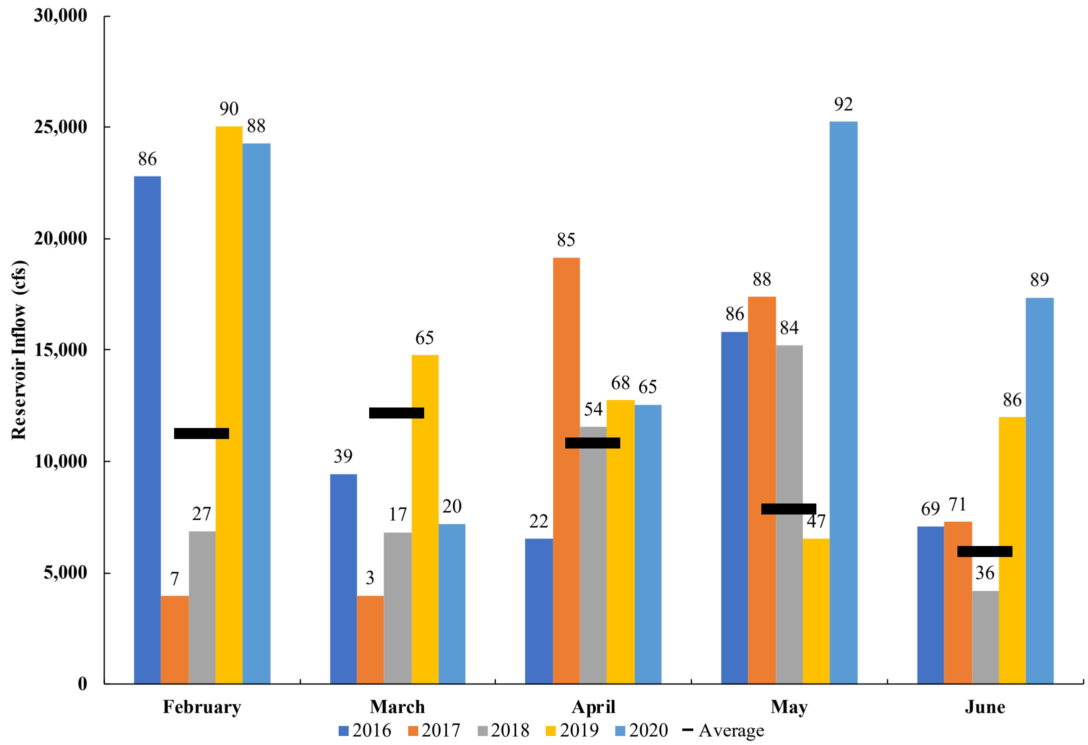


Figure 13. Monthly inflow data for John H. Kerr Reservoir on the Roanoke River during February–June of 2016–2020. Data were provided by USACE staff. Numbers of the columns provide the rank for 92 years of data. A rank of 1 is driest and rank of 92 is wettest.

CSMA

The rivers in the CSMA are less regulated than the Roanoke River, and specific, optimal flow requirements are unknown. The Tar-Pamlico River is impounded by Rocky Mount Mills Dam (rm 124) and Tar River Reservoir Dam (rm 130). Rocky Mount Mills Dam is a small, historic hydropower facility that is not currently regulated by FERC, and Tar River Reservoir is a drinking water reservoir. Both dams are run-of-river operations, and neither has enough storage capacity to provide beneficial spawning flows for striped bass. Rocky Mount Mills Dam is an impediment to anadromous fish migrations, but it is unlikely that striped bass would benefit from passage beyond the dam as the typical spawning habitat is downstream. However, regulated flows, such as hydropeaking, could reduce striped bass spawning success. Because the mill dam lacks FERC oversite, continued communication between resource agencies and the dam operators is critical to maintain striped bass spawning habitat on the upper Tar-Pamlico River. The Neuse River has benefitted from several dam removals over the last few decades, including Quaker Neck Dam (rm 140) in 1998 and Milburnie Dam (rm 218) in 2017. Falls of the Neuse Dam at rm 236 is now the first impediment to striped bass migration. Falls Dam is operated by the USACE for flood control and drinking water supply. There are no formal spawning flow agreements for Falls Dam, but the USACE consults with resource agency staff weekly regarding water releases on the Neuse River and tries to provide increased streamflow when water is available. The Cape Fear River is heavily impacted by three USACE locks and dams at rm 60, 93, and 116. Additionally, Buckhorn Dam is a run-of-river low-head dam at rm 196, and B. Everett Jordan Dam, operated by USACE, is operated for flood control and a drinking water reservoir located on the Haw River upstream of the beginning of the Cape Fear River. There are no formal striped bass spawning streamflow agreements for B. Everett Jordan Dam; however, beginning in 2020, the USACE modified reservoir release patterns into the Cape Fear River during the peak migratory season in an attempt to submerge all three locks and dams and enhance upstream passage of striped bass and other anadromous fishes to historic spawning grounds.

Egg densities and buoyancy in different systems have been shown to be suited for the predominant flow rate of that river (Bergey et al. 2003). Chesapeake Bay striped bass eggs are lighter and maintain their position in the water column of calm waters, whereas Roanoke River striped bass eggs are heavier and maintain their water column position in a high energy system (Bergey et al. 2003). A recent study indicated that, egg size and buoyancy from the Tar-Pamlico and Neuse rivers appear to be adapted to their specific river systems based on salinity alone (Kowalchyk 2020; Reading et al. 2020). Striped bass from the Tar-Pamlico and Neuse rivers have smaller and heavier eggs compared to other rivers in NC and may require higher flow rates to remain suspended in the water column (Kowalchyk 2020, Reading et al. 2020). Because low streamflow and shallow water may lead to eggs contacting the bottom (Bain and Bain 1982), striped bass spawning success in CSMA rivers may be limited to years when rainfall produces enough streamflow to keep eggs suspended, provided spawning stock biomass is adequate.

## RESEARCH NEEDS

The research recommendations listed below are offered by the division to improve future management strategies of the estuarine striped bass fishery. They are considered high priority as they will help to better understand the stiped bass fishery and meet the goal and objectives of the FMP. A comprehensive list of research recommendations is provided in the annual FMP Review and Research Priorities documents available on the Fishery Management Plans website.

- Identify environmental factors (e.g., flow, salinity, predation, dissolved oxygen, algal blooms) affecting survival of striped bass eggs, larvae, and juveniles and investigate methods for incorporating environmental variables into stock assessment models.
- Refine discard mortality estimates for recreational and commercial fisheries by conducting delayed mortality studies to estimate discard losses for recreational and commercial gear during all seasons factoring in relationships between salinity, dissolved oxygen, and water temperature.
- Determine mixing rates between A-R and CSMA striped bass stocks to better inform stock assessments and management.
- Expand, modify, or develop fishery independent sampling programs to fully encompass all striped bass life stages (egg, larval, juvenile, and adult).
- Enhance recreational and commercial data collection to better characterize the magnitude and demographics (e.g., length, weight, age) of discards

## STRIPED BASS AMENDMENT 2 MANAGEMENT STRATEGY

**The NCMFC selected management options:**

APPENDIX 2: ACHIEVING SUSTAINABLE HARVEST FOR THE ALBEMARLE SOUND-ROANOKE RIVER STRIPED BASS STOCK

1. Manage for Sustainable Harvest through harvest restrictions
   A. Continue to use stock assessments and stock assessment projections to determine the TAL that achieves a sustainable harvest for the A-R stock
2. Management of striped bass harvest in the commercial fishery as a bycatch fishery
   A. Status quo: continue managing the ASMA striped bass fishery as a bycatch fishery
3. Accountability Measures to address TAL overages
   D. If the landings in any one of the management areas' three fisheries (RRMA recreational, ASMA recreational, and ASMA commercial) exceeds their allocated TAL in a calendar year, any landings in excess of their allocated TAL will be deducted from that fisheries' allocated TAL the next calendar year.
4. Size limits to expand the age structure of the stock
   C. In the ASMA, implement a harvest slot of a minimum size of 18-inches TL to not greater than 25 inches TL in the commercial and recreational sectors
   E. In the RRMA, maintain current harvest slot limit of a minimum size of 18-inches TL to not greater than 22-inches TL with no harvest allowed on fish greater than 22 inches.
5. Gear modifications and area closures to reduce striped bass discard mortality
   A. Status quo-continue to allow commercial harvest of striped bass with gill nets in joint and coastal waters of the ASMA and continue recreational harvest and catch-and-release fishing in the ASMA and RRMA, including striped bass spawning grounds in the Roanoke River. The requirement that from April 1 through June 30, only a single barbless hook or lure with single barbless hook (or hook with barb bent down) may be used in the inland waters of the Roanoke River upstream of U.S. Highway 258 Bridge will remain in effect.
   E. Implement a requirement to use non-offset barbless circle hooks when fishing with live or natural bait in the inland waters of the Roanoke River (upstream of Hwy 258 bridge) from May 1 through June 30
6. Adaptive Management

   Adaptive management for the A-R stock and fisheries in the ASMA and RRMA encompasses the following measures:

   - Use peer reviewed stock assessments and updates to recalculate the BRPs and/or TAL. Stock assessments will be updated at least once between benchmarks. Increases or decreases in the TAL will be implemented through a Revision to the Amendment. A harvest moratorium could be necessary if stock assessment results calculate a TAL that is too low to effectively manage, and/or the stock continues to experience spawning failures.
   - Use estimates of $F$ from stock assessments to compare to the $F$ BRP and if $F$ exceeds the $F_{Target}$ reduce the TAL to achieve the $F_{Target}$ in one year through a Revision to the Amendment.

- Ability to change daily possession limits in the commercial and recreational fisheries to keep landings below the TAL.
- Ability to open and close recreational harvest seasons and commercial harvest seasons and areas to keep landings below the TAL and reduce interactions with endangered species.
- Ability to require commercial and recreational gear modifications including, but not limited to, the use of barbless or circle hooks, area closures, yardage limits, gill net mesh size restrictions and setting requirements to reduce striped bass discards.

APPENDIX 3: ACHIEVING SUSTAINABLE HARVEST FOR THE TAR-PAMLICO AND NEUSE RIVERS STRIPED BASS STOCKS

1. Striped Bass Harvest
   A. Continue the no-possession measure in Supplement A to Amendment 1
2. Gear Restrictions/Limits
   A. Maintain gill net closure above the ferry lines and maintain the 3-foot tie-downs below the ferry lines
3. Adaptive Management

   - In 2025, review data through 2024 to determine if populations are self-sustaining and if sustainable harvest can be determined

In addition, the MFC included in its motion "*that the DMF study the effects of the gill net closure and reevaluate it at the next full amendment review. This research will be conducted, preferably within two years, and this closure be addressed based on that study*".

APPENDIX 4: ACHIEVING SUSTAINABLE HARVEST FOR THE CAPE FEAR RIVER STRIPED BASS STOCK

1. Striped Bass Harvest
   A. Status Quo: maintain Cape Fear River harvest moratorium
2. Adaptive Management

   - Continue YOY surveys and PBT analysis after the adoption of the FMP
   - If YOY surveys and/or PBT analysis suggest levels of natural reproduction have increased or decreased compared to what was observed up to the time of FMP adoption, then management measures may be re-evaluated using this new information and adjusted by proclamation using the authority granted to DMF and WRC directors. Rule changes or suspensions would be required to allow harvest.
   - Management measures which may be adjusted include means and methods, harvest area, as well as season, size and creel limit (as allowed for in rule).
   - Use of the DMF director's proclamation authority for adaptive management is contingent on evaluation of adaptive management measures by the Striped Bass Plan Development Team and consultation with the Finfish Advisory Committee.

## APPENDIX 5: THE USE OF HOOK AND LINE AS A COMMERCIAL GEAR IN THE ESTUARINE STRIPED BASS FISHERY

1. Hook and Line as a Commercial Gear

   A. Do not allow hook and line as a commercial gear in the estuarine striped bass fishery at this time.

2. Adaptive Management

- If hook and line is allowed for the commercial harvest of striped bass and NC TTP and Quota Monitoring data indicate the TAL will either be quickly exceeded or unable to be met during the potential striped bass season, then management measures may be re-evaluated and adjusted by the proclamation authority granted to the Fisheries Director (as is currently occurring under the existing management strategy).
- If hook and line is allowed for the commercial harvest of striped bass and Marine Patrol enforcement activity or License and Statistics data suggest significant amounts of unreported commercial striped bass catch is occurring, then additional tagging or reporting requirements may be developed and implemented.
- Management measures that may be adjusted include means and methods, harvest area, as well as season, size and limit.
- Implementation of adaptive management measures to enact additional increased tagging or reporting requirements is contingent on evaluation of these measures by the Striped Bass Plan Development Team and consultation with the Marine Fisheries Commission.

## APPENDICES

## APPENDIX 1: STRIPED BASS STOCKING IN COASTAL NORTH CAROLINA

### STOCKING HISTORY

Striped Bass culture originated in North Carolina in the late 19th century with the establishment of the Weldon Hatchery adjacent to the spawning grounds of the Roanoke River (Baird 1880; Worth 1884). The Weldon Hatchery was operated from 1884–1991 by federal and state fisheries agencies, including the North Carolina Wildlife Resources Commission (WRC; Harrell et al. 1990). The Edenton National Fish Hatchery (ENFH), operated by the USFWS, was also heavily involved in striped bass production, and operated the Weldon Hatchery as a sub-station before it was transferred to WRC. Striped Bass eggs and fry (larvae) produced at the Weldon Hatchery from Roanoke River broodfish were widely distributed throughout the U.S. Although annual egg and fry production totals from the early years of the Weldon Hatchery are available for most years (1906–1947; Woodroffe 2011), little is known about fry stocking numbers and locations until WRC records began in 1943. Since that time, over 96 million fry have been released in North Carolina coastal systems (Table 1.1). A detailed overview of historical striped bass stocking in North Carolina and the southeastern U.S. can be found in Woodroffe (2011).

By the 1970s collapse of the Atlantic striped bass stock, hatchery techniques had been refined to achieve grow-out to phase-I (25–50 mm; 1–2 in) and phase-II (125–200 mm; 5–8 in) sizes, providing additional opportunities for stocking. The North Carolina Division of Marine Fisheries (NCDMF) and the USFWS began a pilot project in 1979 to evaluate the restoration potential of stocking phase-II fish. In 1986, the two agencies, along with the WRC, developed a cooperative program to restore self-sustaining stocks of anadromous fishes in coastal North Carolina waters through a combination of fishery management techniques including stocking, regulations, and assessment (Appendix 1.A). The cooperative agreement included plans for USFWS production of Phase-I and Phase-II fish. All sizes of striped bass (fry; phase-I; phase-II; sub-adults; adult broodfish) have been stocked into North Carolina coastal river systems since the agreement. The three agencies produce an annual workplan that details stocking strategies of multiple species including striped bass.

#### Albemarle Sound

The earliest record of stocking phase-II fish in the Albemarle Sound area occurred in 1978; however, the DMF tagging program and cooperative stockings began in January 1981 (Table 1.2). From 1981–1996, over 700,000 phase-II fish were stocked in the Albemarle Sound system with nearly 54,000 fish tagged. All phase-II fish stocked in Albemarle Sound from 1991–1996 were tagged to avoid natural stock confusion. In addition, over 800,000 phase-I fish were stocked in the Albemarle Sound system from 1979–1981 and 1985. An additional 160,410 phase-I fish were stocked in the Roanoke River from 1976–1979, and 106,392 phase-I fish were stocked in 1992. Stocking in the Albemarle Sound system was discontinued in 1996 due to recovery of the stock. Poor recruitment and the overfished status of the Albemarle-Roanoke stock, however, led the WRC and DMF to develop a stocking contingency plan for the Albemarle Sound in 2021. The contingency plan outlines the decision-making process for stocking surplus phase-I fish from

Roanoke River broodstock if high flow conditions are expected to limit natural recruitment. The Albemarle-Roanoke striped bass contingency plan will be part of the annual cooperative workplan agreement, and its use will be determined each year by agreement of the agencies.

Tar-Pamlico River

Phase-II stocking began in the Tar-Pamlico River in 1977 when 4,380 fish were stocked. Phase-II fish were periodically stocked from 1982–2005, and annual stockings of phase-II fish occurred from 2007–2020 (Table 1.2). The change to annual stocking of phase-II fish was a recommendation in the NC Estuarine Striped Bass FMP (NCDMF 2004). Nearly 2.4 million phase-II fish have been stocked in the Tar-Pamlico River basin since 1977, and more than 2.8 million phase-I fish since 1979. Phase-I fish stocked in 1979 and 1983 were likely surplus, but in 1994 the WRC and ENFH began stocking phase-I fish in the Tar-Pamlico River basin with an annual stocking goal of 100,000 phase-I fish. Annual stocking of phase-I fish was discontinued in 2009 by recommendation in Amendment 1 of the NC Estuarine Striped Bass FMP (NCDMF and NCWRC 2013). Surplus phase-I fish, however, were stocked in 2013, 2014, and 2016. A portion of all phase-II fish were tagged yearly to determine migration and contribution of stocked fish to recreational and commercial fisheries. From 1998–2011, all stocked fish were marked with oxytetracycline (OTC), which leaves a chemical mark on fish otoliths (ear bone) that can be seen under fluorescent light. Parentage-based tagging (PBT) analysis using microsatellite markers was used for genetically identifying fish stocked from 2010–2020.

Neuse River

Recent stocking history of striped bass in the Neuse River basin is similar to the Tar-Pamlico River basin. A small number of phase-II fish were stocked in the Neuse River in 1975. Phase-II fish were periodically stocked from 1981–2007, and annual stockings occurred from 2009–2020 (Table 1.2). More than 2.1 million phase-II fish have been stocked in the Neuse River basin. Additionally, more than 2.4 million phase-I fish have been stocked in the Neuse River basin, with an annual goal of 100,000 fish from 1993–2009. Stocking requests for phase-I fish ended with Amendment 1, but surplus fish were stocked in the Neuse River in several years following 2009. A portion of all phase-II fish were tagged each year to determine migration patterns and contribution of stocked fish to recreational and commercial fisheries. All stocked fish were marked with OTC from 1998–2011, and all striped bass stocked since 2010 are genetically traceable with PBT analysis.

Cape Fear River

The Cape Fear River was first stocked with 4,000 phase-II fish in 1968, and periodic stockings of phase-I and phase-II fish occurred from 1979–2000 (Table 1.2). Infrequent stockings in the Cape Fear River were due to low numbers of tag returns and complications posed by the presence of hybrid striped bass from Jordan Reservoir. Hybrid striped bass stocking was discontinued in Jordan Reservoir in 2002 in favor of striped bass (Table 1.3). Phase-II fish stocking was reinitiated in the Cape Fear River, with stocking in 2004, 2006, and annually since 2008. Phase-I fish were stocked annually from 2001–2009, and surplus phase-I fish were also stocked in 2012 and 2014. A portion of the phase-II fish were tagged. All stocked fish were marked with OTC between 1998–2011, and all striped bass stocked since 2010 are genetically traceable with PBT analysis.

Northeast Cape Fear River

The WRC stocked approximately 26,000 phase-II fish in the Northeast Cape Fear River in 1999 and 2000 (Table 1.2). The WRC also stocked phase-I fish annually during 2001–2009. A final stocking of phase-I fish in the Northeast Cape Fear River occurred in 2012. Approximately 818,000 phase-I fish were stocked in the Northeast Cape Fear River (Table 1.2). All stocked fish, except for those stocked in 2012, were marked with OTC, and the 2012 year-class is genetically traceable with PBT analysis.

Broodstock source

Striped bass originating from the Roanoke River have provided most fish used for stocking in North Carolina waters, but many broodstock sources have been used throughout the state. Early fry stockings from the Weldon Hatchery were entirely from Roanoke River broodfish. Phase-II fish stocked in the Albemarle Sound region were supplied by the ENFH and the USFWS McKinney Lake National Fish Hatchery in NC, with supplemental fish produced in South Carolina, Georgia, Alabama, and Texas, all of which used various broodstock sources. During most years, phase-I fish stocked by WRC originated from Roanoke River broodstock. Broodstock from Roanoke River; Monks Corner, SC; and Weldon/Monks Corner crosses were artificially spawned at the hatcheries to provide fish for grow-out to phase-II. When WSFH began striped bass production in 1994, nearly all striped bass broodstock used for all coastal river stockings were collected from the Roanoke River and Dan River (Roanoke River basin) each year (Jeff Evans, WRC hatchery manager, personal communication). In 2010, however, local broodstock were used for producing phase-II fish for stocking in the Cape Fear River, and local broodstock have been used for stocking the Tar-Pamlico and Neuse rivers since 2012.

Broodstock collection

Striped bass broodstock are collected during annual electrofishing surveys conducted by WRC on the spawning grounds of the Roanoke, Tar-Pamlico, Neuse, and Cape Fear rivers. WRC biologists coordinate broodstock collections with hatcheries staff. Gravid (egg laden) females and three to four males per female are collected and transported to hatcheries. The number of females collected annually varies based on stocking goals and hatchery needs. Broodstock for Tar-Pamlico and Neuse rivers phase-II production are typically delivered to ENFH, whereas broodstock for phase-I production for the Cape Fear and the Roanoke rivers and inland reservoirs are delivered to WSFH. Prior to 2014, WSFH transferred fry to ENFH for grow-out to phase-II.

Table 1.1. Striped bass fry stocked into coastal systems of North Carolina, 1943–2019. Data are from WRC hatchery cards (1943–1971), ENFH records (1982–1990), and the WRC warmwater stocking database, which includes ENFH records (1994–2019).

| Roanoke River | | Chowan River | | Albemarle Sound | | Tar-Pamlico River | | Neuse River | | White Oak River | | Northeast Cape Fear River | | Cape Fear River | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Fry Stocked | Year | Fry Stocked | Year | Fry Stocked | Year | Fry Stocked | Year | Fry Stocked | Year | Fry Stocked | Year | Fry Stocked | Year | Fry Stocked |
| 1944 | 3,938,000 | 1949 | 171,500 | 1951 | 474,200 | 1943 | 493,000 | 1949 | 100,000 | 1955 | 330,000 | 1965 | 150,000 | 1968 | 1,830,000 |
| 1949 | 1,000,000 | 1951 | 359,500 | 1952 | 1,025,000 | 1947 | 250,000 | 1951 | 139,000 | 1957 | 270,000 | 1966 | 200,000 | 1982 | 399,928 |
| 1950 | 1,500,000 | 1952 | 750,000 | 1953 | 800,000 | 1948 | 266,000 | 1952 | 175,000 | 1960 | 33,000 | 1967 | 300,000 | 2002 | 900,000 |
| 1958 | 400,000 | 1953 | 400,000 | 1954 | 1,000,000 | 1949 | 475,000 | 1953 | 397,000 | 1964 | 80,000 | 1968 | 425,000 | 2004 | 900,000 |
| 1959 | 862,000 | 1954 | 2,030,000 | 1955 | 820,000 | 1950 | 160,000 | 1954 | 1,045,000 | 1983 | 61,772 | 1969 | 320,000 | | |
| 1960 | 4,964,000 | 1955 | 860,000 | 1956 | 150,000 | 1954 | 690,000 | 1955 | 330,000 | 1984 | 45,000 | 1970 | 187,000 | | |
| 1962 | 1,335,000 | 1956 | 300,000 | 1957 | 820,000 | 1955 | 1,126,000 | 1956 | 305,000 | | | 1971 | 100,000 | | |
| 1963 | 3,811,000 | 1959 | 105,000 | 1959 | 200,000 | 1956 | 200,000 | 1957 | 550,000 | | | 2000 | 999,999 | | |
| 1964 | 1,536,000 | 1961 | 175,000 | 1961 | 525,000 | 1957 | 420,000 | 1959 | 185,000 | | | 2002 | 500,000 | | |
| 1965 | 1,052,000$^{+}$ | 1962 | 225,000 | 1962 | 677,000 | 1959 | 260,000 | 1960 | 25,000 | | | 2003 | 115,000 | | |
| 1966 | 1,005,000$^{+}$ | 1964 | 69,000 | 1964 | 274,000 | 1961 | 460,000 | 1961 | 260,000 | | | | | | |
| 1967 | 1,567,500 | 1965 | 219,000 | 1965 | 375,000 | 1962 | 3,250,000 | 1962 | 360,000 | | | | | | |
| 1968 | 6,334,000 | 1966 | 350,000$^{+}$ | 1966 | 925,000 | 1964 | 393,000 | 1964 | 90,000 | | | | | | |
| 1969* | 2,718,000$^{+}$ | 1967 | 297,000 | 1967 | 592,000 | 1965 | 150,000 | 1965 | 150,000 | | | | | | |
| 1970 | 1,375,000 | 1968 | 985,100 | 1968 | 2,063,250 | 1966 | 200,000$^{+}$ | 1966 | 200,000 | | | | | | |
| 1971 | 175,000 | 1969 | 309,800 | 1969 | 619,650 | 1967 | 510,000 | 1967 | 400,000 | | | | | | |
| 1990 | 240,000 | 1970 | 63,000 | 1970 | 156,000 | 1968 | 975,000 | 1968 | 766,000 | | | | | | |
| | | 1971 | 250,000 | 1971 | 150,000 | 1969 | 1,943,000 | 1969 | 2,049,200 | | | | | | |
| | | | | | | 1970 | 6,528,000 | 1970 | 66,600 | | | | | | |
| | | | | | | 1971 | 1,164,000 | 1971 | 66,666 | | | | | | |
| | | | | | | 1994 | 1,500,000 | 1983 | 176,547 | | | | | | |
| | | | | | | 2018 | 608,384 | 1984 | 182,000 | | | | | | |
| | | | | | | 2019 | 813,000 | 2015 | 799,700 | | | | | | |
| | | | | | | | | 2016 | 1,173,000 | | | | | | |
| | | | | | | | | 2018 | 670,464 | | | | | | |
| | | | | | | | | 2019 | 1,755,000 | | | | | | |
| Totals | 33,812,500 | | 7,918,900 | | 11,646,100 | | 22,834,384 | | 12,416,177 | | 819,772 | | 3,296,999 | | 4,029,928 |

*55 million eggs were also released; $^{+}$includes records with unknown size and date of release that are assumed to be fry based on year of release and data source.

Table 1.2. Stocking records of phase-I and phase-II fish released in coastal systems of North Carolina, 1967–2020. Note, some phase-II fish were stocked in January of the calendar year following the production year-class causing some discrepancies with tables in previous fishery management plans.

| | Albemarle Sound | | Roanoke River | | Tar-Pamlico River | | Neuse River | | Northeast Cape Fear River | | Cape Fear River | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year-Class | Phase-I | Phase-II | Phase-I | Phase-II | Phase-I | Phase-II | Phase-I | Phase-II | Phase-I | Phase-II | Phase-I | Phase-II |
| 1967 | | | | | | | | | | | | 4,000 |
| 1974 | | | | | *Unknown | | | | | | | |
| 1975 | | | | | | | | 2,124 | | | | |
| 1976 | | | 18,074 | | | | | | | | | |
| 1977 | | | 25,000 | | | 4,380 | | | | | | |
| 1978 | | 2,358 | 30,336 | | | | | | | | | |
| 1979 | 100,013 | - | 87,000 | | 104,000 | | 93,480 | | | | 3,000 | 14,874 |
| 1980 | 441,689 | 87,181 | | | | | | | | | 12,410 | |
| 1981 | 215,706 | - | | | | | | 47,648 | | | | |
| 1982 | | 106,675 | | | | 76,674 | | | | | | |
| 1983 | | 67,433 | | | 28,000 | - | | | | | | 13,401 |
| 1984 | | 236,242 | | | | 26,000 | | | | | | 56,437 |
| 1985 | 45,011 | 45,200 | | | | | | 39,769 | | | | |
| 1986 | | 118,345 | | | | | | | | | | |
| 1987 | | 15,435 | | | | 17,993 | | | | | | |
| 1988 | | 5,000 | | | | | | | | | | |
| 1989 | | 3,289 | | | | | | | | | | 77,242 |
| 1990 | | 9,466 | | | | 1,195 | | 61,877 | | | 169,792 | |
| 1991 | | 2,994 | | | | 30,801 | | | | | | |
| 1992 | | 2,465 | 106,392 | | | - | | | | | | |
| 1993 | | 2,180 | | | | 118,600 | 48,000 | | | | | |
| 1994 | | 2,481 | | | 127,635 | 183,254 | 103,057 | 79,933 | | | 100,733 | |
| 1995 | | 2,498 | | | 100,000 | 140,972 | 99,176 | | | | 100,000 | |
| 1996 | | 2,490 | | | 39,450 | | 100,000 | 100,760 | | | | |
| 1997 | | | | | 28,022 | 24,031 | | | | | | |
| 1998 | | | | | 230,786 | | 107,730 | 83,195 | | | | 30,479 |
| 1999 | | | | | 100,000 | 17,954 | 100,000 | | | 10,327 | | |
| 2000 | | | | | 188,839 | | 121,993 | 108,000 | | 15,635 | | 8,915 |

Table 1.2 (continued).

| | Albemarle Sound | | Roanoke River | | Tar-Pamlico River | | Neuse River | | Northeast Cape Fear River | | Cape Fear River | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year-Class** | **Phase-I** | **Phase-II** | **Phase-I** | **Phase-II** | **Phase-I** | **Phase-II** | **Phase-I** | **Phase-II** | **Phase-I** | **Phase-II** | **Phase-I** | **Phase-II** |
| 2001 | | | | | 171,000 | 37,000 | 103,000 | | 94,083 | | 90,149 | |
| 2002 | | | | | 39,110 | | | 147,654 | 50,000 | | 50,000 | |
| 2003 | | | | | 100,000 | 159,996 | 100,000 | | 151,873 | | 104,775 | |
| 2004 | | | | | 100,000 | | 100,000 | 168,011 | 50,000 | | 50,000 | 172,055 |
| 2005 | | | | | 114,000 | 267,376 | 114,000 | | 54,500 | | 54,500 | |
| 2006 | | | | | 134,100 | | 146,340 | 99,595 | 84,125 | | 80,450 | 102,283 |
| 2007 | | | | | 160,995 | 69,871 | 172,882 | 69,953 | 79,690 | | 80,376 | |
| 2008 | | | | | 331,202 | 91,962 | 314,298 | | 190,460 | | 395,226 | 92,580 |
| 2009 | | | | | 99,730 | 61,054 | 100,228 | 104,061 | 51,750 | | 166,812 | 112,674 |
| 2010 | | | | | | 114,012 | | 107,142 | | | | 210,105 |
| 2011 | | | | | | 107,767 | | 102,089 | | | | 130,665 |
| 2012 | | | | | | 45,667 | 50,180 | 91,985 | 12,384 | | 45,000 | 127,070 |
| 2013 | | | | | 257,404 | 123,416 | 181,327 | 113,784 | | | | 195,882 |
| 2014 | | | | | 138,889 | 92,727 | 79,864 | 78,866 | | | 211,726 | 141,752 |
| 2015 | | | | | | 52,922 | | 109,107 | | | | 116,011 |
| 2016 | | | | | 234,718 | 121,190 | 80,910 | 134,559 | | | | 70,734 |
| 2017 | | | | | | 101,987 | | 14,203 | | | | 154,024 |
| 2018 | | | | | | 120,668 | 96,900 | 86,556 | | | | 101,254 |
| 2019 | | | | | | 97,920 | | 85,694 | | | | 105,405 |
| 2020 | | | | | | 90,614 | | 96,933 | | | | 73,038 |
| Totals | 802,419 | 711,732 | 266,802 | 0 | 2,827,880 | 2,398,003 | 2,413,365 | 2,133,498 | 818,865 | 25,962 | 1,714,949 | 2,110,880 |

*DMF report indicates Phase-I fish were stocked in the Tar-Pamlico in 1974, but records have not been located.

Table 1.3. Striped bass and hybrid striped bass stocked by the NC Wildlife Resources Commission in B. Everett Jordan Reservoir located in the Cape Fear River basin, 1988–2020.

| | Striped bass | Hybrid striped bass | | | |
|---|---|---|---|---|---|
| Year-Class | Phase-I | Fry | Phase-I | Phase-II | Total |
| 1988 | | | 42,517 | | 42,517 |
| 1989 | | | 30,000 | 96 | 30,096 |
| 1990 | | | 12,114 | | 12,114 |
| 1991 | | | 96,887 | | 96,887 |
| 1993 | | | 214,710 | 21,447 | 236,157 |
| 1994 | | 600,000 | | | 600,000 |
| 1995 | 21,780 | | 50,600 | | 50,600 |
| 1996 | 15,867 | | 29,000 | | 29,000 |
| 1997 | 35,000 | | 35,000 | | 35,000 |
| 1998 | 37,766 | | 13,692 | | 13,692 |
| 1999 | 51,567 | | 37,330 | | 37,330 |
| 2000 | 42,150 | | 42,118 | | 42,118 |
| 2001 | 35,000 | | 35,000 | | 35,000 |
| 2002 | 70,000 | | | | |
| 2003 | 70,000 | | | | |
| 2004 | 70,000 | | | | |
| 2005 | 70,000 | | | | |
| 2006 | 70,000 | | | | |
| 2007 | 70,000 | | | | |
| 2008 | 70,000 | | | | |
| 2009 | 70,000 | | | | |
| 2010 | 70,000 | | | | |
| 2011 | 70,000 | | | | |
| 2012 | 100,000 | | | | |
| 2013 | 100,000 | | | | |
| 2014 | 100,000 | | | | |
| 2015 | 78,000 | | | | |
| 2016 | 78,000 | | | | |
| 2017 | 100,000 | | | | |
| 2018 | 128,164 | | | | |
| 2019 | 120,000 | | | | |
| 2020 | 120,000 | | | | |
| Totals | 1,863,294 | 600,000 | 638,968 | 21,543 | 1,260,511 |

Fry production

North Carolina hatcheries use established striped bass culture techniques adapted from Harrell et al. (1990). At the hatchery, male and female striped bass are injected with human chorionic gonadotropin (hCG) hormone to induce spawning. One female to three or four males are placed in a circular spawning tank and allowed to spawn. Eggs are collected by gravity and flow in a secondary circular tank equipped with an extra fine mesh egg retention screen equipped with a bubble curtain to prevent eggs from contacting the screen. Water-hardened eggs are transferred to McDonald style hatching jars at a density of 75,000 to 125,000 eggs per jar and supplied with flow-through well water to keep eggs in suspension. Incubation typically takes 48 hours, and as eggs hatch, fry are collected in aquaria. At 2 days post-hatch, fry are transferred to circular tanks and inventoried. During the period of 4–7 days post-hatch, fry are fed brine shrimp Artemia nauplii through an automated feeding system for first feeding. Fry are then transferred to earthen production ponds for phase-I fingerling production.

Fingerling production

Fry are stocked into fertilized production ponds where they feed on naturally produced zooplankton. Supplemental feeding begins 15 days after stocking. Harvest of phase-I fingerling ponds is scheduled after a 35–45-day pond culture period. Phase-I fingerlings are then cultured inside in raceways for 30–45 days. They are then graded to similar size, and advanced fingerlings are pond-stocked at a rate of 15,000–20,000 fingerlings/acre for a final pond grow-out period. Advanced fingerlings are fed sinking pellet food, and phase-II production ponds are typically treated to control algae and aquatic vegetation and to offer protection from birds. Harvest of phase-II fingerling ponds is scheduled after a 120–130-day pond culture period. Harvested fingerlings range from 5–8 fingerlings/lb. Stocking of phase-II fingerlings typically occurs from October–December yearly.

EARLY STOCKING EVALUATIONS

The DMF striped bass tagging program provided an opportunity to evaluate the contribution of stocked fish to commercial and recreational fisheries. Prior to 1980, however, striped bass stockings in coastal North Carolina systems were not formally evaluated. Winslow (2010) analyzed tag-return data for phase-II fish stocked from 1981–2008 and found stocked phase-II fish contributed to the commercial and recreational fisheries as well as the spawning stock in the Tar-Pamlico and Neuse rivers.

Studies evaluating OTC marks were conducted by WRC to estimate the contribution of stocked phase-I and phase-II fish to the spawning stocks in the Tar-Pamlico and Neuse rivers in the early 2000s. Otoliths from adult striped bass from 2000–2004 in the Neuse River and from 2002–2004 in the Tar-Pamlico River were analyzed for the presence of an OTC mark (Barwick et al. 2008). Results suggested striped bass stocked in the Tar-Pamlico and Neuse rivers contributed little to the spawning stocks in these systems. In the Tar-Pamlico River in 2004 and Neuse River from 2000–2002, no stocked juveniles were recaptured as spawning adults. Fewer than three stocked fish were recaptured as adults in other years. However, results from this study may have been impacted by low mark retention.

With low abundance of stocked striped bass documented on the spawning grounds, WRC research efforts shifted to evaluating the contribution of stocked phase-I fish to seine and electrofishing samples conducted in the Neuse River. During the summers of 2006 and 2007, beach seining and electrofishing was conducted at estuarine and inland sampling locations (Barwick and Homan 2008). No juvenile striped bass were collected in 2006 and only five were collected in 2007. Three were collected close to the stocking location near New Bern, N.C. and two without OTC marks were collected upstream, all were hatchery fish. Results from this project suggested limited benefit of phase-I stocking as a management option to supplement striped bass populations in the Neuse River. In addition, the overall low number of juveniles indicated poor reproductive success, poor survival, or a combination of these two factors (Barwick and Homan 2008).

In response to a research need identified in Amendment 1 to determine factors impacting survivability of stocked fish in each system (NCDMF and NCWRC 2013), Bradley et al. (2018) acoustically tagged 100 hatchery-reared phase-II juveniles stocked in the Neuse River to estimate mortality and monitor movement and seasonal distribution. Annual discrete total mortality of phase-II stocked striped bass juveniles was 66.3% and was not related to seasonal variation in dissolved oxygen, temperature, or salinity. High observed mortality could be related to inadequate feeding or lack of predator avoidance. Future research should address whether changes in hatchery protocols could improve survival of stocked fish.

PARENTAGE-BASED TAGGING STOCKING EVALUATION

In 2010, WRC began using PBT to evaluate contributions of stocked striped bass to the populations in the Tar-Pamlico, Neuse, and Cape Fear rivers. PBT method uses genetic microsatellite markers to match stocked fish with broodfish used in hatchery production (Denson et al. 2012). Evaluating stocking with PBT is non-lethal as it requires a small fin clip. Fish are permanently marked with PBT without the issues of poor mark retention seen with OTC and without having to physically tag every fish with external tags. However, PBT cannot distinguish the origin of non-hatchery striped bass. Fish determined to not be of hatchery origin could be the result of wild reproduction in any system. Additionally, striped bass stocked prior to 2010 are not identifiable using this technique.

The WRC and DMF began collecting striped bass fin clip samples for PBT analysis in 2011. Fin clips are processed and analyzed by the South Carolina Department of Natural Resources Hollings Marine Laboratory. Samples in the early years focused on small fish, but as more PBT year-classes became available, fin clip samples were analyzed from all size-classes of striped bass. PBT analysis of samples collected on the spawning grounds and internal coastal fishing waters of the Tar-Pamlico, Neuse, and Cape Fear rivers revealed stocked striped bass can make up greater than 90% of the fish sampled some years (O'Donnell and Farrae 2017); however, results from 2017 and 2018 indicated a noticeable decrease in contribution of hatchery-stocked fish in the Tar-Pamlico and Neuse rivers (Farrae and Darden 2018).

Tar-Pamlico River

In 2012, WRC began collecting fin clips in the Tar-Pamlico River during annual spawning area surveys for PBT evaluation. DMF began collecting additional samples from adult striped bass in lower portions of the Tar-Pamlico River in 2016. Annual hatchery contribution from 2012–2019 ranged between 38%–94% (Table 1.4) and were similar between WRC and DMF samples (Table 1.5). Non-PBT fish overlapped with size-classes of 2010 and 2011 stocked cohorts (Figure 1.1 and 1.2). These results indicate stocked fish heavily contribute to the Tar-Pamlico striped bass population, but there is some evidence of natural recruitment, particularly in 2014 and 2015 (Figure 1.2). It is possible these recruits were migrants from the Albemarle-Roanoke stock or some other source as a DMF telemetry study indicated non-PBT fish tagged in the Tar-Pamlico River migrated to the Albemarle Sound, suggesting mixing in the systems (NCDMF unpublished data). Continued sampling to document young-of-the-year production will be required to verify natural recruitment in the Tar-Pamlico River.

Table 1.4. Parentage-based tagging results for Tar-Pamlico, Neuse, and Cape Fear River at-large striped bass samples collected by WRC and DMF, 2011–2019. Data presented here do not include results for hybrids, broodfish, duplicates, and errors.

| | | Hatchery Cohort | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **River Basin** | **Sample Year** | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | **2018** | **Unknown** | **Total** | **Hatchery Percentage** |
| Tar-Pamlico | 2012 | 19 | 12 | | | | | | | | 14 | 45 | 69% |
| | 2013 | 99 | 41 | | | | | | | | 23 | 163 | 86% |
| | 2014 | 55 | 112 | 5 | | | | | | | 29 | 201 | 86% |
| | 2015 | 22 | 79 | 56 | 34 | | | | | | 12 | 203 | 94% |
| | 2016 | 28 | 102 | 101 | 98 | 6 | | | | | 51 | 386 | 87% |
| | 2017 | 7 | 35 | 17 | 86 | 24 | 1 | 1 | | | 78 | 249 | 69% |
| | 2018 | 4 | 11 | 6 | 38 | 43 | 3 | 21 | 9 | | 225 | 360 | 38% |
| | 2019 | | 7 | 1 | 7 | 9 | 4 | 57 | 11 | 4 | 85 | 185 | 54% |
| Neuse | 2011 | 36 | | | | | | | | | 0 | 36 | 100% |
| | 2012 | 24 | 8 | | | | | | | | 1 | 33 | 97% |
| | 2013 | 123 | 5 | 2 | 1 | | | | | | 69 | 200 | 66% |
| | 2014 | 96 | 77 | 20 | 99 | | | | | | 55 | 347 | 84% |
| | 2015 | 31 | 53 | 34 | 11 | | | | | | 55 | 184 | 70% |
| | 2016 | 20 | 25 | 42 | 83 | 22 | 1 | | | | 42 | 235 | 82% |
| | 2017 | 16 | 30 | 35 | 70 | 65 | 5 | 1 | | | 78 | 300 | 74% |
| | 2018 | 14 | 19 | 26 | 35 | 67 | 76 | 39 | | | 117 | 393 | 70% |
| | 2019 | 3 | 10 | 5 | 19 | 21 | 42 | 158 | 6 | 9 | 57 | 330 | 83% |
| Cape Fear | 2011 | 55 | | | | | | | | | 0 | 55 | 100% |
| | 2012 | 72 | 35 | | | | | | | | 3 | 110 | 97% |
| | 2013 | 109 | 27 | 14 | | | | | | | 92 | 242 | 62% |
| | 2014 | 39 | 42 | 75 | 67 | | | | | | 65 | 288 | 77% |
| | 2015 | 45 | 31 | 32 | 41 | 10 | | | | | 66 | 225 | 71% |
| | 2016 | 18 | 24 | 59 | 84 | 25 | | | | | 28 | 238 | 88% |
| | 2017 | 17 | 9 | 37 | 46 | 51 | 18 | 1 | | | 17 | 196 | 91% |
| | 2018 | 12 | 8 | 26 | 50 | 38 | 34 | 13 | 10 | | 24 | 215 | 89% |
| | 2019 | 6 | 2 | 10 | 10 | 7 | 7 | 25 | 85 | 115 | 31 | 298 | 90% |

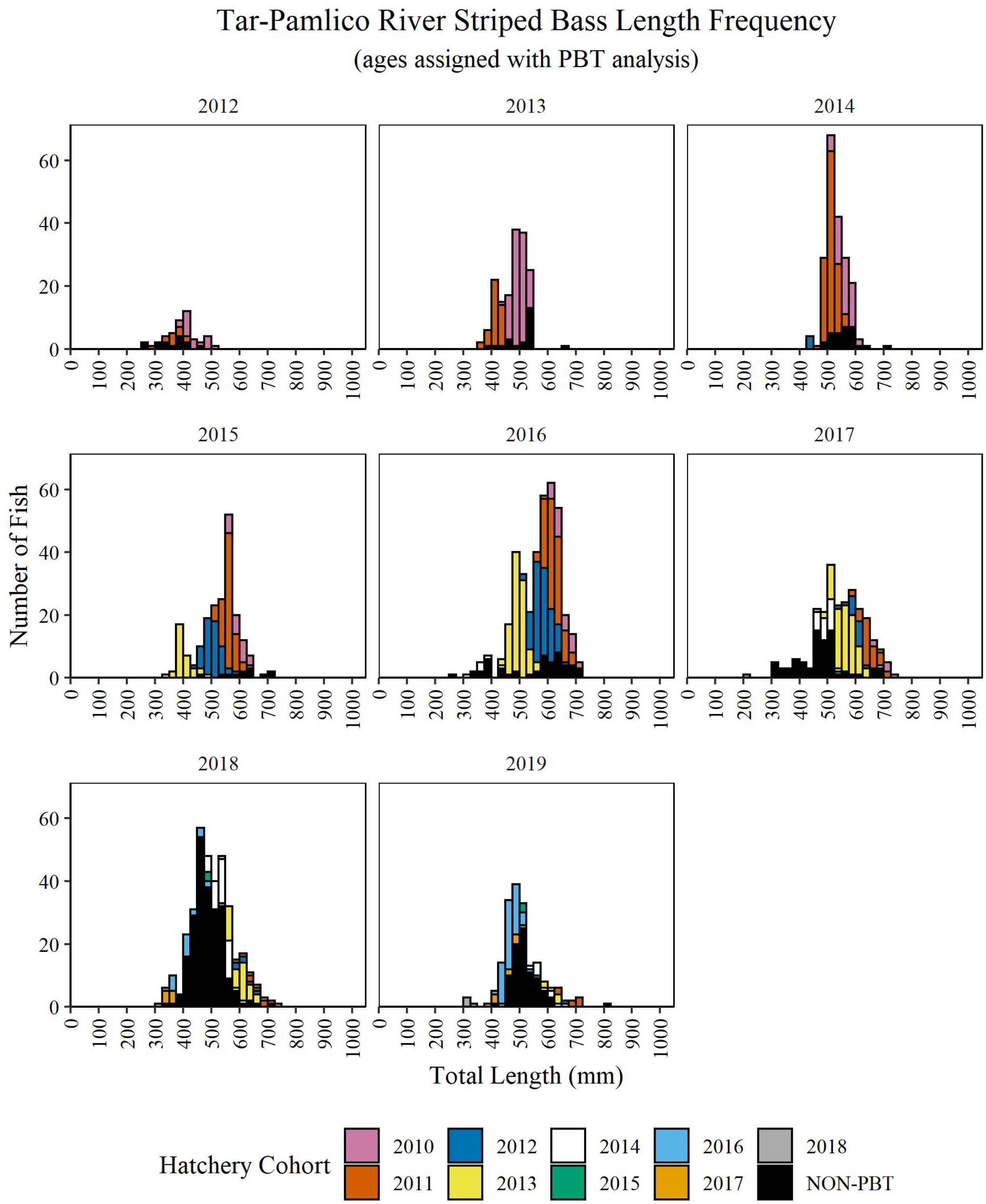


Figure 1.1. Length-frequency histograms for at-large striped bass collected in the Tar-Pamlico River by WRC and DMF, 2012–2019. Hatchery cohorts identified by parentage-based tagging analysis (PBT) are plotted within each 25-mm length group. Fish identified as non-PBT were not assigned to a hatchery cohort because they did not match to a broodstock pair.

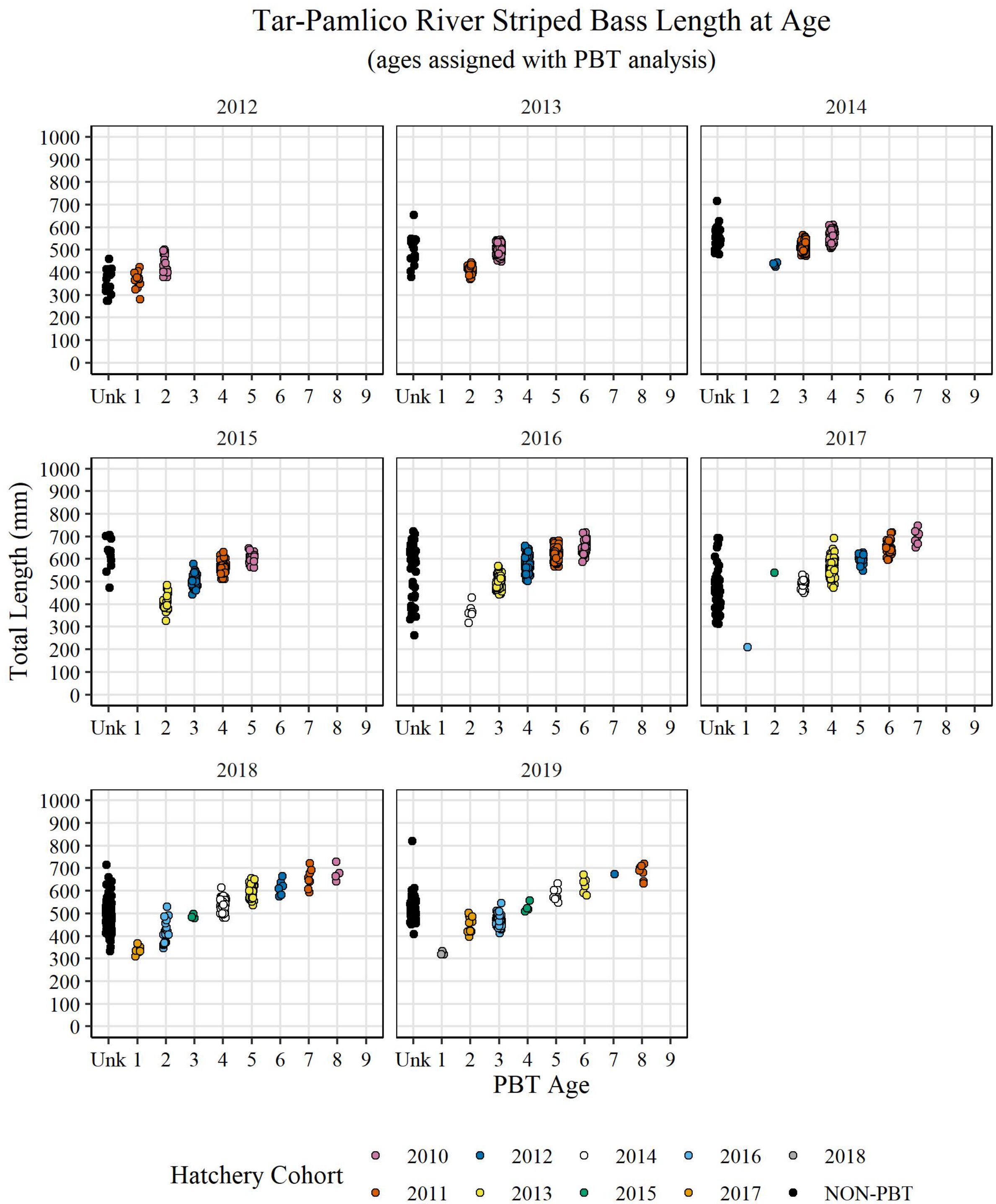


Figure 1.2. Length at age for at-large Tar-Pamlico River striped bass collected by WRC and DMF, 2012–2019. Ages were identified using parentage-based tagging (PBT) analysis. Those fish with an unknown age (Unk) each year were not identified as hatchery cohorts by PBT analysis and could not be assigned an age. Points are jittered about each age column to clarify overlapping data points. Outliers were removed before plotting.

Table 1.5. Parentage-based tagging hatchery contribution for at-large samples (excluding hybrids, broodfish, duplicates, and errors) collected by WRC during the Tar-Pamlico River spawning area survey and by DMF in downstream portions of the Tar-Pamlico River basin.

| | WRC Samples | | | DMF Samples | | |
|---|---|---|---|---|---|---|
| Year | Non-PBT | Total | Hatchery Percentage | Non-PBT | Total | Hatchery Percentage |
| 2016 | 25 | 196 | 87% | 26 | 190 | 86% |
| 2017 | 31 | 100 | 69% | 47 | 149 | 68% |
| 2018 | 93 | 154 | 40% | 132 | 206 | 36% |
| 2019 | 26 | 78 | 67% | 59 | 107 | 45% |

Neuse River

WRC began collecting fin clips from the Neuse River spawning area survey in 2011. DMF began collecting additional samples in lower portions of the Neuse River basin in 2016. Annual hatchery contribution from 2011–2019 ranged between 66%–100% (Table 1.4; Figures 1.3–1.4). Non-PBT contribution estimated in early years of this study may have fish from age classes before 2010. Results from 2019 are more likely to accurately reflect actual hatchery contribution for the Neuse River striped bass population and indicate non-PBT recruitment in 2014 and 2015 is contributing to the Neuse River striped bass population. The non-hatchery fish from the 2014 and 2015 year-classes could be wild-spawned fish from the Neuse River or another system. Telemetry studies conducted by DMF documented that striped bass tagged in the lower Neuse River migrated to the Albemarle Sound (NCDMF unpublished data), suggesting mixing in these populations. Additionally, hatchery contribution was much higher for WRC samples collected on the Neuse River spawning grounds compared to DMF samples collected in the lower Neuse River in 2017–2019 (Table 1.6). The lower hatchery contribution for the downstream samples could indicate striped bass from the Albemarle-Roanoke population mix with the Neuse River population. Nevertheless, results indicate some non-PBT fish from the 2015 year-class are participating in the upstream spawning migration.

Table1.6. Parentage-based tagging hatchery contribution for at-large samples (excluding hybrids, broodfish, duplicates, and errors) collected by WRC during the Neuse River spawning area survey and by DMF in downstream portions of the Neuse River basin.

| | WRC Samples | | | DMF Samples | | |
|---|---|---|---|---|---|---|
| Year | Non-PBT | Total | Hatchery Percentage | Non-PBT | Total | Hatchery Percentage |
| 2016 | 34 | 85 | 60% | 8 | 150 | 95% |
| 2017 | 26 | 182 | 86% | 52 | 118 | 56% |
| 2018 | 77 | 307 | 75% | 40 | 86 | 53% |
| 2019 | 23 | 228 | 90% | 34 | 102 | 67% |

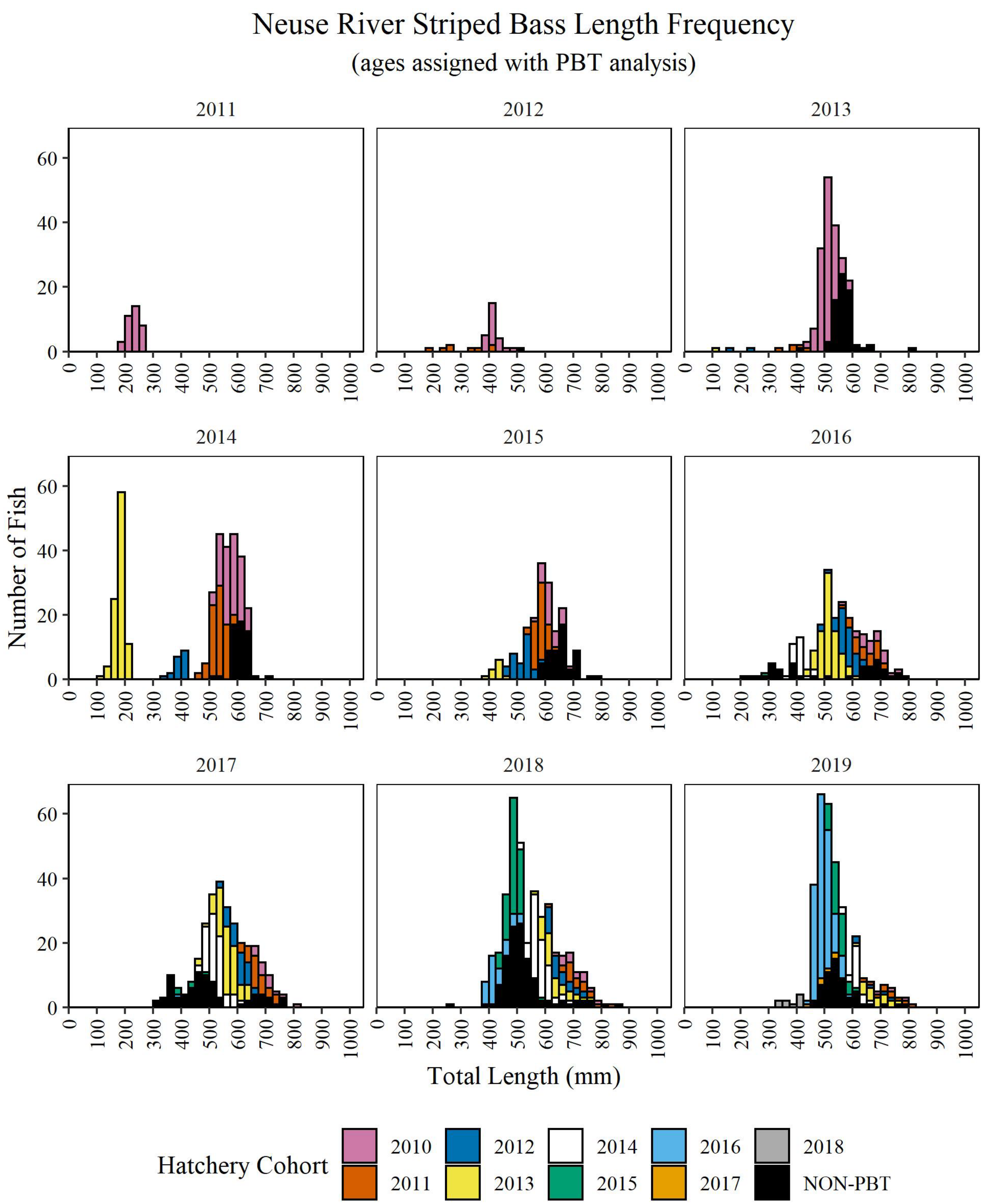


Figure 1.3. Length-frequency histograms for at-large striped bass collected in the Neuse River basin by WRC and DMF, 2011–2019. Hatchery cohorts identified by parentage-based tagging analysis (PBT) are plotted within each 25-mm length group. Fish identified as non-PBT were not assigned to a hatchery cohort because they did not match to a broodstock pair.

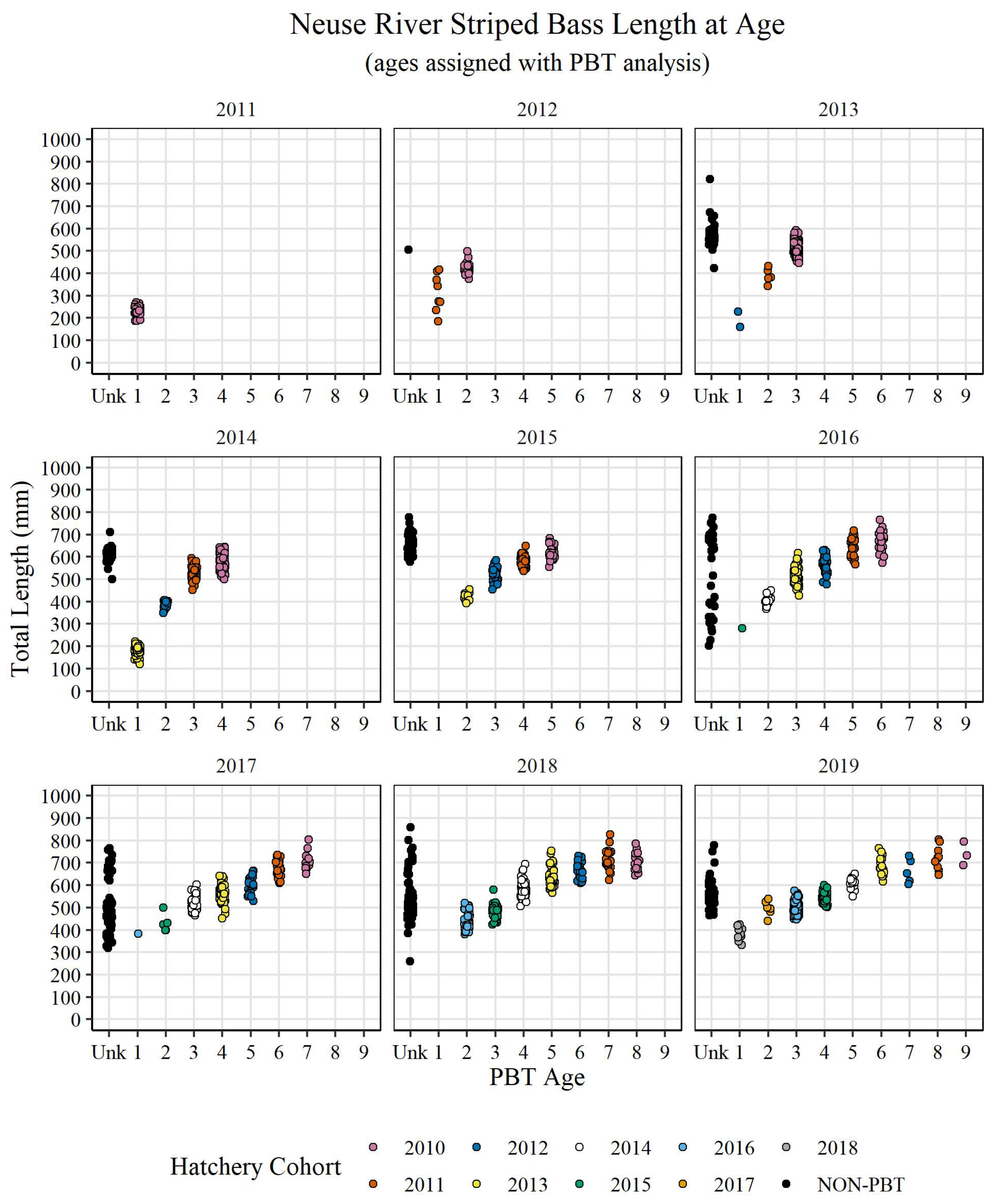


Figure 1.4. Length at age for at-large Neuse River striped bass collected by WRC and DMF, 2011–2019. Ages were identified using parentage-based tagging (PBT) analysis. Those fish with an unknown age (Unk) each year were not identified as hatchery cohorts by PBT analysis and could not be assigned an age. Points are jittered about each age column to clarify overlapping data points. Outliers were removed before plotting.

Cape Fear River

In 2011, WRC began annual PBT analysis of striped bass captured in the Cape Fear spawning survey. DMF provided samples from the lower Cape Fear River in 2011 and 2012. Starting in 2017, DMF began collecting additional samples from adult fish in the lower portion of the Cape Fear River during winter months. Additionally, DMF tested fin clips from five young-of-the-year striped bass collected in the Northeast Cape Fear River during 2018. Results of PBT analysis from both agencies combined show hatchery-origin fish comprise between 62%–100% of the fish tested annually with increasing percentage of hatchery-origin fish each year since 2013 (Table 1.4). Despite the high hatchery contribution in 2019, there was evidence of wild recruitment in the 2018 year-class (Figures 1.5 and 1.6). Juveniles collected in the Northeast Cape Fear River in 2018 were not of hatchery origin suggesting limited natural reproduction

Escapement of striped bass stocked in Jordan Reservoir is the source of most striped bass found in the Cape Fear River upstream of the locks and dams. PBT analysis revealed an increasing proportion of fish stocked in upriver reservoirs in later year-classes, increasing as sites move upriver (Figure 1.7). The Jordan Reservoir striped bass fishery is entirely hatchery supported to provide recreational fishing opportunities in the reservoir. Due to low survival and low angler participation, WRC fisheries biologists stopped striped bass stocking in Jordan Reservoir in 2021 (C. Oakley, WRC, personal communication). Future striped bass stock enhancement decisions in the Cape Fear River need to account for the loss in contribution from striped bass escapement from Jordan Reservoir. Additionally, stocking decisions regarding hybrid striped bass in Jordan Reservoir should consider escapement potential and effects on the Cape Fear River.

MANAGEMENT CONSIDERATIONS

Historically, many hatchery programs have operated as harvest augmentation or production hatcheries with the primary goal of producing as many fish as possible for put-grow-take fisheries (Trushenski et al. 2015, 2018). Conversely, supplementation hatchery programs compensate for poor recruitment caused by limitations related to habitat quantity or quality, environmental quality, or intense harvest pressure (Trushenski et al. 2015). Many anadromous fish stocking programs have experienced a shift since 2000 (Trushenski et al. 2018), using a hatchery model with increased emphasis on producing fish genetically equivalent to wild fish with a long-term goal of producing a self-sustaining, naturally spawning population. The Amendment 1 objective of the striped bass stocking program in North Carolina coastal rivers (NCDMF and NCWRC 2013) employs an integrated hatchery program model "to increase spawning stock abundance while promoting self-sustaining population levels appropriate for various habitats and ecosystems."

Hatchery rearing, stocking, and stocking evaluation methods vary depending upon stocking program goals. Lorenzen et al. (2010) identified that lack of clear fishery management objectives, lack of stock assessments, ignoring the need for a structured decision-making process, lack of stakeholder involvement, and failure to integrate flexible and adaptive management into the stocking plan are weaknesses of hatchery programs. When implementing a stocking program, Lorenzen et al. (2010) recommended managers should set goals used to evaluate the potential for stocking, establish appropriate rearing protocols to ensure the genetic and physiological integrity of stocked fish, and define and implement management plans with metrics that can be used to evaluate program success/failure. The cooperative agreement between the USFWS, DMF, and

WRC established the current striped bass stocking program in coastal North Carolina. This agreement should be revisited annually to provide adaptive management and reaffirm program goals and objectives, integrate evaluation results, and update future needs for stocking in each specific system. The contingency plan created for outlining the decision-making process for stocking surplus phase-I fish in the Albemarle Sound provides a template for stocking decisions in other North Carolina coastal river systems, though the process for each system will be unique based on local challenges.

Striped bass stocking practices have likely altered natural population genetics in North Carolina's coastal rivers. Patrick and Stellwag (2001) identified six distinct lineages among striped bass from the Roanoke, Tar-Pamlico, and Neuse rivers; the Tar-Pamlico and Roanoke rivers populations were similar but were significantly different from the Neuse River population. The researchers concluded that stocking practices could potentially affect the natural genetic distribution in these populations and suggested that broodstock should be taken from each specific population, especially when stocking the Neuse River. LeBlanc et al. (2020) showed that Cape Fear River striped bass were genetically similar to the Roanoke River population; and although North Carolina rivers, including the Tar-Pamlico and Neuse rivers, may have once supported genetically distinct populations, evidence suggests there is currently little genetic differentiation between populations (Reading 2020). While maintaining native population genetics is often a goal of restoration stocking programs (Lorenzen et al. 2010), introducing different genetic strains may be beneficial especially if native population genetics have been altered. Potential benefits, consequences, feasibility, and utility of alternative broodstock sources from systems outside coastal North Carolina systems should be thoroughly evaluated before introducing new genetic strains of striped bass.

The effectiveness of the striped bass stocking program in coastal North Carolina river systems has changed throughout the evaluation period of 1980–2019. Initial evaluations indicated limited contribution of stocked fish to commercial and recreational fisheries and little contribution to fish collected during spawning grounds surveys. Results of new evaluation methods indicated striped bass stocks in the Tar-Pamlico, Neuse, and Cape Fear rivers are maintained by phase-II stocking. Natural recruitment is low in these systems, and striped bass stocking has yet to produce self-sustaining populations. Stocking remains a necessary tool for persistence of striped bass populations in the Tar-Pamlico, Neuse, and Cape Fear river systems (Mathes et al. 2020). Stocking strategies should complement management measures that promote natural reproduction and recruitment to sustain the populations.

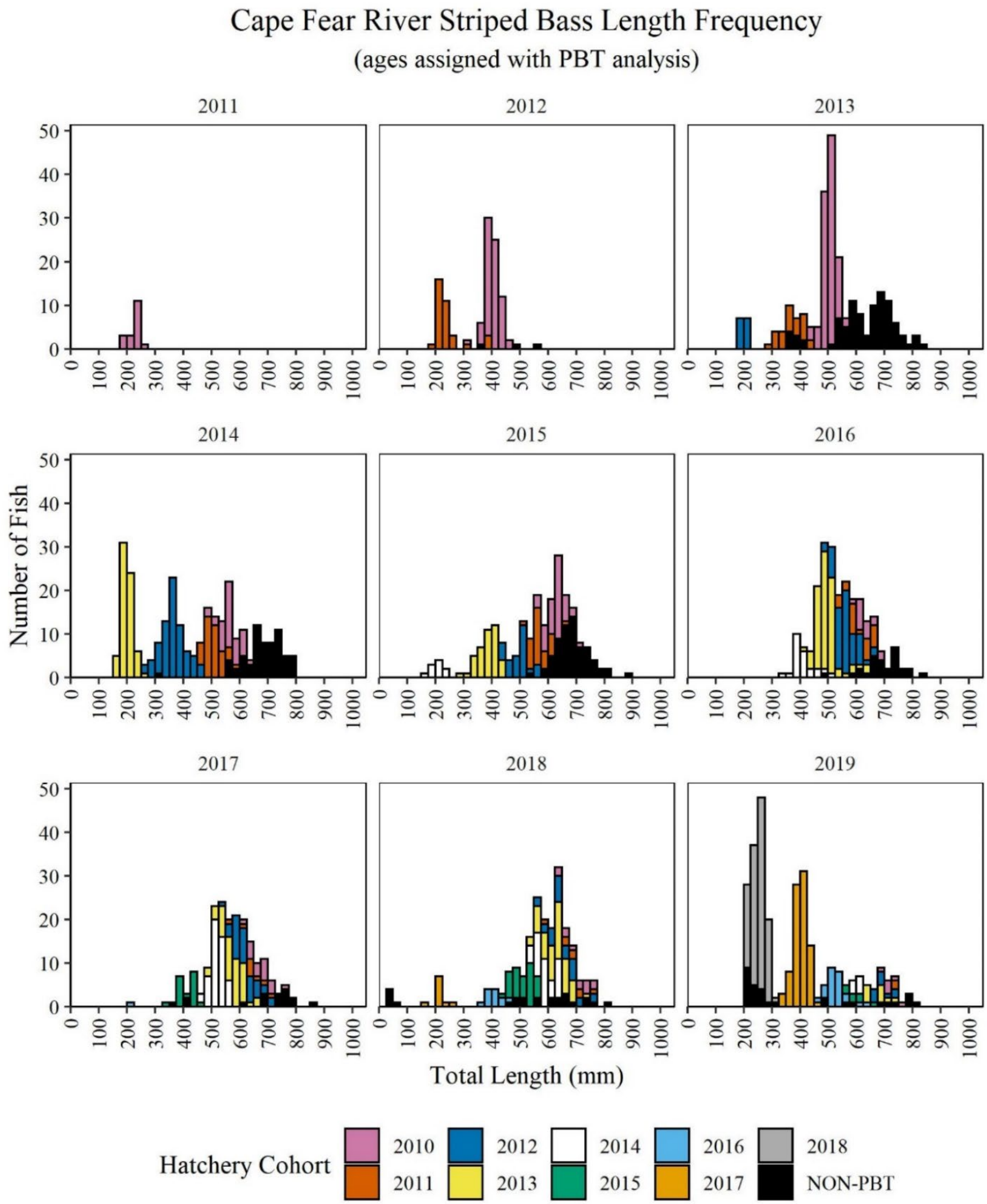


Figure 1.5. Length-frequency histograms for at-large striped bass collected in the Cape Fear River basin by WRC and DMF, 2011–2019. Hatchery cohorts identified by parentage-based tagging analysis (PBT) are plotted within each 25-mm length group. Fish identified as non-PBT were not assigned to a hatchery cohort because they did not match to a broodstock pair.

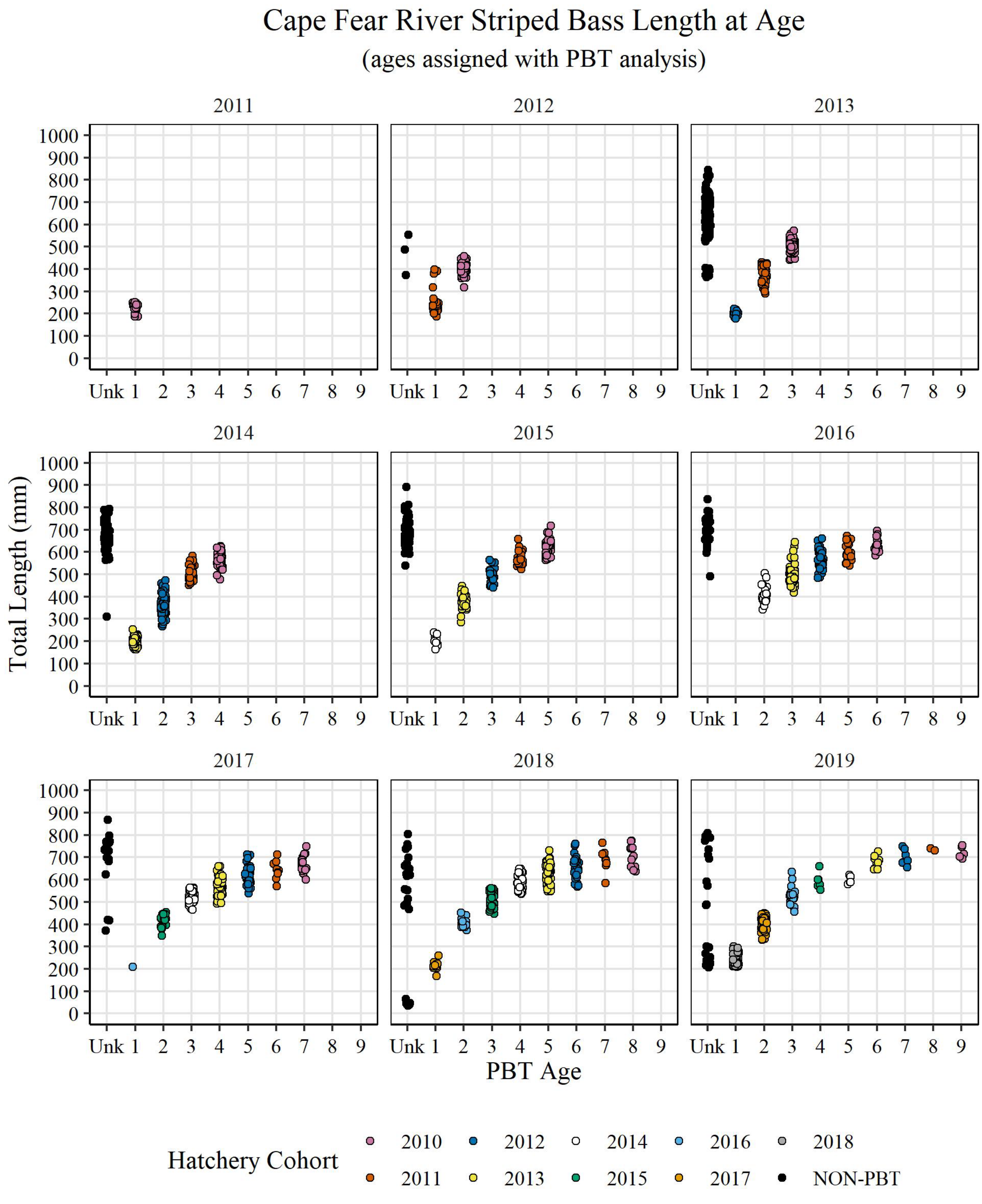


Figure 1.6. Length at age for at-large Cape Fear River striped bass collected by WRC and DMF, 2011–2019. Ages were identified using parentage-based tagging (PBT) analysis. Those fish with an unknown age (Unk) each year were not identified as hatchery cohorts by PBT analysis and could not be assigned an age. Points are jittered about each age column to clarify overlapping data points. Outliers were removed before plotting.

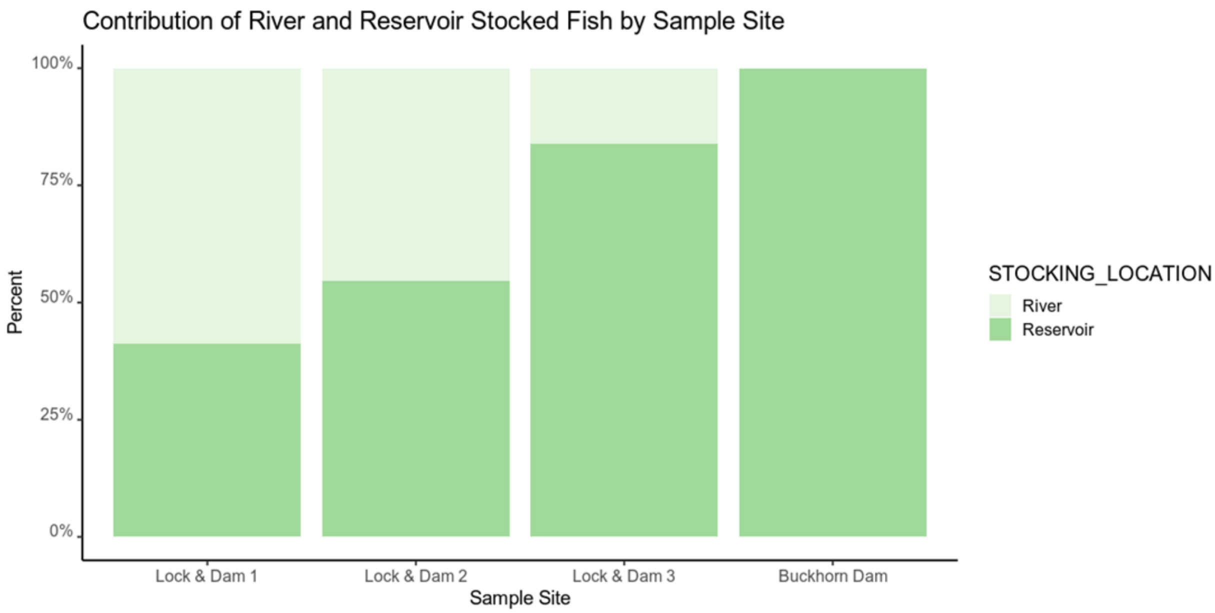


Figure 1.7. Relative contribution of hatchery-origin striped bass by stocking location to each WRC electrofishing sample site in the Cape Fear River, 2015–2019.

## ADDITIONAL RESEARCH NEEDS

Parentage-based tagging analysis allows for precise investigation of multiple stocking treatments when using genetically distinct broodstock families. Various stocking treatments, including fry, phase-I, phase-II and different stocking locations, have been attempted in the Tar-Pamlico, Neuse, and Cape Fear rivers. Results from multiple treatments should be analyzed in the future to provide more precise guidance of future stocking decisions.

## APPENDIX 1.A. COOPERATIVE AGREEMENT BETWEEN USFWS, DMF AND WRC THAT ESTABLISHED THE CURRENT VERSION OF THE NORTH CAROLINA COASTAL STRIPED BASS STOCKING PROGRAM, 1986.

AGREEMENT NO. 14-16-0004-87-904

COOPERATIVE AGREEMENT

for Anadromous Species Restoration in Historically Significant

Coastal River Basins

Between

U.S. Fish and Wildlife Service

and

Department of Natural Resources and Community Development

and

North Carolina Wildlife Resources Commission

I. Purpose

THIS AGREEMENT is made and entered into by and between the Fish and Wildlife Service, United States Department of the Interior—hereinafter referred to as the "Service," and the Department of Natural Resources and Community Development and the North Carolina Wildlife Resources Commission—hereinafter referred to as the "State," to establish by mutual agreement the restoration of self-sustaining stocks of anadromous species in North Carolina coastal river basins. For the purposes of this agreement, anadromous species shall include striped bass, American shad, hickory shad, blueback herring, and alewife. Principal emphasis shall be on the restoration of self-sustaining stocks of striped bass. The State's authority to engage in this agreement is set forth in Gen. Stat. of NC §§ 113-181 (a) and NC §§ 113-224. The Government of the United States has expressed a national interest in maintaining our fishery resources and has authorized the Service through the Fish and Wildlife Coordination Act (16 U.S.C. 661-666c, as amended) and other related legislation to provide assistance and cooperate with other Federal agencies and the States in the maintenance and development of fishery resources, and has further expressed a particular interest in restoration of anadromous species such as striped bass on the east coast as demonstrated by the Chafee amendment to the Anadromous Fish Conservation Act (16 U.S.C. 757g, as amended) and the Atlantic Striped Bass Conservation Act (P.L. 98-613). The Service, through its Fishery Resources Program's Statement of Responsibilities and Role document, seeks to foster strong and mutually supportive linkages with the States and other Federal agencies to restore and protect depleted nationally significant interjurisdictional fishery resources, with particular emphasis on Atlantic and Gulf anadromous striped bass as well as other anadromous and migratory intercoastal/estuarine fishes.

This agreement also complements an intrast te agreement between the North Carolina Wildlife Resources C mmission and the Department of Natural Resources and Community Development concerning regulations and management of striped bass in Albemarle Sound and the Roanoke River.

II. Mutual Agreement

North Carolina waters are recognized as historically providing major contributions to the coastal stocks of anadromous fishes on the east coast.

River herring (blueback herring and alewife) stocks have declined drastically since the early 1970s, and recovery has been very slow, probably due to poor water quality in the Albemarle Sound spawning areas. Stocks of American shad are much below the levels of the 1960s and earlier throughout the south Atlantic coastal area. Striped bass stocks in North Carolina coastal waters have declined since the mid-1970s and are currently at extremely low levels. The Albemarle Sound stock, which has historically supported important recreational and commercial fisheries, is exceptionally depressed and has shown no ability to rebound.

The State and the Service entered into a pilot program in October 1979 to evaluate the potential for hatchery Phase II striped bass production and stocking to determine (1) effects on the commercial and recreational fisheries, and (2) contributions of stocked fish to spawning runs. Tagging returns, to date, have conclusively shown that these stocked fish have contributed to spawning runs and have recruited into the recreational and commercial fisheries.

The State has the responsibility to manage the fishery resources within its boundaries, including the mixed species fisheries which harvest anadromous fishes along with other species in coastal waters. The State has expressed a desire to continue to stock hatchery-reared striped bass fingerlings as a management tool in the restoration of this species, and the Service has the hatchery capability with which to assist the State in the production of striped bass.

It is the joint desire of the State and the Service to enter into a cooperative program to restore self-sustaining stocks of anadromous fishes in coastal North Carolina waters through a combination of fishery management techniques including stocking, regulations, and assessment.

Therefore, it is mutually agreed that:

1. The Service will produce Phase I and Phase II striped bass fingerlings based on restoration objectives established by the Service and the State for specific rivers in North Carolina.

2. The Service will provide facilities for holding and tagging striped bass, a hatchery truck to transport the fish to the release site(s), appropriate supervision in handling the fish to minimize mortality, and advisory personnel for the tagging project and related technical assistance efforts.

3. The State will provide personnel, tags and equipment for tagging the fish prior to release from hatcheries, tag rewards, and publicity on the cooperative program.

4. The State will evaluate survival and contribution of the hatchery fish to the population and spawning stocks and provide a report annually to the Service.

5. News releases on the cooperative restoration program initiated by the Service will receive prior approval from the State, and news releases initiated by the State will receive prior approval from the Service.

6. As an initial action, the cooperators will jointly develop a Striped Bass Restoration Plan for coastal North Carolina waters including goals, objectives, and milestones reflecting both the restoration as well as the maintenance of stocks. Restoration plans for other anadromous species such as American shad will be developed at a later date.

7. The Service will establish a Project Coordinator in North Carolina to provide liaison with the State for restoration purposes.

8. The principal signatory parties shall meet annually to review project progress and plan future activities.

9. A technical committee with representation from each signatory of this agreement shall meet quarterly and oversee the development of restoration plans and their implementation. Chairmanship of the technical committee will be rotated among the three cooperating agencies. Term of the chairman will be one year.

This agreement shall be contingent upon the availability of funds for the expenditures contemplated herein. The liability of the parties to this agreement, to each other, and to third persons shall be governed by applicable laws and regulations, now and hereafter in force.

The Equal Opportunity clause prescribed in 1-12.803-2 of the Federal Procurement Regulations is hereby incorporated into this agreement by reference and made a part thereof. No members of or delegate to Congress or Resident Commissioner shall be admitted to any share or part of this agreement, or to any benefit that may arise therefrom.

This agreement will become effective upon the date subscribed by the last signatory and shall continue in force from year to year until cancelled by any signatory party on 30 days' written notice to the other parties. The agreement and its addenda may be amended by mutual consent of all parties.

Date: 11/19/86 By: [signature]
S. Thomas Rhodes, Secretary
North Carolina Department of Natural Resources and Community Development

Date 12/1/86 By: [signature]
Charles R. Fullwood, Jr.
Executive Director
North Carolina Wildlife Resources Commission

Date 12/12/86 By: [signature]
James W. Pulliam, Jr.
Regional Director
U.S. Fish and Wildlife Service
Region 4, Atlanta, GA

TOTAL P.07

## APPENDIX 2: ACHIEVING SUSTAINABLE HARVEST FOR THE ALBEMARLE SOUND-ROANOKE RIVER STRIPED BASS STOCK

### ISSUE

Implement long term management measures to achieve sustainable harvest, end overfishing, and rebuild the Albemarle Sound-Roanoke River (A-R) striped bass spawning stock biomass.

### ORIGINATION

North Carolina Division of Marine Fisheries (DMF) and North Carolina Wildlife Resources Commission (WRC).

### BACKGROUND

#### Albemarle Sound-Roanoke River Striped Bass Stock Status

The 2020 A-R striped bass stock assessment was approved for management use by peer reviewers and the DMF for at least five years. Results indicate in the terminal year (2017) the A-R striped bass stock is overfished and overfishing is occurring, relative to the biological reference points (BRPs). Overfishing BRPs are based on a fishing mortality (*F*) rate of $F_{Target}$ = 0.13 and $F_{Threshold}$ = 0.18 and overfished BRPs are based on a level of spawning stock biomass (SSB) of $SSB_{Target}$ = 350,371 pounds and $SSB_{Threshold}$ = 267,390 pounds (Lee et al. 2020). In the terminal year of the assessment *F*=0.27, above the $F_{Threshold}$, meaning overfishing is occurring. Female SSB was 78,576 pounds, below the $SSB_{Threshold}$, indicating the stock is overfished. For more details, see the Amendment 2 Stock Status section and Lee et al. (2020).

The Fisheries Reform Act of 1997 requires management measures be enacted to end overfishing within two years and end the overfished status within 10 years with at least a 50% probability of achieving sustainable harvest (NCGS 113-182.1), with exceptions related to biology, environmental conditions, or lack of sufficient data. Amendment 1 to the North Carolina Estuarine Striped Bass FMP and Amendment 6 to the ASMFC Interstate FMP for Atlantic Striped Bass stipulate “Should the target *F* be exceeded then restrictive measures will be imposed to reduce *F* to the target level” (NCDMF 2013; ASMFC 2003). Therefore, adaptive management measures were implemented in January 2021 to reduce the total allowable landings (TAL) to 51,216 pounds, a level projected to lower *F* to the $F_{Target}$, in one year, and represents a 47.6% reduction in *F* (NCDMF 2020).

#### Striped Bass Management Areas and their Fisheries

The striped bass commercial and recreational fisheries in the ASMA and RRMA have been managed with a TAL since 1991 (Table 2.1). Combined landings from both commercial and recreational sectors in the ASMA and RRMA have ranged from 108,432 lb in 2013 to 460,853 lb in 2004. Landings followed the TAL closely until 2003 for the recreational sectors and 2005 for the commercial sector. During 2003–2014, when the TAL was increased to 550,000 lb, neither sector reached their TAL (Figure 2.1; Table 2.2). The low level of landings observed in some of these years was due to multiple poor year classes produced since 2001. For more information on the commercial and recreational fisheries see the Amendment 2 Description of the Fisheries section.

Table 2.1. Total allowable landings (TAL) in pounds for the Albemarle Sound and Roanoke River Management Areas (ASMA & RRMA) 1991–2021.

| Years | Total Allowable Landings (lb) | ASMA Commercial (lb) | ASMA Recreational (lb) | RRMA Recreational (lb) |
|---|---|---|---|---|
| 1991—1997 | 156,800 | 98,000 | 29,400 | 29,400 |
| 1998 | 250,800 | 125,400 | 62,700 | 62,700 |
| 1999 | 275,880 | 137,940 | 68,970 | 68,970 |
| 2000—2002 | 450,000 | 225,000 | 112,500 | 112,500 |
| 2003—2014 | 550,000 | 275,000 | 137,500 | 137,500 |
| 2015—2020 | 275,000 | 137,500 | 68,750 | 68,750 |
| 2021 | 51,216 | 25,608 | 12,804 | 12,804 |

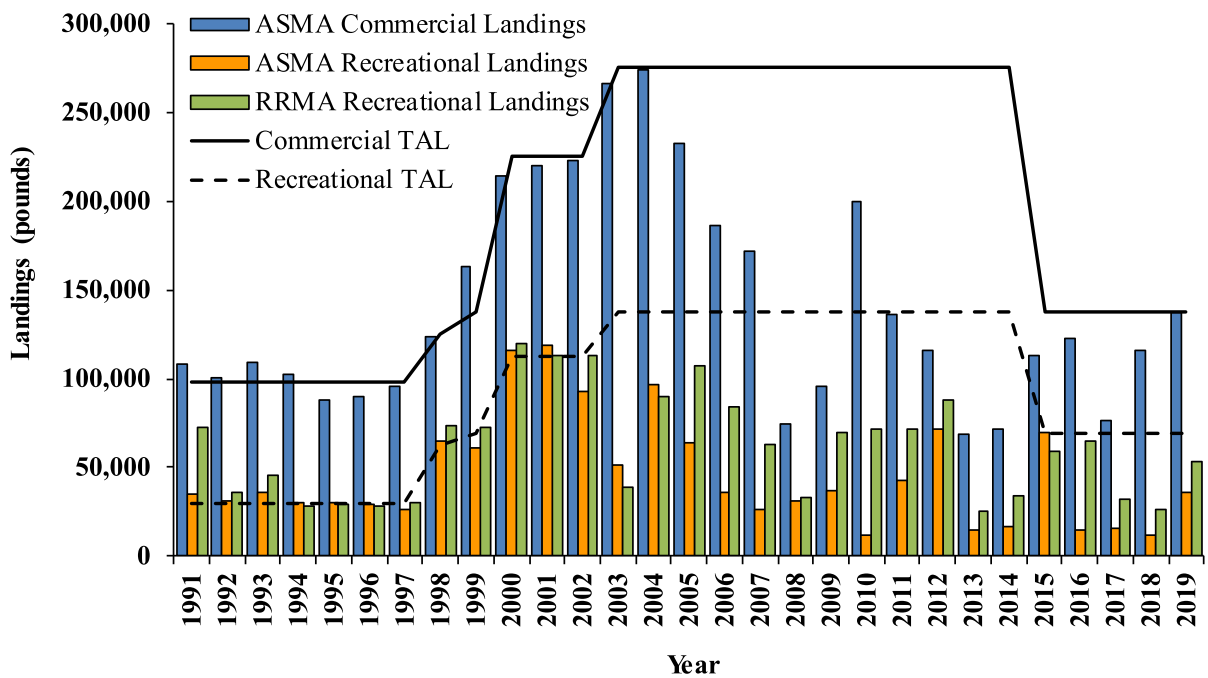


Figure 2.1. Striped bass landings from the Albemarle Sound Management Area (ASMA) commercial and recreational sectors, the Roanoke River Management Area (RRMA) recreational sector, and the annual total allowable landings (TAL) by sector, 1991–2019.

Table 2.2. Total allowable landings (TAL) and the annual harvest in pounds for striped bass from the commercial and recreational sectors in the Albemarle Sound Management Area (ASMA) and Roanoke River Management Area (RRMA). Bolded and underlined numbers indicate a TAL that was lowered due to previous year's overage, and red numbers in parentheses indicate landings that exceeded the respective TAL. (See NCDFM 1993, 2004)

| | ASMA Commercial | | | ASMA Recreational | | | RRMA Recreational | | | Total | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | TAL | Landings | (+)/- | TAL | Landings | (+)/- | TAL | Landings | (+)/- | TAL | Landings |
| 1991 | 98,000 | 108,460 | (10,460) | 29,400 | 35,344 | (5,944) | 29,400 | 72,529 | (43,129) | 156,800 | (216,333) |
| 1992 | 98,000 | 100,549 | (2,549) | 29,400 | 30,758 | (1,358) | 29,400 | 36,016 | (6,616) | 156,800 | (167,323) |
| 1993 | 98,000 | 109,475 | (11,475) | 29,400 | 36,049 | (6,649) | 29,400 | 45,145 | (15,745) | 156,800 | (190,669) |
| 1994 | 98,000 | 102,370 | (4,370) | 29,400 | 30,217 | (817) | 29,400 | 28,089 | 1,311 | 156,800 | (160,676) |
| 1995 | ***93,630*** | 87,836 | 5,794 | ***28,583*** | 30,564 | (1,981) | 29,400 | 28,883 | 517 | ***151,613*** | 147,283 |
| 1996 | 98,000 | 90,133 | 7,867 | ***27,419*** | 29,186 | (1,767) | 29,400 | 28,178 | 1,222 | ***154,819*** | 147,497 |
| 1997 | 98,000 | 96,122 | 1,878 | ***27,633*** | 26,581 | 1,052 | 29,400 | 29,997 | (597) | ***155,033*** | 152,700 |
| 1998 | 125,400 | 123,927 | 1,473 | 62,700 | 64,580 | (1,880) | 62,700 | 73,541 | (10,841) | ***250,800*** | (262,048) |
| 1999 | 137,940 | 162,870 | (24,930) | ***67,090*** | 61,338 | 5,752 | 68,970 | 72,967 | (3,997) | ***274,000*** | (297,175) |
| 2000 | ***200,070*** | 214,023 | (13,953) | 112,500 | 116,158 | (3,658) | 112,500 | 120,091 | (7,591) | ***425,070*** | (450,272) |
| 2001 | ***211,047*** | 220,233 | (9,186) | ***108,842*** | 118,506 | (9,664) | 112,500 | 112,805 | (305) | ***432,389*** | (451,544) |
| 2002 | ***215,814*** | 222,856 | (7,042) | ***102,836*** | 92,649 | 10,187 | 112,500 | 112,698 | (198) | ***431,150*** | 428,203 |
| 2003 | ***267,958*** | 266,555 | 1,403 | 137,500 | 51,794 | 85,706 | 137,500 | 39,170 | 98,330 | ***542,958*** | 357,519 |
| 2004 | 275,000 | 273,565 | 1,435 | 137,500 | 97,097 | 40,403 | 137,500 | 90,191 | 47,309 | 550,000 | 460,853 |
| 2005 | 275,000 | 232,693 | 42,307 | 137,500 | 63,477 | 74,023 | 137,500 | 107,530 | 29,970 | 550,000 | 403,700 |
| 2006 | 275,000 | 186,399 | 88,601 | 137,500 | 35,997 | 101,503 | 137,500 | 84,521 | 52,979 | 550,000 | 306,917 |
| 2007 | 275,000 | 171,683 | 103,317 | 137,500 | 26,663 | 110,837 | 137,500 | 62,492 | 75,008 | 550,000 | 260,838 |
| 2008 | 275,000 | 74,921 | 200,079 | 137,500 | 31,628 | 105,872 | 137,500 | 32,725 | 104,775 | 550,000 | 139,274 |
| 2009 | 275,000 | 96,134 | 178,866 | 137,500 | 37,313 | 100,187 | 137,500 | 69,581 | 67,919 | 550,000 | 203,028 |
| 2010 | 275,000 | 199,829 | 75,171 | 137,500 | 11,470 | 126,030 | 137,500 | 72,037 | 65,463 | 550,000 | 283,336 |
| 2011 | 275,000 | 136,266 | 138,734 | 137,500 | 42,536 | 94,964 | 137,500 | 71,561 | 65,939 | 550,000 | 250,363 |
| 2012 | 275,000 | 115,605 | 159,395 | 137,500 | 71,456 | 66,044 | 137,500 | 88,271 | 49,229 | 550,000 | 275,332 |
| 2013 | 275,000 | 68,338 | 206,662 | 137,500 | 14,897 | 122,603 | 137,500 | 25,197 | 112,303 | 550,000 | 108,432 |
| 2014 | 275,000 | 71,372 | 203,628 | 137,500 | 16,867 | 120,633 | 137,500 | 33,717 | 103,783 | 550,000 | 121,956 |
| 2015 | 137,500 | 113,475 | 24,025 | 68,750 | 70,008 | (1,258) | 68,750 | 58,962 | 9,788 | 275,000 | 242,445 |
| 2016 | 137,500 | 123,108 | 14,392 | 68,750 | 14,487 | 54,263 | 68,750 | 65,218 | 3,532 | 275,000 | 202,813 |
| 2017 | 137,500 | 75,990 | 61,510 | 68,750 | 15,480 | 53,270 | 68,750 | 32,569 | 36,181 | 275,000 | 124,039 |
| 2018 | 137,500 | 115,711 | 21,789 | 68,750 | 11,762 | 56,988 | 68,750 | 26,796 | 41,954 | 275,000 | 154,269 |
| 2019 | 137,500 | 137,156 | 344 | 68,750 | 29,005 | 39,745 | 68,750 | 53,379 | 15,371 | 275,000 | 219,540 |

Stock Concerns

Annual recruitment is influenced by spawning stock biomass, egg and larval transport to nursery areas, predation, food availability, and optimum water quality conditions. The occurrence of recruitment failures since 2001, especially since 2017, is thought to be a function of spring flooding events in the upper Roanoke basin during critical periods of egg and larval transport. Extended periods of flood or high flow releases during the critical spawning period (May through early June) negatively impact successful transport and delivery of eggs and fry down the Roanoke River and into the western Albemarle Sound nursery area. There is high year-to-year variability regarding flow releases and year-class strength. Consequently, all years with documented high flow rates (2017, 2018, 2020) had very low juvenile abundance index values, indicating poor spawning success (NCDMF 2020). It should also be noted the last year of data in the stock assessment was 2017, so poor recruitment from 2018–2021 impacts have not been modeled.

## AUTHORITY

The MFC and the WRC implemented a Memorandum of Agreement in 1990 to address management of the A-R striped bass stock in the Albemarle Sound and Roanoke River (see Appendix I in DMF 1993). This was the first agreement between the two agencies to jointly manage the A-R striped bass stock. North Carolina's existing fisheries management system for estuarine striped bass is adaptive, with rulemaking authority vested in the MFC and the WRC within their respective jurisdictions. The MFC also may delegate to the fisheries director the authority to issue public notices, called proclamations, suspending or implementing, in whole or in part, particular MFC rules. Management of recreational and commercial striped bass regulations within the ASMA are the responsibility of the MFC. Within the RRMA commercial regulations are the responsibility of the MFC while recreational regulations are the responsibility of the WRC. The commercial harvest of striped bass in the RRMA is prohibited by 15A NCAC 03M .0202 (b). It should also be noted that under the provisions of Amendment 1 to the North Carolina Estuarine Striped Bass FMP the DMF Director maintains proclamation authority to establish seasons, authorize or restrict fishing methods and gear, limit quantities taken or possessed, and restrict fishing areas as deemed necessary to maintain a sustainable harvest. The WRC Executive Director maintains proclamation authority to establish seasons.

### NORTH CAROLINA GENERAL STATUTES

*N.C. General Statutes*

| | |
|---|---|
| G.S. 113-132. | JURISDICTION OF FISHERIES AGENCIES |
| G.S. 113-134. | RULES |
| G.S. 113-182. | REGULATION OF FISHING AND FISHERIES |
| G.S. 113-182.1. | FISHERY MANAGEMENT PLANS |
| G.S. 113-221.1. | PROCLAMATIONS; EMERGENCY REVIEW |
| G.S. 113-292. | AUTHORITY OF THE WILDLIFE RESOURCES COMMISSION IN REGULATION OF INLAND FISHING AND THE INTRODUCTION OF EXOTIC SPECIES. |
| G.S. 143B-289.52. | MARINE FISHERIES COMMISSION—POWERS AND DUTIES |
| G.S. 150B-21.1. | PROCEDURE FOR ADOPTING A TEMPORARY RULE |

### NORTH CAROLINA RULES

*N.C. Marine Fisheries Commission Rules 2020 and N.C. Wildlife Resources Commission Rules 2020* (15A NCAC)

| | |
|---|---|
| 15A NCAC 03H .0103 | PROCLAMATIONS, GENERAL |

| | |
|---|---|
| 15A NCAC 03M .0201 | GENERAL |
| 15A NCAC 03M .0202 | SEASON, SIZE AND HARVEST LIMIT: INTERNAL COASTAL WATERS |
| 15A NCAC 03M .0512 | COMPLIANCE WITH FISHERY MANAGEMENT PLANS |
| 15A NCAC 03Q .0107 | SPECIAL REGULATIONS: JOINT WATERS |
| 15A NCAC 03Q .0108 | MANAGEMENT RESPONSIBILITY FOR ESTUARINE STRIPED BASS IN JOINT WATERS |
| 15A NCAC 03Q .0109 | IMPLEMENTATION OF ESTUARINE STRIPED BASS MANAGEMENT PLANS: RECREATIONAL FISHING |
| 15A NCAC 03Q .0202 | DESCRIPTIVE BOUNDARIES FOR COASTAL-JOINT-INLAND WATERS |
| 15A NCAC 03R .0201 | STRIPED BASS MANAGEMENT AREAS |
| 15A NCAC 10C .0107 | SPECIAL REGULATIONS: JOINT WATERS |
| 15A NCAC 10C .0108 | SPECIFIC CLASSIFICATION OF WATERS |
| 15A NCAC 10C .0110 | MANAGEMENT RESPONSIBILITY FOR ESTUARINE STRIPED BASS IN JOINT WATERS |
| 15A NCAC 10C .0111 | IMPLEMENTATION OF ESTUARINE STRIPED BASS MANAGEMENT PLANS: RECREATIONAL FISHING |
| 15A NCAC 10C .0301 | INLAND GAME FISHES DESIGNATED |
| 15A NCAC 10C .0314 | STRIPED BASS |

## DISCUSSION

The November 2020 Revision to Amendment 1 implemented a lower TAL calculated to end overfishing in one year. Management measures developed in Amendment 2 will be implemented to ensure long term sustainable harvest and end the overfished stock status within 10-years as required by law. If adopted in Amendment 2 adaptive management measures will allow the flexibility outlined in this issue paper.

Option 1. Manage for sustainable harvest through harvest restrictions

The General Statutes of North Carolina require that a FMP specify a time period not to exceed two years from the date of the adoption to end overfishing (G.S. 113-182.1). The statutes also require that a FMP specify a time period not to exceed 10 years from the date of adoption and at least a 50% probability to achieve a sustainable harvest. A sustainable harvest is attained when the stock is no longer overfished (G.S. 113-129). The statutes allow some exceptions to these stipulations related to biology, environmental conditions, or lack of sufficient data.

Sustainable harvest levels for the A-R striped bass stock have been determined using stock assessments and stock projections since the 1995 assessment (Gibson 1995).

Option 1.A. Continue to use stock assessments and stock assessment projections to determine the TAL that achieves a sustainable harvest for the A-R stock

A TAL is a management measure used to set harvest levels for a stock with the goal of preventing overfishing and ensuring the stock does not get in an overfished state. The 1991 TAL was set at 156,800 pounds, which was 20% of the average harvest from 1972–1979, (see Appendix I in NCDMF 1993). Under Amendment 1, the TAL for the A-R stock is determined through stock assessments and stock assessment projections. Projections are used to calculate the annual amount of harvest that maintains SSB at its target level and provides for long-term sustainable harvest. In the event the stock assessment results indicate fishing mortality is above the $F_{\text{Target}}$, adaptive management allows for calculation of a new TAL to reduce $F$ back to the $F_{\text{Target}}$ in one year, as was done with the November 2020 Revision to Amendment 1. Adaptive management allows managers to quickly address overfishing while allowing for and monitoring fishing. See adaptive management in this issue paper for more information on determining the TAL. The use of a TAL is a management option proven effective in recovery of the striped bass stock.

A key component of successfully using a TAL is the ability to accurately monitor recreational and commercial harvest in a timely manner and close fishing sectors when harvest is nearing the sector TAL. The DMF and WRC use agency-run creel surveys specifically designed to estimate recreational striped bass catch and effort in the ASMA and RRMA. Data is available 1–2 weeks after collection. It is important to note, harvest estimates calculated with one or two weeks of data have greater uncertainty than harvest estimates calculated monthly. Striped bass dealer permits are required for dealers to purchase commercially harvested striped bass and dealers must report daily the number and pounds of striped bass bought to the DMF. The ability to monitor harvest from the recreational and commercial sectors in a timely manner means the DMF and WRC have a greater likelihood of keeping annual harvest below the TAL in their respective management areas.

Flexibility in authority given to the DMF Director and the Executive Director of the WRC is used to prevent harvest from exceeding the TAL. Harvest seasons have been closed early in the RRMA by proclamation in years when the harvest estimate approached the TAL. Conversely, proclamation authority has also been used to extend the harvest season beyond April 30 by a few days. The decision to extend the season in the RRMA is based on availability of remaining landings within the TAL and environmental conditions, such as flood control operations and water temperatures. Due to much higher mortality of striped bass discards when the water temperature is warmer, both recreational and commercial harvest seasons have been closed during the summer months, typically May–September, since 1991.

Daily possession limits for the recreational and commercial sectors have been used since 1991 to limit or expand harvest opportunities and keep landings below the TAL. The DMF Director has proclamation authority to change the daily possession limits in the ASMA throughout the harvest seasons. The WRC can change daily possession limits and size limits in the RRMA through permanent or temporary rulemaking processes. In the absence of proclamation authority to change size limits or creel limits, temporary rulemaking can be used by the WRC to expedite conservation measures. Recreational sector daily possession limits have ranged from 1 to a maximum of 3 fish per person per day since 1991. Daily possession limits for the commercial sector have ranged from 3–25 fish per day per commercial operation.

Over the long-term, combined use of a TAL with other management measures has maintained landings in the A-R striped bass fisheries below or near the TAL. However, if actual recruitment is less than the estimated recruitment used in projections, stock abundance will not support harvest of the TAL and the $F_{\text{Target}}$ may be exceeded and SSB may fall below the $\text{SSB}_{\text{Threshold}}$, as the 2020 stock assessment currently indicates. Continuing use of a TAL with the ability to monitor harvest, adjust harvest seasons, and change daily possession limits to provide the greatest likelihood of keeping harvest below the TAL allows a balance of conservation needs and stakeholder access to the resource while the stock is rebuilding.

Option 1.B. Implement a harvest moratorium

A complete harvest moratorium could potentially recover the striped bass stock more quickly than if a low level of harvest is allowed. However, any anchored, set gill net fisheries occurring in the ASMA and recreational catch-and-release for striped bass, will continue to contribute to discard mortality. Discard mortality in the anchored set gill net fishery for American shad would be substantial if that fishery was to continue to operate with a striped bass harvest moratorium in the ASMA. If poor environmental conditions persist on the spawning grounds during May and early June, recovery may not occur even with a harvest moratorium.

The A-R stock has experienced several years of poor recruitment since 2000. The juvenile abundance index (JAI) during 2017–2020 indicated few eggs and larval striped bass survived. However, the recent five years of poor recruitment (2017–2021) do not compare to chronic spawning failures the stock experienced during 1978–1992 (Figure 2.2). When a TAL was implemented in 1991, it was set at nearly three times the 2021 TAL. In 2014 and 2015, the stock produced year classes above the long-term average level of recruitment (FMP Figure 2), indicating that with favorable environmental conditions during the spawning period the stock can produce strong year classes even during periods of low SSB. Based on past trends, stock abundance can increase quickly under the right conditions. The 2020 stock assessment indicated SSB increased from 145,962 pounds in 1996 to above the $SSB_{Target}$ (350,371 pounds) in two years (FMP Figure 2.3). However, future stock conditions, driven by continued poor recruitment and decreasing stock abundance, may warrant a harvest moratorium.

Projections evaluated overfishing with trends in SSB under the existing TAL and a complete harvest moratorium. Discards were assumed equal to the terminal year of the stock assessment and three recruitment scenarios were input to account for the uncertainty and the variability of recruitment observed in the stock; 1) the average level of recruitment for the entire time series of the assessment, 1991–2017, 2) a high level of recruitment observed in years 1991–2001, and 3) a low level of recruitment as observed in years 2004–2017. Under the harvest moratorium the stock would no longer be overfished in 2024, while under the current TAL the stock would no longer be overfished in 2026 (Figure 2.3).

Option 2. Management of striped bass harvest in the commercial fishery as a bycatch fishery

The commercial fishery for striped bass in the ASMA has been managed as a bycatch fishery since 1995. Often the term “bycatch” is associated with species captured in a fishing operation that were not intended and are discarded and is generally considered something that should be avoided. However, a bycatch fishery management strategy in multi-species fisheries means a portion of overall landings must be landed in order to land striped bass. The striped bass bycatch provision requires 50% of commercial landings by weight be other finfish species.

The bycatch provision was implemented as a management tool in the ASMA striped bass commercial fishery to prevent fishers not already participating in the American shad and southern flounder gill net fisheries from entering to specifically target striped bass. The idea being, that if additional participants entered the striped bass fishery, the TAL would be caught more quickly and the large mesh gill net fisheries continuing to operate would have higher numbers of striped bass discards. However, daily landings limits discourage fishers from targeting striped bass in the same fashion, making it less profitable to sell only striped bass each day without additional finfish catch.

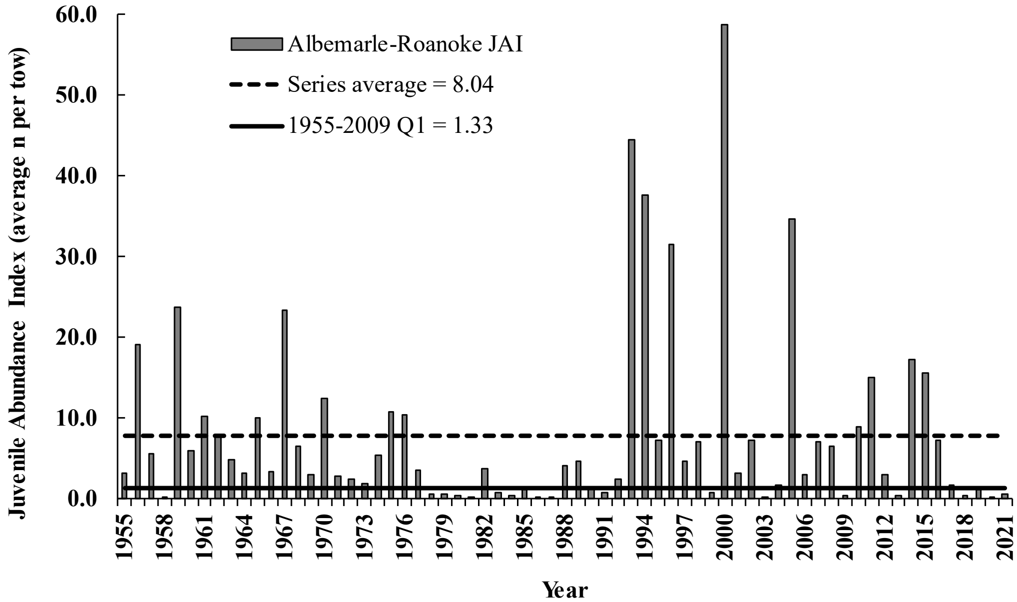


Figure 2.2. The juvenile abundance index (JAI) for Albemarle Sound-Roanoke River striped bass, North Carolina, 1955–2021. A JAI value below the first quartile (Q1 solid black line) is considered a spawning failure.

The gill net fisheries have changed considerably since the early 1990s and the bycatch provision may no longer be necessary. The number of participants that landed striped bass in the ASMA peaked at nearly 450 in 2000 but has decreased to just more than 150 in 2019. The number of fishers and trips taken each year in the American shad and flounder gill net fisheries has also declined steadily to less than 83 and 143 participants respectively in 2019 (Tables 2.3 and 2.4). The harvest season for American shad since 2015 has been March 3–March 24, whereas prior to 2015 it was open January 1–April 14. Floating gill nets are not allowed in the ASMA outside of shad season. In addition, the harvest season for southern flounder in 2021 was September 15–October 1 in the ASMA, whereas the harvest season previously was open 11–12 months each year.

Currently, gill nets configured for harvesting flounder are removed from the water when flounder harvest season is closed (NCDMF 2019).

If the bycatch provision for harvesting striped bass were removed, it is possible there would not be a significant increase in participants in the striped bass fishery because the daily landings limit and TAL would still apply. Removing the bycatch provision associated with harvesting striped bass makes it easier to allow hook and line as a commercial gear (see the Hook and Line Issue Paper for more information). If, however, the option is chosen to stop requiring 50% of other finfish species associated with striped bass harvest, and a large number of participants did enter the fishery, adaptive management could stipulate the DMF Director may reinstitute the bycatch requirements at any time through proclamation authority. There has also been concern expressed from some commercial participants that removing the bycatch provision could potentially reduce the price per pound of striped bass and/or some of the most commonly landed species associated with striped bass catch. Since 2010 the top five species landed on trip tickets along with striped bass in the ASMA include southern flounder, American shad, white perch, catfishes, striped mullet, yellow perch, and spotted seatrout.

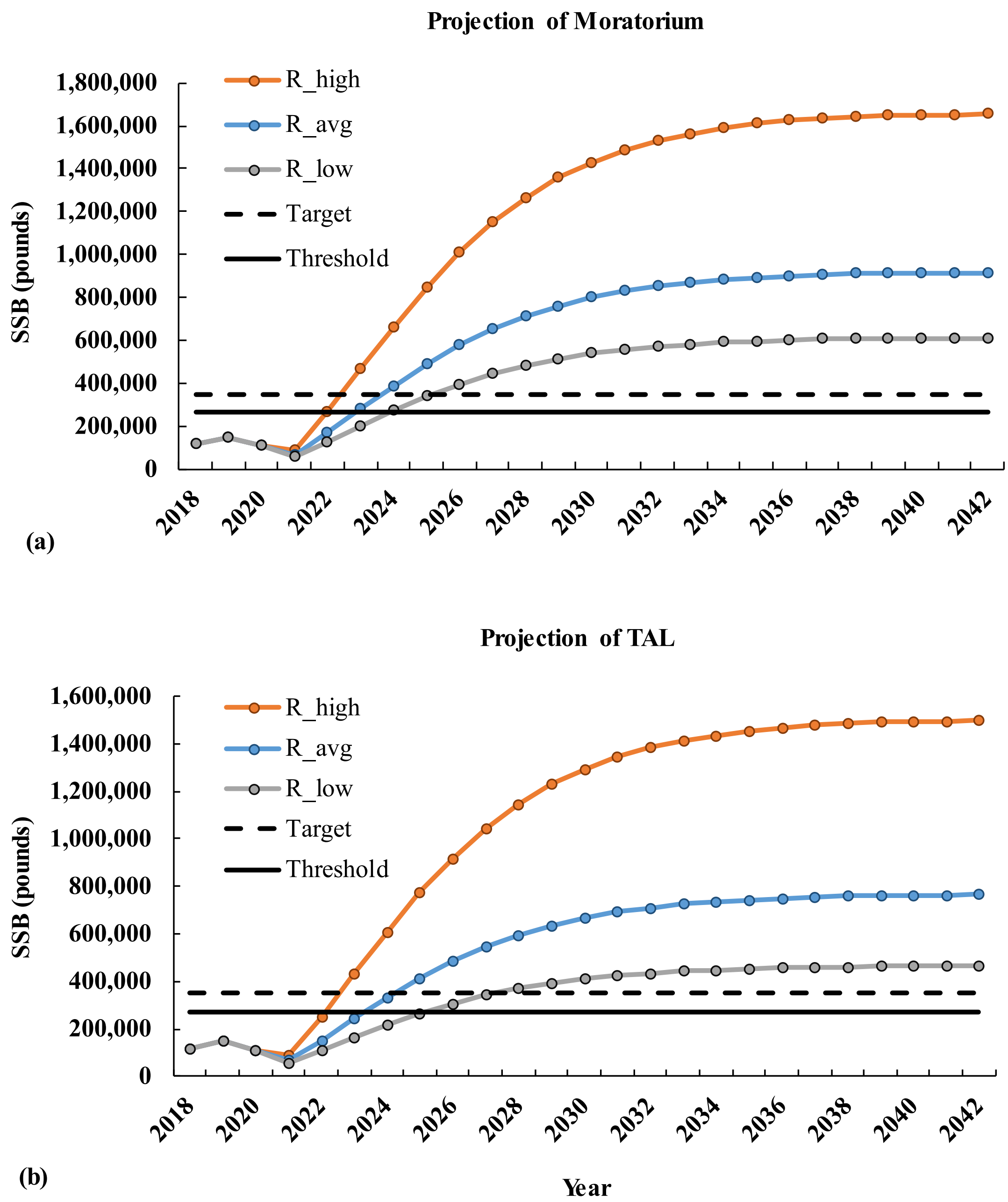


Figure 2.3. Projections of spawning stock biomass (SSB) in pounds for the Albemarle Sound-Roanoke River striped bass stock under the current total allowable landings (TAL) of 51,216 lb (a) and a harvest moratorium (b). Average recruitment (R_avg), low recruitment (R_low), and high recruitment (R_high) refer to the three recruitment scenarios used in the projections.

Table 2.3. Number of gill net trips, number of participants, total pounds of seafood landed, and dockside value from gill net trips that landed American shad in the ASMA, 2010–2019.

| Year | Trips | Participants | Seafood sold (lb) | Dockside value |
|---|---|---|---|---|
| 2010 | 2,520 | 176 | 539,233 | $444,350 |
| 2011 | 1,960 | 138 | 481,801 | $384,421 |
| 2012 | 1,922 | 139 | 391,407 | $368,776 |
| 2013 | 1,953 | 132 | 411,081 | $436,262 |
| 2014 | 714 | 92 | 206,733 | $153,559 |
| 2015 | 817 | 98 | 252,993 | $193,043 |
| 2016 | 587 | 73 | 178,947 | $150,806 |
| 2017 | 601 | 73 | 167,906 | $148,854 |
| 2018 | 387 | 55 | 109,855 | $96,226 |
| 2019 | 690 | 83 | 215,279 | $167,537 |

Table 2.4. Number of gill net trips, number of participants, total pounds of seafood landed, and dockside value from gill net trips that landed southern flounder in the ASMA, 2010–2019.

| Year | Trips | Participants | Seafood sold (lb) | Dockside value |
|---|---|---|---|---|
| 2010 | 5,389 | 323 | 801,426 | $1,111,612 |
| 2011 | 1,990 | 204 | 325,799 | $327,779 |
| 2012 | 5,661 | 324 | 821,383 | $1,558,772 |
| 2013 | 7,417 | 335 | 1,202,078 | $2,210,127 |
| 2014 | 5,772 | 297 | 818,565 | $1,373,840 |
| 2015 | 3,289 | 234 | 506,042 | $819,664 |
| 2016 | 2,306 | 181 | 368,867 | $613,572 |
| 2017 | 3,321 | 193 | 368,709 | $894,733 |
| 2018 | 2,681 | 164 | 294,802 | $682,719 |
| 2019 | 2,001 | 143 | 259,438 | $486,475 |

Option 3. Accountability Measures to Address TAL Overages

Fisheries managed with a TAL commonly include accountability measures to address situations when the TAL is exceeded. One common and simple option is to subtract the number of pounds the TAL was exceeded in one year from the following year's TAL. A more complex option is to adapt accountability measures to current stock status. For example, if *F* and SSB targets are being met, accountability measures may include management measures to reduce harvest the following year without subtracting overages from the TAL. However, if the stock is in an overfished or overfishing state accountability measures will be more conservative.

In most quota-managed fisheries, unused quota is not added to the following year's quota. The reasoning for this is twofold: 1) any amount of uncaught quota will benefit the stock in the long-term and 2) if the quota is not being caught because stock abundance is declining and can no longer support the current quota, then increasing the quota also increases the likelihood of causing the stock to become overfished and/or cause overfishing to occur. The TAL for the A-R striped bass stock in Amendment 1 is allocated with a 50/50 split to the recreational and commercial fisheries. The ASMA commercial fishery receives 50% of the TAL with the RRMA recreational and the ASMA recreational fisheries each receiving a 25% allocation of the TAL. The current accountability measures for TAL overages under Amendment 1 are:

<u>Short-term Overages:</u> point harvest estimate exceeds the total TAL by 10 percent in a single year, overage deducted from the next year and restrictive measures implemented in the responsible fishery(ies).

<u>Long-term Overages:</u> five year running average of point estimate exceeds the five-year running average of the total TAL harvest by 2 percent, the responsible fishery exceeding the harvest limit will be reduced by the amount of the overage for the next five years.

The requirement that harvest must exceed the total TAL by 10% before a reduction in the succeeding year's TAL is imposed was adopted in the 2004 FMP and re-adopted in Amendment 1 (NCDMF 2013). The rationale was that because recreational harvest estimates are generated from a statistical survey with uncertainty it was argued that as long as the lower bounds of the harvest estimate encompassed the TAL, then the harvest estimate was not statistically different from the TAL, and there was no overage to repay. The 10% buffer is roughly equivalent to a 90% confidence interval when PSE = 10%, which indicates the point estimate lies within the reported range with 90% certainty. In order to keep a buffer to account for the uncertainty in the recreational creel estimates yet recognize the need to ensure harvest levels are sustainable, an additional option for the short-term overages is to reduce the TAL buffer from 10% to 5%. In this situation with such a low buffer the PDT feels there will not be a need to address long-term overages. A third option is to evaluate overages and potential paybacks for each of the management area's fishery(ies) TAL individually rather than the evaluating at the level of the combined TAL. The final and most conservative option is to remove the buffer altogether and use the point estimate of harvest to determine if the TAL has been exceeded and subtract any overages from the succeeding year's TAL.

Option 4. Size limits to expand the age structure of the stock

Size limits are a common management measure to limit and focus harvest on a specific size and age class(es) of fish in the stock. The overall management objectives for a stock and associated fisheries and the life history of the species inform managers of what size limit should be implemented. By setting a minimum size limit based on length at maturity, managers can ensure a portion of the females in the stock have a chance to spawn at least once before harvest. For long-lived fish, a slot limit ensures fish that grow out of the slot will reproduce many times. Female A-R striped bass are 27% mature at age-3 and 97% mature by age-4. The length at maturity is 50% mature at 16.8 inches and 100% mature at 18.8 inches (Boyd 2011; Table 2.5). The current minimum size limit of 18 inches total length (TL) ensures about 75% of females have spawned at least once before subject to harvest.

Table 2.5. Percent mature at age and length (inches) of female Albemarle-Roanoke striped bass.

| Percent Mature at Age | | Percent Mature at Length | |
|---|---|---|---|
| Age | Percent Mature | Length | Percent Mature |
| 1 | 0% | 16.8 | 50% |
| 2 | 1% | 17.4 | 75% |
| 3 | 27% | 18.8 | 100% |
| 4 | 97% | | |
| 5+ | 100% | | |

It is critical to the resiliency of the stock (i.e., the ability to recover SSB after times of poor recruitment), that to maintain a wide range of age classes in the population. Stocks with multiple age classes can withstand several years of poor spawning success. A-R striped bass of 23 and 31 years of age have been observed in the past 5 years based on tag return data from fish tagged on the spawning grounds. Female striped bass also produce more eggs and of higher quality as they get older (Boyd 2011). Female striped bass from the A-R stock produce between 176,873–381,998 eggs at ages 3–6. For ages 8–16, egg production ranges from 854,930 to 3,163,130 eggs (Boyd 2011; Figure 2.4).

Secor (2000) suggested striped bass populations can persist during long periods of poor recruitment due to a long reproductive life span as demonstrated by the presence of fish greater than 30 years of age. This longevity and abundance of older fish provided stock resiliency against an extended period of recruitment overfishing. Marshall et al. (2021) indicated that even when rare in a stock, large fish make very strong contributions to total egg production. They also noted harvest slots with minimum and maximum size limits are a way of maintaining large-sized fish within a population, especially if commercial fisheries use gear types which target within the slot size. The different role in replenishment that larger fish play should be better recognized and incorporated in future management approaches to (Marshall et al. 2021).

Increasing minimum size limits will increase the number of dead discards in the recreational and commercial sectors. Most fish harvested in the ASMA recreational sector are between 18–22-inches (Figure 2.5) even though anglers have no upper harvest size limit like in the RRMA. The same is true in the RRMA due to the 18–22-inch TL harvest slot limit and limiting possession to 1 fish greater than 27 inches (Figure 2.6). The fish harvested in the ASMA commercial fishery have a wider length distribution compared to the recreational harvest (Figure 2.7). If the minimum size limit is increased, a significant percentage of harvest will turn into discards, of which a proportion will die. Research from a gill net study in Delaware determined 43% of fish released alive died (ASMFC stock assessment citation). Depending on salinity at the study location and the time of year of numerous hook and line studies, delayed mortality estimates range from 6.4% to 74% (Wilde et al. 2000).

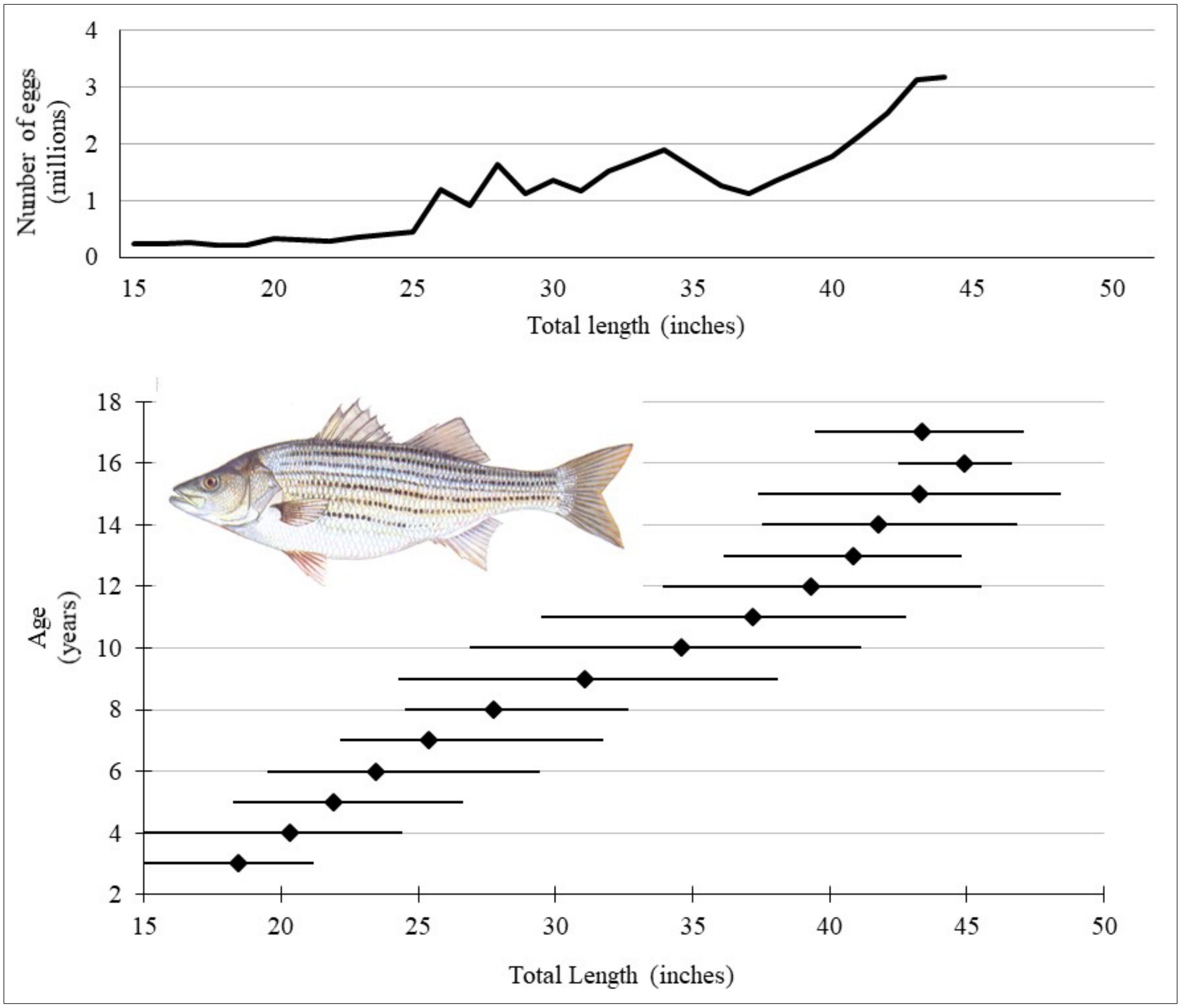


Figure 2.4. Number of eggs produced by female Albemarle-Roanoke striped bass at age and the average length of female striped bass at age. The diamond represents the average total length, and the lines represent the minimum and maximum observed length. Number of eggs at age data from Boyd 2011. Length at age based on annual spawning stock survey in the Roanoke River near Weldon (WRC data).

A harvest slot limit will increase the number of older fish in the population. However, if the slot limit is too wide, savings may be insignificant. A slot limit too narrow will result in additional dead discards if fishing practices do not match the selected slot size. Commercial sampling in the ASMA indicates 86% of the striped bass measured were below 25 inches (Figure 2.9). An 18–25-inch TL harvest slot size limit would include most of the current harvest in both the recreational and commercial sectors and not lead to significant increases in discards, while protecting fish once they grow out of the slot to increase abundance of older and larger striped bass in the A-R stock.

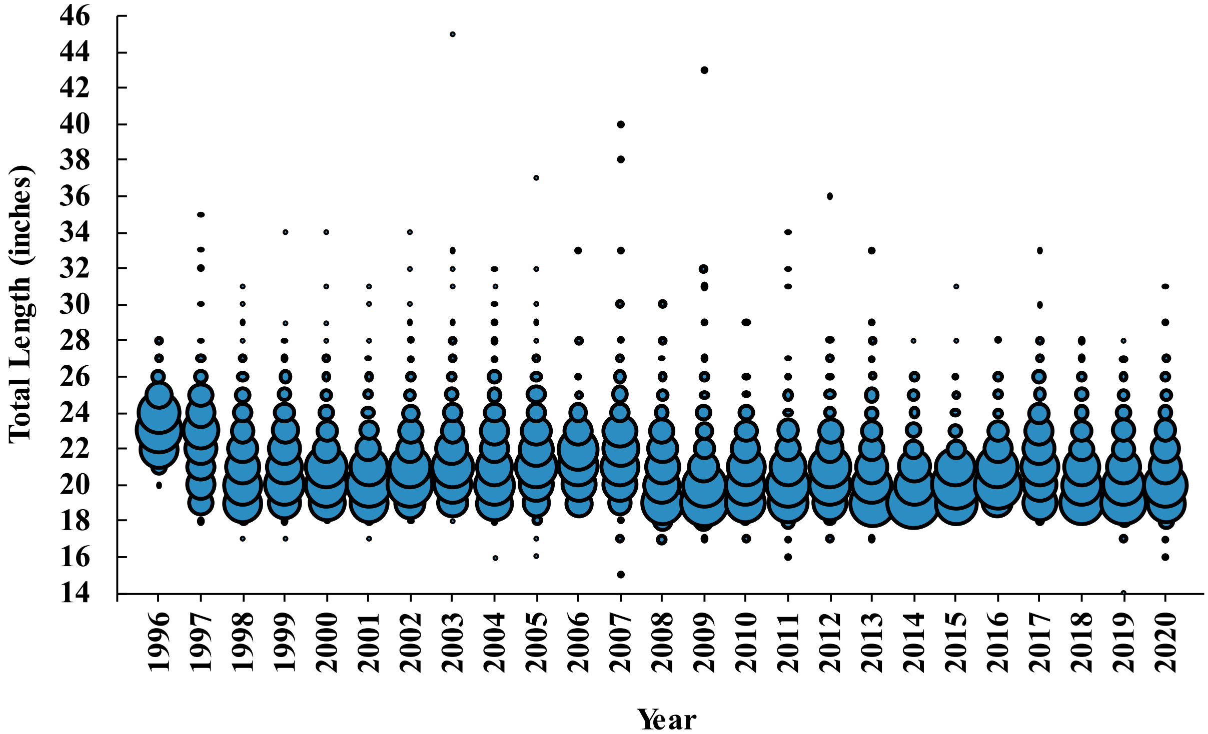


Figure 2.5. Recreational length frequency (total length, inches) of striped bass harvested in the ASMA, NC, 1996–2020. Bubble size represents the proportion of fish at length.

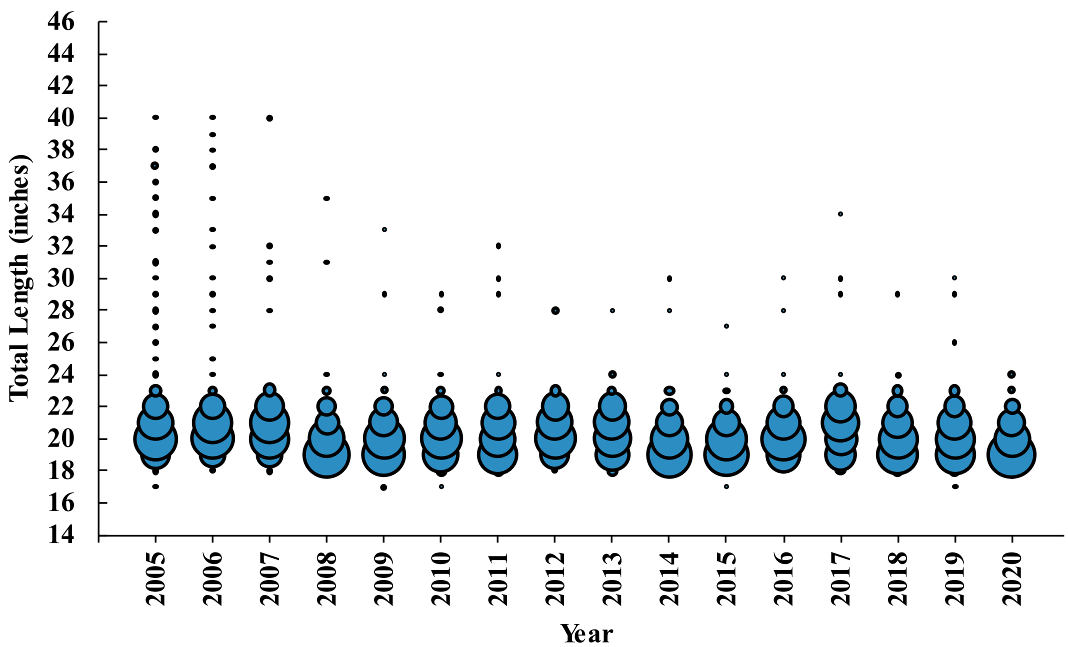


Figure 2.6. Recreational length frequency (total length, inches) of striped bass harvested in the RRMA, NC, 2005–2020. Bubble size represents the proportion of fish at length.

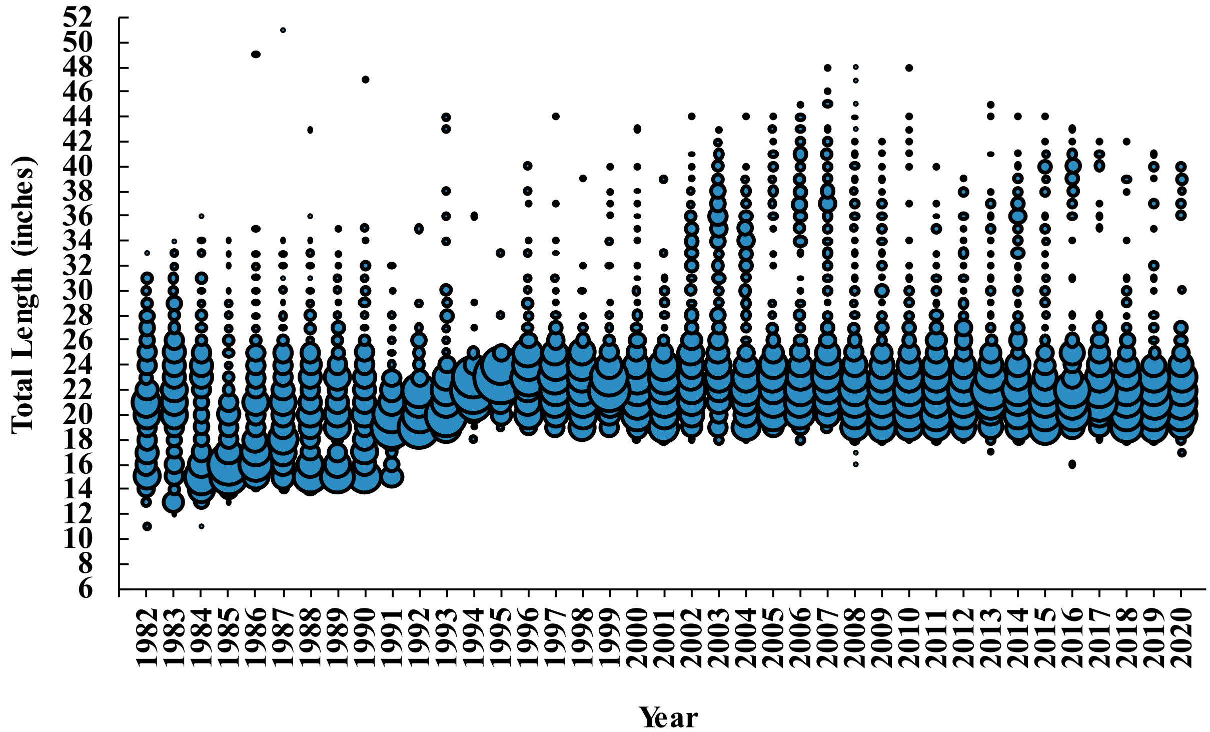


Figure 2.7. Commercial length frequency (total length, inches) of striped bass harvested in the ASMA, NC, 1982–2020. Bubble size represents the proportion of fish at length.

Option 5. Gear modifications and area closures to reduce discard mortality

Commercial Fisheries

To reduce discard mortality from gill nets, gear modifications have included: reducing maximum yardage allowed, restricting mesh sizes, attendance requirements, not allowing harvest during the summer months when water temperatures are higher and discard mortality increases significantly, and requiring tie-downs in the flounder fishery.

Area closures are another tool used to reduce discard mortality. Since 1987 the mouth of the Roanoke River from Black Walnut Point to the mouth of Mackey's Creek has been closed to the use of all gill nets during times of the year when striped bass are present in large concentrations and/or water temperatures are warmer and discard mortality will be high. Other closures have eliminated the use of small mesh gill nets in shallow waters close to shore to reduce undersized discards from large year classes.

The MFC requested analysis to reduce striped bass discard mortality through the elimination of gill net use in the ASMA. While such a measure cannot be pursued in the Estuarine Striped Bass FMP, the MFC does have the authority to eliminate harvest of striped bass with gill nets. However, if the gill net fisheries for American shad and flounder continue, and striped bass cannot be retained, striped bass discards will still occur and will increase. If the large mesh gill net fisheries in the ASMA that create unacceptable levels of striped bass discards are eliminated, serious economic impacts will occur to numerous fishers currently participating in these fisheries. The number of gill net trips, number of participants, pounds of seafood landed at dealers, and dockside value associated with the American shad and southern flounder fisheries in the ASMA are presented in Tables 2.3 and 2.4. The number of gill net trips, number of participants, pounds of seafood landed at dealers, and the dockside value associated with all of the gill net trips (large and small mesh) in the ASMA are presented in Table 2.8.

Table 2.8. Number of gill net trips, number of participants, total pounds of seafood landed, and dockside value from all gill net trips in the ASMA, 2010–2019.

| Year | Trips | Participants | Seafood sold (lb) | Dockside value |
|---|---|---|---|---|
| 2010 | 11,691 | 420 | 2,003,385 | $1,972,341 |
| 2011 | 7,484 | 370 | 1,673,071 | $1,280,433 |
| 2012 | 10,253 | 427 | 1,860,312 | $2,316,010 |
| 2013 | 13,685 | 432 | 2,188,732 | $3,199,403 |
| 2014 | 9,164 | 396 | 1,607,618 | $1,903,979 |
| 2015 | 7,855 | 336 | 1,614,889 | $1,578,145 |
| 2016 | 6,001 | 268 | 1,012,693 | $1,108,990 |
| 2017 | 6,678 | 284 | 1,269,011 | $1,521,611 |
| 2018 | 6,340 | 273 | 1,318,485 | $1,349,733 |
| 2019 | 5,822 | 234 | 1,307,117 | $1,148,976 |

At the MFC August 2021 business meeting, a motion passed relative to the Small Mesh Gill Net Rules Modification Information Paper which stated, *"to not initiate rulemaking on small mesh gill nets but refer the issue to the FMP process for each species, and any issues or rules coming out of the FMP process be addressed at that time".* The Information Paper focused mainly on options that could be implemented to address small mesh gill nets south of Gill Net Management Unit A (roughly the same area as the ASMA), as small mesh gill nets have a long history of being regulated more strictly in the Albemarle Sound area because of the concern over the striped bass stocks during the 1970s–1980s.

Some of the earliest small mesh gill net rules were implemented through proclamation authority in the Albemarle Sound region as early as 1979 (see Appendix 3, 2004 N.C. Estuarine Striped Bass FMP). The intent of issuing small mesh gill net regulations from 1979–1990 was focused on reducing striped bass harvest rather than reducing discards, as the minimum size for striped bass was still 12 inches TL for the commercial sector. Starting in 1991 when the minimum size limit increased to 18 inches TL and a TAL was implemented in the ASMA, the focus of small mesh gill net regulations shifted to reducing dead discards, as most striped bass captured in small mesh nets are under 18 inches TL.

The various gill net regulations implemented in the ASMA since 1979 have focused on closing areas during times of high striped bass concentrations, restricting mesh sizes, requiring tie-downs in deep water for both large and small mesh nets, and implementing mandatory attendance of small mesh gill nets (NCDMF 2004). The mandatory attendance serves a dual purpose to reduce dead discards and reduce effort.

The target species in the anchored, multi-species small mesh gill net fishery in the ASMA has changed significantly over the past 30 years. The biggest change was the moratorium on the harvest of river herring in 2008 (NCDMF 2007 RH FMP). Trip ticket data that included landings of river herring, white perch, striped mullet, spotted seatrout, yellow perch, and spot were used as a proxy to determine a small mesh gill net trip in the ASMA. Analysis indicates an overall, steady decline of anchored, small mesh gill net trips in the ASMA from a high of 9,490 trips in 1999 to a low of 1,589 trips in 2018 (Figure 2.8).

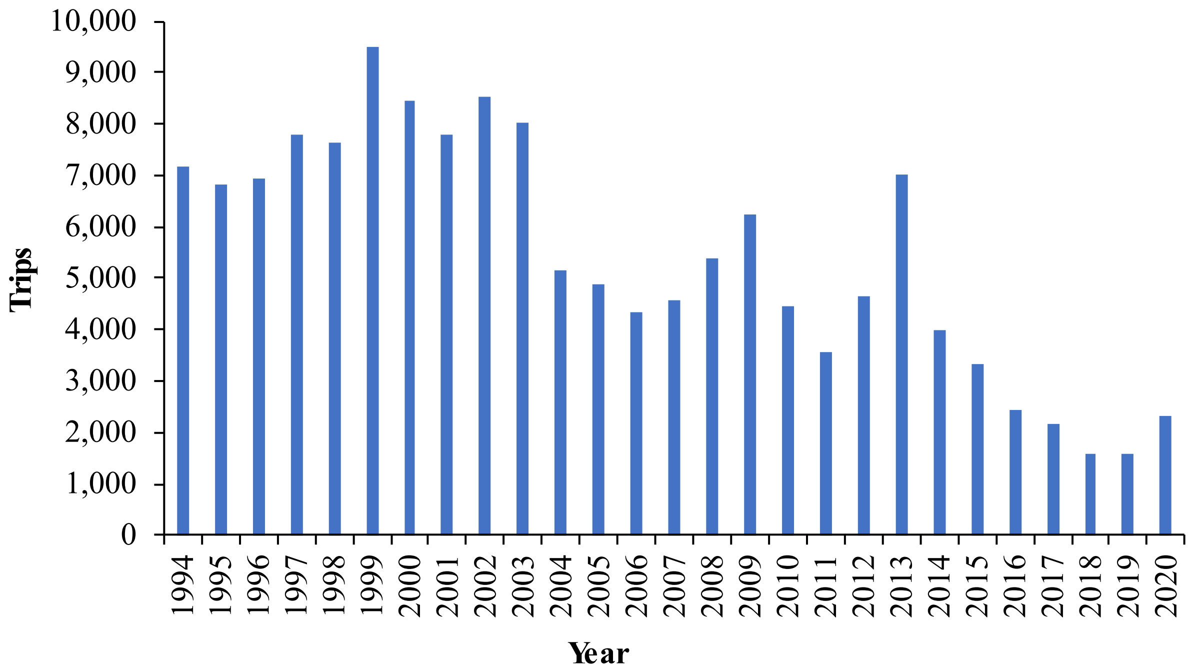


Figure 2.8. Number of anchored gill net trips in the ASMA that landed either river herring, white perch, striped mullet, spotted seatrout, yellow perch, or spot. These species were selected to determine a "small mesh" gill net trip in the ASMA.

Estimating striped bass dead discards in the small and large mesh gill net fisheries in the ASMA is part of the annual compliance with the ASMFC Interstate FMP for striped bass since 1994. The method for estimating striped bass discards has changed through the years based on available on-board observer coverage. Amendment 1 contains a detailed discussion of the methods (NCDMF 2013). Since 2012, striped bass released alive from gill nets have a 48% delayed mortality rate applied. A detailed explanation of discard modeling can be found in the A-R striped bass stock assessment (Lee et al. 2020). Dead discards in the ASMA large and small mesh gill net fisheries have averaged 1,870 fish per year with a high of 6,429 fish in 2013 and a low of 1,175 fish in 2019 (Table 2.9).

Table 2.9. Number of striped bass dead discards from large and small mesh anchored gill net fisheries in the ASMA estimated from on-board observer data and trip ticket data.

| Year | Large Mesh (N) | Small Mesh (N) |
|---|---|---|
| 2012 | 1,607 | 3,419 |
| 2013 | 1,846 | 4,583 |
| 2014 | 1,028 | 2,850 |
| 2015 | 1,600 | 3,814 |
| 2016 | 1,311 | 2,854 |
| 2017 | 1,695 | 2,260 |
| 2018 | 778 | 976 |
| 2019 | 465 | 709 |
| 2020 | 409 | 1,457 |

Recreational Fisheries

Since 1997, WRC has required use of single barbless hooks for all anglers during the striped bass spawning season in the inland portions of the RRMA to reduce discard mortality. Reducing discard mortality in the RRMA is particularly important due to recreational fishery discards being many times greater than harvest. Barbless hooks reduce discard mortality by reducing the time it takes an angler to remove the hook from fish and by reducing the damage to the mouth of fish (Nelson 1994).

Use of circle hooks and barbless treble hooks to reduce discard mortality of fish is gaining popularity among the recreational fishing industry. DMF staff presented information on the efficacy of using circle hooks and bent-barbed treble hooks to reduce discard mortality of captured-and-released fish to the MFC at its May 2020 business meeting (see Information on requiring the use of circle hooks and bent-barbed treble hooks in North Carolina NCDMF 2020a). Circle hooks reduce discard mortality compared to traditional J hooks because fish are much less likely to get deep hooked (Cook et al. 2021; Kerstetter and Graves 2006). Circle hooks are required in the Atlantic Ocean waters of North Carolina when fishing for striped bass or sharks and using natural bait. Amendment 1 to the North Carolina Red Drum FMP (NCDMF 2008) requires the use of circle hooks in certain times and areas of the Pamlico Sound when anglers target large red drum using natural bait to reduce deep hooking and release mortality (Aguilar 2003, Beckwith and Rand 2004).

Although less research has been done on the effects of bent or barbless treble hooks on the survival of captured-and-released fish, the same reasons are thought to reduce hook trauma when using single barbless hooks applies. However, as noted in the May 2020 circle hook information paper, the promotion of barbless treble hooks as a conservation measure has largely been replaced by the use of single inline hooks instead of treble hooks on artificial lures. Use has been encouraged for a variety of reasons including: less damage to fish, ease of unhooking, fish hooked more securely, less likely to collect grass or debris, and angler safety. Many manufacturers have started selling lures rigged with single hooks. This trend is being driven by the tackle industry, retailers, and conservation-minded anglers (NCDMF 2020a).

Area closures could also be implemented in the recreational fisheries to reduce striped bass discards. Catch-and-release fishing for striped bass during the closed harvest season is popular in several areas, including the old Manns Harbor Bridge in Manteo, the highway 32 bridge crossing the Albemarle Sound at Pea Ridge, Corey's Ditch located in the Mackay Island National Wildlife Refuge in Currituck, and in the Roanoke River. While data do not exist to determine the exact extent of economic losses, closing areas to the use of recreational hook and line when striped bass harvest is not allowed would impact numerous industries that rely in part or whole on recreational fishing. Closing an area to targeting striped bass is unenforceable.

An area closure on the spawning grounds to eliminate the harvest and catch-and-release of striped bass as they gather in large numbers and spawn also serves to reduce discard mortality. Releases after the harvest period has closed on the spawning grounds has ranged from 9,754–271,328 fish (FMP Table 5). Closing the spawning grounds to the harvest of fish is a common practice in many fisheries to protect the spawning stock, although there is no research on the impacts of catch-and-release fishing on the quality or amount of egg production for striped bass. Based on experience, the A-R striped bass stock has recovered from low stock abundance and produced strong year classes under catch-and-release fishing practices on the spawning grounds.

Option 6. Adaptive management

Adaptive management is a structured decision-making process when uncertainty exists, with the objective to reduce uncertainty through time with monitoring. Adaptive management is based on a learning process to improve management outcomes (Holling 1978). Adaptive management provides flexibility to incorporate new information and accommodate alternative and/or additional actions. As flexibility increases, so do the resources needed to acquire and analyze data, as well as to implement and enforce complexities of management. These elements create trade-offs that must be balanced for all users.

The ASMFC uses annual juvenile abundance indices as an indicator of year class strength and a trigger for management evaluations (ASMFC 2010). If the JAI is below 75% of the other JAI values for three consecutive years, the ASMFC Striped Bass Technical Committee will review the state's data and make a recommendation to the ASMFC Striped Bass Management Board about possible causes for the spawning failures and if management action is needed. The A-R striped bass juvenile abundance index met this trigger in 2020, the third year in a row the index value was below the 75% threshold (Figure 2.2).

Adaptive management for the A-R stock and fisheries in the ASMA and RRMA encompass the following measures:

- Use of peer reviewed stock assessments and updates to recalculate the BRPs and/or TAL if assessment results deem it necessary. Stock assessments will be updated at least once between benchmarks. Changes in the TAL will be implemented through a Revision to the Amendment.
- Use estimates of $F$ from stock assessments to compare to the $F$ BRP and if $F$ exceeds the $F_{\text{Target}}$ reduce the TAL to achieve the $F_{\text{Target}}$ in one year through a Revision to the Amendment.

- Ability to change daily possession limits in the commercial and recreational fisheries to keep landings below the TAL.
- Ability to open and close recreational harvest seasons and commercial harvest seasons and areas to keep landings below the TAL and reduce interactions with endangered species.
- Ability to require commercial and recreational gear modifications including, but not limited to, the use of barbless or circle hooks, area closures, yardage limits, gill net mesh size restrictions and setting requirements to reduce striped bass discards.

## MANAGEMENT OPTIONS AND IMPACTS

(+ Potential positive impact of action)
(- Potential negative impact of action)

1. Manage for Sustainable Harvest through harvest restrictions

   A. Continue to use stock assessments and stock assessment projections to determine the TAL that achieves a sustainable harvest for the A-R stock.

      + The best option to maintain harvest at a sustainable level when mechanisms exist to monitor recreational and commercial harvest in near real-time and close fisheries when the TAL is calculated to be reached.
      + Maintains a sustainable harvest if the TALs are set appropriately and updated at regular intervals.
      - Will not achieve sustainable harvest if TALs are set too high and not updated at regular intervals.
      - Does not allow for increased harvest based on year class strength if TALs are not updated often enough through stock assessments.

   B. Implement a harvest moratorium

      + Would eliminate all harvest which would likely reduce fishing mortality to the stock even more than the current TAL of 51,216 pounds
      + Would likely increase abundance and further expand the age structure
      - Mortality associated with discards in other commercial and recreational fisheries would still occur and likely increase
      - May not achieve the desired results if environmental factors have a greater influence than the level of SSB on the formation of strong year classes
      - Would have significant economic impacts across the commercial sector if fisheries and gears that interact with striped bass were also eliminated
      - Would have significant economic impacts to businesses across the recreational sector supported by recreational fishing for striped bass

2. Management of striped bass harvest in the commercial fishery as a bycatch fishery

   A. Status quo: continue managing the ASMA striped bass fishery as a bycatch fishery

      + Consistent with regulations since 1995

+ May still discourage additional participants from entering the fishery and harvesting striped bass quota that don't normally participate in the other multi-species large mesh gill net fisheries in the ASMA
- Makes it more difficult to implement hook-and-line as a commercial gear

B. Stop managing the ASMA striped bass fishery as a bycatch fishery

+ Would reduce enforcement issues for Marine Patrol
+ Would make it easier to implement hook and line as a commercial gear by not requiring bycatch provisions for one gear and not another
+ Would have no impact on the other management measures (e.g., daily possession limits) intended to maintain harvest below the TAL
+ Would offer a more resource friendly gear that has less discard mortality than gill nets and would have less interactions with endangered species compared to gill nets
+ Would be an additional gear available to the commercial sector to harvest striped bass when gill nets may not be allowed due to excessive interactions with endangered species are because of harvest reductions needed in other FMPs (e.g. southern flounder and American shad)
- Could potentially lead to increased participants in the commercial fishery which would possibly decrease the annual income received per participant in the fishery
- Could potentially lead to increased participants in the commercial fishery which could cause the TAL to be reached quicker and cause gill net fisheries for other species (e.g., American shad) to close earlier than planned

3. Accountability Measures to Address TAL Overages (Examples in Table 2.10)

A. Single Year Overages: if the landings from the management area/sectors three fisheries combined (RRMA recreational, ASMA recreational, and ASMA commercial) exceeds the total TAL by 10% in a single calendar year, then each fishery that exceeded their allocated TAL will have their allocated TAL reduced the next calendar year. The reduction required for a fishery will be equal to the percent contribution that fishery made to the combined TAL overage.

Chronic Overages: if the five-year running average of the landings from the management area/sectors three fisheries combined (RRMA recreational, ASMA recreational, and ASMA commercial) exceeds the five-year running average of the total TAL by 2%, the fishery(ies) exceeding their allocated TAL will deduct the annual average overage from their annual TAL for the next five years.

+ Allows for a buffer around the TAL to account for the uncertainty associated with estimates of recreational harvest
+ Could prevent constantly changing the TAL each year if overages are below the 10% buffer
+ Will be less confusing to anglers if regulations do not change often
- Exceeding the TAL by less than the prescribed buffer, would potentially reduce the ability to maintain a sustainable harvest

B. If the landings from the management area/sectors three fisheries combined (RRMA recreational, ASMA recreational, and ASMA commercial) exceeds the total TAL by 5% in a single calendar year, then each fishery that exceeded their allocated TAL will have their allocated TAL reduced the next calendar year. The reduction for a fishery will be equal to the percent contribution that fishery made to the combined TAL overage.

The same positives and negatives apply to this option, it is just a more conservative buffer than option 3.A.

C. If the landings in any one of the management areas' three fisheries (RRMA recreational, ASMA recreational, and ASMA commercial) exceeds their allocated TAL by 5% in a calendar year, any landings in excess of their allocated TAL will be deducted from that fisheries' allocated TAL the next calendar year.

D. If the landings in any one of the management areas' three fisheries (RRMA recreational, ASMA recreational, and ASMA commercial) exceeds their allocated TAL in a calendar year, any landings in excess of their allocated TAL will be deducted from that fisheries' allocated TAL the next calendar year.

+ Is the most conservative approach to managing a TAL and will provide the greatest chance at rebuilding the stock and maintaining a sustainable harvest
- Does not incorporate statistical uncertainty in inherent to recreational harvest estimates
- Can lead to very short seasons, or no season at all for some years, if TALs are exceeded often and/or by significant amounts when TALs are low
- Can cause confusion among users if regulations change every year

For all overage options: overages will be deducted from the management area/sectors fishery(ies) TAL, not the management area/sectors fishery(ies)TAL plus a buffer; if paybacks to a fishery exceed the next year's allocated TAL for that fishery, paybacks will be required in subsequent years to meet the full reduction amount; in situations where a fisheries allocated TAL has been reduced from a previous year's overage, if the reduced TAL is exceeded, any required paybacks the subsequent year are reduced from the fisheries' original allocated TAL, not from the reduced TAL.

Managing agencies will implement strategies, including proclamations to close harvest seasons, to prevent landings from exceeding the TAL, rather than attempting to harvest the TAL and the buffer.

Table 2.10. EXAMPLES of Accountability measures to address TAL Overage.

| Option | Buffer | When Payback Is Required | Management Area/Sector | Area/Sector TAL | TAL + Buffer | Area/Sector Landings | Landings Over/Under TAL | Total Payback Required | Percent Contribution to Overage | Payback | Next Season Area/Sector TAL (lb) | Explanation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.A. | 10% over TAL | Overall landings are greater than (Overall TAL + Buffer) | RRMA recreational | 12,804 | 14,084 | 27,546 | 14,742 | 12,197 | 88% | 12,197 x 88% = 10,733 lb | 2,071 | Total TAL+10% exceeded so payback is necessary. |
| | | | ASMA recreational | 12,804 | 14,084 | 8,258 | -4,546 | | 0% | 12,197 x 0% = 0 lb | 12,804 | |
| | | | ASMA Commercial | 25,608 | 28,169 | 27,609 | 2,001 | | 12% | 12,197 x 12% = 1,464 lb | 24,144 | |
| 3.B. | 5% over TAL | Overall landings are greater than (Overall TAL + Buffer) | RRMA recreational | 12,804 | 13,444 | 17,804 | 5,000 | 0 | 100% | 0 | 12,804 | Despite RRMA recreational exceeding TAL, Total TAL+5% not exceeded so no paybacks are necessary. |
| | | | ASMA recreational | 12,804 | 13,444 | 4,000 | 0 | | 0% | 0 | 12,804 | |
| | | | ASMA Commercial | 25,608 | 26,888 | 25,608 | 0 | | 0% | 0 | 25,608 | |
| 3.C. | 5% over Fishery TAL | Fishery landings are greater than (Fishery TAL + Buffer) | RRMA recreational | 12,804 | 13,444 | 12,000 | -804 | Not Applicable | | 0 | 12,804 | ASMA recreational landings exceeded TAL+5% so must pay back full overage. ASMA commercial exceeded TAL by less than 5% buffer so no paybacks are necessary. |
| | | | ASMA recreational | 12,804 | 13,444 | 14,000 | 1,196 | | | 1,196 lb | 11,608 | |
| | | | ASMA Commercial | 25,608 | 26,888 | 26,200 | 392 | | | 0 | 25,608 | |
| 3.D. | No Buffer | Landings greater than Fishery TAL | RRMA recreational | 12,804 | 12,804 | 12,954 | 150 | | | 150 lb | 12,654 | Each area/sector exceeded their TAL and must pay back all landings in excess of their TAL. |
| | | | ASMA recreational | 12,804 | 12,804 | 13,494 | 690 | | | 690 lb | 12,114 | |
| | | | ASMA Commercial | 25,608 | 25,608 | 25,825 | 217 | | | 217 lb | 25,391 | |

4. Size limits to expand the age structure of the stock

+ Will provide resiliency to the stock during times of poor recruitment
+ Can provide anglers with the opportunity of a "trophy" fishery, even if it is catch-and-release only
- Can reduce the number of fish available for harvest depending on the size limit chosen
- Can increase the number of dead discards from fisheries depending on the size limit chosen

A. Status Quo-maintain the current minimum size limit of 18-inch TL in the ASMA, and in the RRMA maintain the current harvest size limit of a minimum of 18-inch TL to 22-inch TL maximum, with a no harvest slot of fish 22–27 inches, with only one fish in the daily creel being greater than 27 inches

+ Is consistent with management since the 1990s
+ Provides some harvest protection of females in the 22–27 inch no harvest slot while on the spawning grounds
- Does not offer as much protection of fish greater than 27 inches as a harvest slot with a maximum allowed harvest size would

B. Increase the minimum size limit in all sectors in the ASMA and RRMA

+ Could increase chances of achieving a sustainable harvest by allowing females to spawn more times before becoming available to harvest
+ Will provide consistent regulations across all sectors and management areas
- Will lead to greater and greater discards the higher the minimum size limit is raised
- Will decrease the percentage of recreational anglers that will catch and retain the daily limit of striped bass (the greater the increase in the minimum size limit the greater the decrease in the percentage of anglers that keep a daily landing limit)
- Will not allow the harvest of a "trophy" fish by anglers

C. In the ASMA, implement a harvest slot of a minimum size of 18-inches TL to not greater than 25 inches TL in the commercial and recreational sectors

+ Will provide resiliency to the stock during times of poor recruitment
+ Can provide anglers with the opportunity of a "trophy" fishery, even if it is catch-and-release only
- Will reduce the number of fish available for harvest depending on the size limit chosen
- Will increase the number of dead discards from fisheries depending on the size limit chosen
- Will increase the potential to reach TAL quicker in the RRMA if harvest is allowed on larger fish
- Any increase in the abundance of older fish in the population may not be noticeable if the slot is too large

D. In the RRMA, maintain current harvest slot limit of a minimum size of 18-inches TL to 22-inches TL with a no harvest slot of 22–40 inches TL, and the ability to harvest one fish greater than 40 inches per day to allow for harvest of a trophy fish.

E. In the RRMA, maintain current harvest slot limit of a minimum size of 18-inches TL to not greater than 22-inches TL with no harvest allowed on fish greater than 22 inches.

.5. Gear modifications and area closures to reduce striped bass discard mortality

A. Status quo-continue to allow commercial harvest of striped bass with gill nets in joint and coastal waters of the ASMA and continue recreational harvest and catch-and-release fishing in the ASMA and RRMA, including striped bass spawning grounds in the Roanoke River. The requirement that from April 1 through June 30, only a single barbless hook or lure with single barbless hook (or hook with barb bent down) may be used in the inland waters of the Roanoke River upstream of U.S. Highway 258 Bridge will remain in effect.

+ Consistent with management since 1990
+ Allows for harvest with traditional gears and in traditional locations user groups are accustomed to
+ Experience has demonstrated the stock can recover from low levels of abundance and produce strong year classes with these fishing practices in place
- Gill nets interact with endangered species and require incidental take permits to operate
- Catch rates can be extremely high when striped bass are congregated on the spawning grounds
- There has been little research on the effects of catch-and-release fishing to egg production and quality

B. Do not allow the harvest of striped bass with gill nets in the ASMA commercial fishery

+ Will reduce dead discards associated with harvesting striped bass with gill nets
- Will create a significant number of dead discards unless all other gill net fisheries in the ASMA are eliminated
- Will have a significant economic impact to commercial fishers using gill nets to harvest striped bass unless they can easily and inexpensively switch to another gear

C. Do not allow harvest or targeted catch-and-release fishing for striped bass while on the spawning grounds or other areas of high concentration.

+ Would reduce all discards associated with hook and line fishing on the spawning grounds and in other areas of high striped bass concentration
+ Would likely increase abundance and further expand the age structure
- May not achieve the desired results if environmental factors have a greater influence than the level of SSB on the formation of strong year classes

- Would have significant economic impact to all businesses in the areas supported by recreational angling for striped bass while on the spawning grounds and in other areas of high concentration
- Would eliminate access to the resource by the user groups in the area of the spawning grounds and in other areas of high concentration unless they travel to another area to harvest striped bass

D. Implement single barbless hook rule in the remainder of the RRMA during the open harvest season and catch-and-release season

+ Would reduce mortality associated with undersized releases and catch-and-release fishing
- Would have negative impacts on other recreational fisheries mainly largemouth bass fishing in the area and time of year

E. Implement a requirement to use non-offset barbless circle hooks when fishing with live or natural bait in the inland waters of the Roanoke River (upstream of Hwy 258 bridge) from May 1 through June 30

+ Would reduce mortality associated with undersized releases and catch-and-release fishing
- Would require significant angler education on the types of circle hooks that would be required
- Would have significant impact on other recreational fisheries using live bait for other species, such as crickets for bream, if there were not exemptions for certain size J hooks
- Would require significant angler education on the types of J hooks that would be exempted

6. Adaptive Management
Adaptive management for the A-R stock and fisheries in the ASMA and RRMA encompasses the following measures:

- Use peer reviewed stock assessments and updates to recalculate the BRPs and/or TAL. Stock assessments will be updated at least once between benchmarks. Increases or decreases in the TAL will be implemented through a Revision to the Amendment. A harvest moratorium could be necessary if stock assessment results calculate a TAL that is too low to effectively manage, and/or the stock continues to experience spawning failures.
- Use estimates of $F$ from stock assessments to compare to the $F$ BRP and if $F$ exceeds the $F_{Target}$ reduce the TAL to achieve the $F_{Target}$ through a Revision to the Amendment.
- Ability to change daily possession limits in the commercial and recreational fisheries to keep landings below the TAL.
- Ability to open and close recreational harvest seasons and commercial harvest seasons and areas to keep landings below the TAL and reduce interactions with endangered species.

- Ability to require commercial and recreational gear modifications including, but not limited to, the use of barbless or circle hooks, area closures, yardage limits, gill net mesh size restrictions and setting requirements to reduce striped bass discards.

## RECOMMENDATIONS

See Appendix 6 for DMF, WRC, and advisory committees recommendations and a summary of online public.

NCMFC Preferred Management Strategy

Options: 1.A., 2.A., 3.D., 4.C., 4.E., 5.A., 5.E., and 6.

## APPENDIX 3: ACHIEVING SUSTAINABLE HARVEST FOR THE TAR-PAMLICO AND NEUSE RIVERS STRIPED BASS STOCKS

### ISSUE

Consider existing factors that prevent a self-sustaining population in the Tar-Pamlico and Neuse rivers and implement management measures that provide protection for and access to the striped bass resource.

### ORIGINATION

North Carolina Division of Marine Fisheries (DMF) and North Carolina Wildlife Resources Commission (WRC)

### BACKGROUND

Natural reproduction is the primary process responsible for maintaining self-sustaining fish populations at levels that support harvest. In self-sustaining populations, the numbers of offspring produced by natural reproduction are greater than can be stocked by managers. Striped bass stocks that allow harvest and can self-replace through natural reproduction are considered sustainable. Until there are naturally reproducing populations in these rivers capable of self-replacement, the sustainable harvest objective of this plan cannot be met.

The Tar-Pamlico and Neuse rivers striped bass fisheries have been sustained by continuous stocking to maintain the populations while allowing recreational and commercial harvest (O'Donnell and Farrae 2017; see Appendix 1). Roanoke River origin striped bass have either been stocked or used as broodstock in the Tar-Pamlico and Neuse rivers for decades (Bayless and Smith 1962; Woodroffe 2011). It is likely there are no Tar-Pamlico or Neuse River native strains of striped bass remaining in the river systems; however, striped bass in the Tar-Pamlico and Neuse rivers display genetic differences from other striped bass in North Carolina, which is to be expected given the history of stocking in these systems (Cushman et al. 2018). The need for continued conservation management efforts are supported by persistent recruitment failure, multiple mortality sources, absence of older fish on the spawning grounds, non-optimal environmental conditions on the spawning grounds in the spring, impacts from hatchery reared juveniles and escaped hybrid striped bass, and the high percentage of stocked fish in the populations (Bradley et al. 2018; Rachels and Ricks 2018; Mathes et al. 2020). Reliable population estimates have never been determined for Tar-Pamlico River striped bass. In 2018, Bradley et al. (2018) provided a population estimate of 18,457 for Neuse River adult striped bass; however, the persistence of striped bass populations in these rivers to support recreational and commercial fisheries has been the result of continuous stocking efforts (Mathes et al. 2020; NCDMF 2020a).

Tar-Pamlico and Neuse Rivers Striped Bass Stocks Life History

For a comprehensive review of striped bass life history in the Tar-Pamlico and Neuse rivers see Mathes et al. (2020) and NCDMF (2013).

The age structure of striped bass in the Tar-Pamlico and Neuse rivers remains limited, with few fish over ten years old collected in DMF and WRC surveys. Sampling by WRC in 2007 showed age-4 and age-6 fish were common in both rivers (Barwick et al. 2008). Older, larger individuals were seldom encountered. Since adoption of the Estuarine Striped Bass FMP (NCDMF 2004), there has been little change in the size and age distribution in the Tar-Pamlico and Neuse rivers. However, abundance of age-6 and older striped bass began increasing in 2008, peaking in 2014 (Rachels and Ricks 2015). On the Tar River, abundance of age-6 fish has varied considerably with a peak in 2012 (Rundle 2016). WRC scale-aged fish suggest a maximum age of 17 in the Tar-Pamlico River (Homan et al. 2010), and 11 on the Neuse River (WRC - unpublished data 2017). DMF otolith and genetic age data indicate maximum ages of 12 in both rivers (NCDMF 2020a). Survey data indicates limited numbers of larger striped bass in these systems, though gear selectivity likely excludes larger striped bass. Few striped bass larger than 27 inches are commercially harvested in these systems (NCDMF 2020a); however, fishery independent sampling using gill nets with larger mesh sizes (up to 10 inch stretched mesh) indicates the presence of larger, older striped bass in deeper regions of the Tar-Pamlico River (Cuthrell 2012).

Striped bass populations in the Tar-Pamlico and Neuse rivers primarily remain within their native river system throughout their life history. Tagging data indicates limited movement of striped bass from the Neuse and Tar-Pamlico rivers into other systems or the Atlantic Ocean (Setzler et al. 1980; Rulifson et al. 1982, Winslow 2007; Callihan 2012; Callihan et al. 2014; Rock et al. 2018; NCDMF – unpublished data 2020). Multiple studies have indicated striped bass make spawning migrations in the Tar-Pamlico and Neuse rivers and fertilized eggs have been found, indicating reproduction is occurring; however, there is very limited if any striped bass recruitment to the larval and juvenile life stages (Humphries 1965; Kornegay and Humphries 1975; Jones and Collart 1997; Smith and Rulifson 2015; Rock et al. 2018). Surveys suggest egg abundance in the water column downstream from spawning is not sufficient to provide recruitment of juveniles to the population.

Over the past several decades, few larval and juvenile striped bass have been collected from CSMA systems (Marshall 1976; Hawkins 1980; Nelson and Little 1991; Burdick and Hightower 2006; Barwick et al. 2008; Smith and Rulifson 2015; and Buckley et al. 2019). In 2017, the DMF began an exploratory juvenile abundance survey in the Tar-Pamlico and Neuse rivers using trawl and seine nets. As of 2020, no juvenile striped bass have been collected in this survey (Mathes et al. 2020; Darsee et al. 2020).

Striped bass are broadcast spawners that produce non-adhesive, semi-buoyant eggs that must remain neutrally buoyant in the water column as they float downriver for the best chance of survival to larvae. Sufficient current velocity is critical to keep eggs suspended in the water column for a minimum of 48 hours after fertilization (Bain and Bain 1982) preventing contact with the bottom. Eggs differ among striped bass stocks and are ideally suited for certain river flows. Chesapeake Bay stock eggs are lighter and maintain their position in the water column of calmer tidal waters, whereas Roanoke River stock eggs are heavier and maintain their water column position in the more turbulent, high energy Roanoke River system (Bergey et al. 2003). While Chesapeake Bay stock eggs appear genetically predetermined to being lighter, Roanoke River stock eggs are thought to be more adaptable to varying environmental conditions (Kowalchyk 2020). Neuse River water velocities are variable but appear sufficient to keep heavier striped bass eggs suspended until hatching (Burdick and Hightower 2006; Buckley et al. 2019) based on the minimum required water velocity (30 centimeters per second).

In 2017, North Carolina State University initiated research to provide insight into striped bass recruitment by evaluating genetic and environmental influences on egg development. Results reveal the stock with the heaviest and smallest eggs collected in 2018 and 2019 were from Tar-Pamlico and Neuse rivers striped bass broodstock (Kowalchyk 2020). The Tar-Pamlico and Neuse rivers were also found to have significantly different levels of key proteins required to maintain egg hydration compared to other North Carolina river systems, possibly contributing to differences in buoyancy and critically timed nutrient delivery.

It is clear striped bass reproduction is influenced by complex interactions between population structure, environmental, and physiological factors. In addition, reproductive success is likely impacted because the striped bass stocks in the Tar-Pamlico and Neuse rivers are a non-native strain and the physical environment in these systems has changed through time.

Striped Bass Fisheries

Management measures in Amendment 1 consist of daily possession limits, open and closed harvest seasons, seasonal gill net attendance and other gill-net requirements, minimum size limits, and slot limits to work towards the goal of achieving sustainable harvest. Amendment 1 also maintained the stocking measures in the major CSMA river systems (NCDMF 2013). Supplement A to Amendment 1 (NCDMF 2019) implemented a recreational and commercial no-possession provision for striped bass in the internal coastal and joint waters of the CSMA to reduce mortality on striped bass in these systems. Additionally, commercial gill net restrictions were implemented requiring 3-foot tie-downs and 50-yard distance from shore measures in accordance with Supplement A to Amendment 1 year-round (M-5-2019). Proclamation M-6-2019 maintained the year-round tie-down and distance from shore restrictions for large mesh gill nets and prohibited the use of all gill nets upstream of the ferry lines from the Bayview Ferry to Aurora Ferry on the Tar-Pamlico River and the Minnesott Beach Ferry to Cherry Branch Ferry on the Neuse River to further reduce bycatch of striped bass.

*Recreational*

The DMF recreational angler survey started collecting recreational striped bass harvest, discard, effort, and economic data for the Tar-Pamlico and Neuse rivers in 2004. Recreational landings fluctuated between 2004–2018, ranging from a low in 2008 (2,990 pounds) to a high in 2017 (26,973 pounds; Figure 3.1; NCDMF 2020a). Only 959 pounds were harvested in 2019 because the season closed early when Supplement A (February 2019) was approved. From 2016–2017, recreational trips and hours spent targeting striped bass increased with a decline in 2018. On average 3,327 fish were harvested annually from the Tar-Pamlico and Neuse rivers combined. (NCDMF 2020a). Recreational releases during 2009–2018 averaged 43,255 fish per year (Mathes et al. 2020). Due to the number of undersized striped bass available in 2017, there was a large increase in discards during this year.

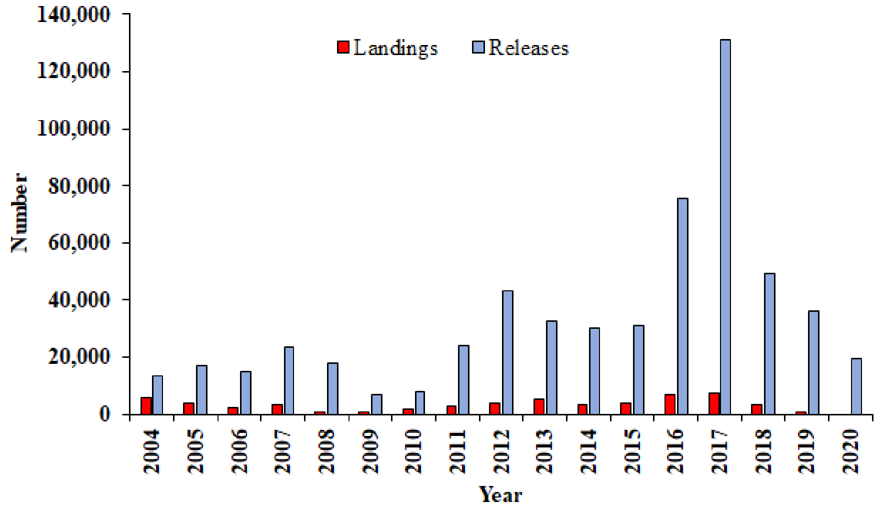


Figure 3.1. Annual recreational catch (harvested and/or released) of striped bass in the CSMA, 2004–2020. There was a limited recreational harvest season in 2019 prior to the closure, lasting from January 1 to March 19, 2019.

*Commercial*

Supplement A closed the commercial striped bass fishery in 2019. From 1994–2018 commercial landings in the CSMA were limited by an annual total allowable landings (TAL) of 25,000 pounds. The TAL was nearly met in all years except for 2008, when less than half of the TAL was landed (Figure 3.2). From 2004–2018, the commercial season opened March 1 and closed when the TAL was reached.

Stock Concerns

Lack of natural recruitment is the biggest factor affecting sustainability of striped bass stocks in the Tar-Pamlico and Neuse rivers. There has been no measurable year class in the Tar-Pamlico and Neuse rivers systems in decades, and therefore, the stocks require continuous stocking to sustain the populations. A model was developed for striped bass in the CSMA to evaluate stocking and management strategies (Mathes et al. 2020). Stock evaluation results from the model provide further evidence that natural recruitment is the primary limiting factor influencing Tar-Pamlico and Neuse rivers stocks and if stocking was stopped the populations would decline (Mathes et al. 2020). Stock evaluation results indicate that striped bass populations in the CSMA are depressed to an extent that sustainability is unlikely at any level of fishing mortality, and that no level of fishing mortality is sustainable (Mathes et al. 2020).

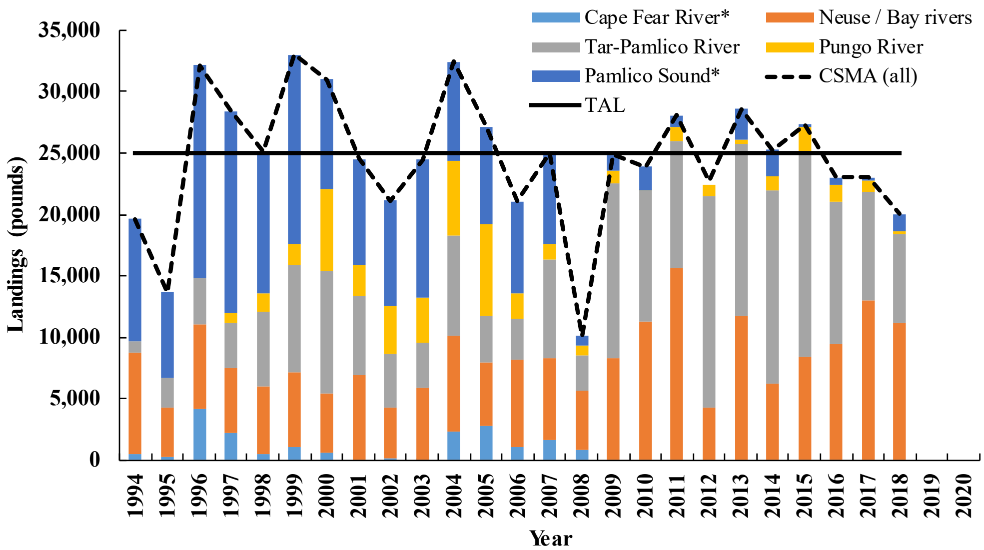


Figure 3.2. Commercial striped bass harvest by system, and the TAL in the CSMA, 1994–2020. There has been a harvest no-possession measure in the Cape Fear River since 2008 and in the CSMA since 2019. *Landings data for the Cape Fear River (2001) and for the Pamlico Sound (2012) are confidential.

Female striped bass in these systems are 100% mature at age-4 (Knight 2015), and fish up to age-8 are not uncommon, providing mature females in these populations that should be capable of producing annual natural recruitment. In the Roanoke River, consistent, measurable year classes are detected in fishery independent surveys even during poor flow years with periods of low spawning stock biomass. Additionally, in the Northeast Cape Fear River, juveniles are captured despite very low stock abundance and limited age structure (Darsee et al. 2020; Lee et al. 2020).

*Reasons for low recruitment*

Several factors have been suggested as potentially affecting natural recruitment in the Tar-Pamlico and Neuse rivers including spawning stock abundance, truncated age structure (Bradley et al. 2018; Rachels and Ricks 2018; Buckley et al. 2019), and egg abundance. In addition, the absence of older individuals in the populations may not be sufficient to provide natural recruitment because of lower egg production from younger, smaller fish.

Eggs produced by hatchery stocked fish produced by Tar-Pamlico and Neuse rivers broodstock are very small, heavy (dense) eggs, which are more likely to sink than float (Kowalchyk 2020). Figure 3.3 shows that eggs produced from fish residing in the Tar-Pamlico and Neuse rivers are statistically less buoyant than Roanoke River or Santee-Cooper striped bass eggs. Egg densities have been shown to be influenced by both genetic and environmental factors (Kowalchyk 2020). Spawning grounds in these river systems are shallow (between 0.2 and 1.0 meters), so the potential for heavy eggs to contact bottom sediment and die is increased. Additionally, because many of the streams and creeks in these systems have been altered by channelization, rapid flow increases can occur shortly after a rainfall event begins followed by a rapid return to base conditions after the end of the rainfall event (NCDWQ 2009; NCDWQ 2010).

Flows during the spring striped bass spawning season are an important factor affecting successful striped bass natural reproduction; however, unlike on the Roanoke River, there are no agreements with the U.S. Army Corp. of Engineers (USACE) to maintain adequate flows for striped bass spawning in the Tar-Pamlico or Neuse rivers. The USACE is consulted weekly regarding water releases in the Neuse River from Falls Lake in Raleigh, but due to the watershed and storage capabilities, it is not possible to manipulate flows in these rivers. Flows on the Tar-Pamlico River are based on pulse rainfall events. The ability to manipulate releases may become important as we get more information on flows in these systems. If flows are too low during the spawning period, heavy eggs may be more likely to contact the bottom before hatching successfully.

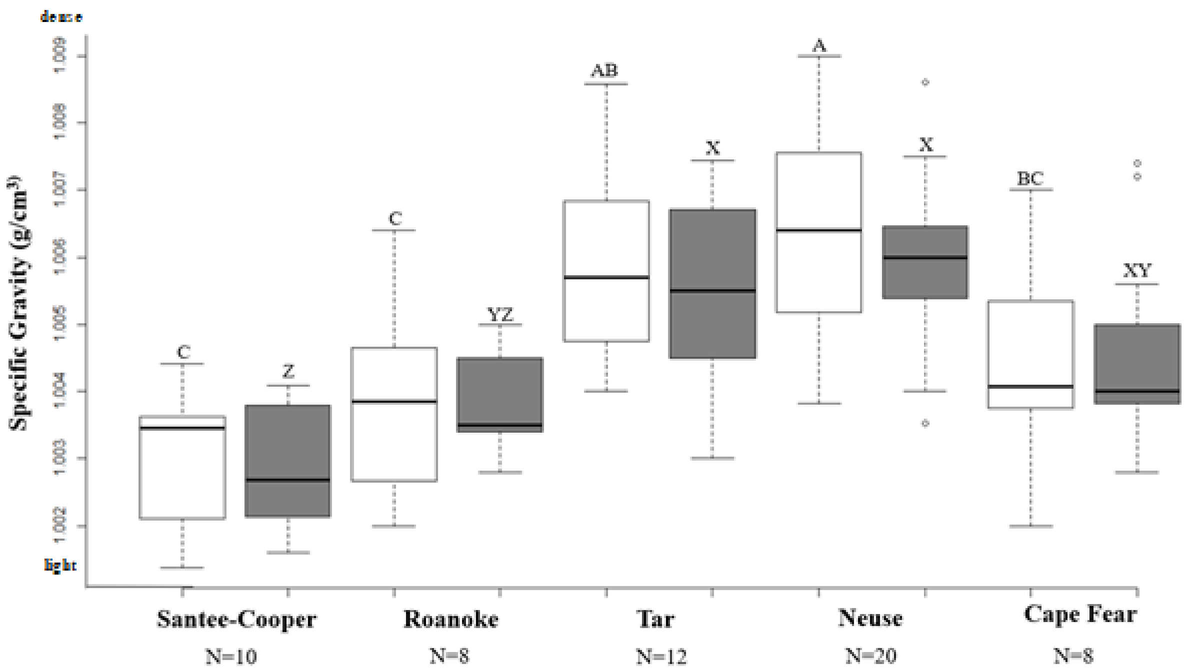


Figure 3.3. Specific gravity (buoyancy; g/cm$^3$) measurements from stage 1 (white boxes) and 4 (gray boxes) fertilized eggs from 2018/2019 hatchery broodstock sampling. Tukey pair wise comparisons are labeled above the boxplots with ABC indicating stage 1 significant differences and XYZ indicating stage 4 significant differences (Tukey HSD, $\alpha$=0.05). N represents number of females spawned.

*Stocking Considerations*

Stocking of striped bass is addressed through the North Carolina Interjurisdictional Fisheries Cooperative annual work plan between DMF, WRC, USFWS (COOP; see Appendix 1). Specific objectives for stocking striped bass include attempts to increase spawning stock abundance while promoting self-sustaining population levels appropriate for various habitats (see Amendment 1, Section 11.2; NCDMF 2013). The annual number stocked was increased starting in 2010 to a goal of 100,000 hatchery reared striped bass in each of the major river systems (Tar-Pamlico, Neuse, and Cape Fear rivers).

Stocking will continue to play a key role recovering striped bass populations. As part of the COOP, consideration of future stocking measures should include evaluation of stocking striped bass with eggs adapted to environmental conditions in the rivers. In addition, because management and stocking strategy simulation results show the populations would likely benefit from stocking more striped bass, discussions related to the number of striped bass stocked annually should be considered as part of the COOP agreement. See Appendix 1 for additional stocking considerations.

## AUTHORITY

North Carolina's existing fisheries management system for striped bass is adaptive, with rulemaking authority vested in the MFC and the WRC within their respective jurisdictions. The MFC also may delegate to the fisheries director the authority to issue public notices, called proclamations, suspending or implementing, in whole or in part, particular MFC rules that may be affected by variable conditions. Management of recreational and commercial striped bass regulations within the Tar-Pamlico and Neuse rivers are the responsibility of the MFC in Coastal and Joint Fishing Waters, and recreational regulations are the responsibility of the WRC in Joint and Inland Fishing Waters. It should also be noted that under the provisions of Amendment 1 to the North Carolina Estuarine Striped Bass FMP the DMF Director maintains proclamation authority to establish seasons, authorize or restrict fishing methods and gear, limit quantities taken or possessed, and restrict fishing areas as deemed necessary to maintain a sustainable harvest. The WRC Executive Director maintains proclamation authority to establish seasons.

## NORTH CAROLINA GENERAL STATUTES

*N.C. General Statutes*

| | |
|---|---|
| G.S. 113-132. | JURISDICTION OF FISHERIES AGENCIES |
| G.S. 113-134. | RULES |
| G.S. 113-182. | REGULATION OF FISHING AND FISHERIES |
| G.S. 113-182.1. | FISHERY MANAGEMENT PLANS |
| G.S. 113-221.1. | PROCLAMATIONS; EMERGENCY REVIEW |
| G.S. 113-292. | AUTHORITY OF THE WILDLIFE RESOURCES COMMISSION IN REGULATION OF INLAND FISHING AND THE INTRODUCTION OF EXOTIC SPECIES. |
| G.S. 143B-289.52. | MARINE FISHERIES COMMISSION—POWERS AND DUTIES |
| G.S. 150B-21.1. | PROCEDURE FOR ADOPTING A TEMPORARY RULE |

## NORTH CAROLINA RULES

*N.C. Marine Fisheries Commission and N.C. Wildlife Resources Commission Rules 2020* (15A NCAC)

| | |
|---|---|
| 15A NCAC 03H .0103 | PROCLAMATIONS, GENERAL |
| 15A NCAC 03M .0201 | GENERAL |
| 15A NCAC 03M .0202 | SEASON, SIZE AND HARVEST LIMIT: INTERNAL COASTAL WATERS |
| 15A NCAC 03M .0512 | COMPLIANCE WITH FISHERY MANAGEMENT PLANS |
| 15A NCAC 03Q .0107 | SPECIAL REGULATIONS: JOINT WATERS |
| 15A NCAC 03Q .0108 | MANAGEMENT RESPONSIBILITY FOR ESTUARINE STRIPED BASS IN JOINT WATERS |

| | |
|---|---|
| 15A NCAC 03Q .0109 | IMPLEMENTATION OF ESTUARINE STRIPED BASS MANAGEMENT PLANS: RECREATIONAL FISHING |
| 15A NCAC 03Q .0202 | DESCRIPTIVE BOUNDARIES FOR COASTAL-JOINT-INLAND WATERS |
| 15A NCAC 03R .0201 | STRIPED BASS MANAGEMENT AREAS |
| 15A NCAC 10C .0107 | SPECIAL REGULATIONS: JOINT WATERS |
| 15A NCAC 10C .0108 | SPECIFIC CLASSIFICATION OF WATERS |
| 15A NCAC 10C .0110 | MANAGEMENT RESPONSIBILITY FOR ESTUARINE STRIPED BASS IN JOINT WATERS |
| 15A NCAC 10C .0111 | IMPLEMENTATION OF ESTUARINE STRIPED BASS MANAGEMENT PLANS: RECREATIONAL FISHING |
| 15A NCAC 10C .0301 | INLAND GAME FISHES DESIGNATED |
| 15A NCAC 10C .0314 | STRIPED BASS |

## DISCUSSION

The Tar-Pamlico and Neuse rivers populations are not self-sustaining and in the absence of stocking cannot support any level of harvest (Mathes et al. 2020). Increasing spawning stock biomass and advancing the female age-structure to older individuals may lead to improved natural recruitment (Goodyear 1984). Based on modeling, a 10-year closure was most effective at increasing adult (age 3+) and old adult (age 6+) abundance (Figure 3.4; Mathes et al. 2020). Model results indicate old adult abundance does not increase for the first five years of the simulation regardless of fishing strategy. The next best fishing strategy consisted of a 5-year closure followed by a 26-inch minimum size limit. However, the 10-year closure resulted in more than two times the number of old adult striped bass than the next best fishing strategy (Figure 3.4).

After the 10-year closure, alternative harvest strategies including minimum size limits, slot limits, and bag limits should be evaluated prior to opening of the fishery. A sufficient time period will be required to achieve an expansion of the age structure and to increase abundance of older fish to promote natural recruitment. This time period should be minimally 10-years from the adoption of Supplement A (2019). Evaluations must account for natural fluctuations in striped bass spawning success due to environmental conditions.

Continue or discontinue the no-harvest measure

Management measures implemented in Supplement A closed the fishery to commercial and recreational harvest and must be incorporated into Amendment 2 to be maintained. If Supplement A management measures are not maintained, alternative management strategies to promote sustainable harvest must be considered.

Closing the fishery to commercial and recreational harvest provides the opportunity to evaluate the population response to management without fishing mortality. If there are no other significant mortality sources (i.e., natural mortality or discard mortality) or population losses (i.e., emigration from the system), no-harvest should allow for expansion of the age structure to include fish greater than age-10.

The no-possession measure in the internal coastal and joint waters of the CSMA was implemented based on genetic evidence suggesting two successful natural spawning events occurred in the Tar-

Pamlico and Neuse rivers in 2014 and 2015 (NCDMF 2019). This potential successful recruitment was an unusual event for Tar-Pamlico and Neuse rivers stocks. Rulifson (2014) concluded 53% of fish sampled from the Neuse River in 2010 were not of hatchery origin providing anecdotal evidence that sporadic, low levels of natural recruitment may occur in these systems. Supplement A was adopted to protect striped bass from the 2014- and 2015-year classes from harvest as they mature and contribute to the spawning stock.

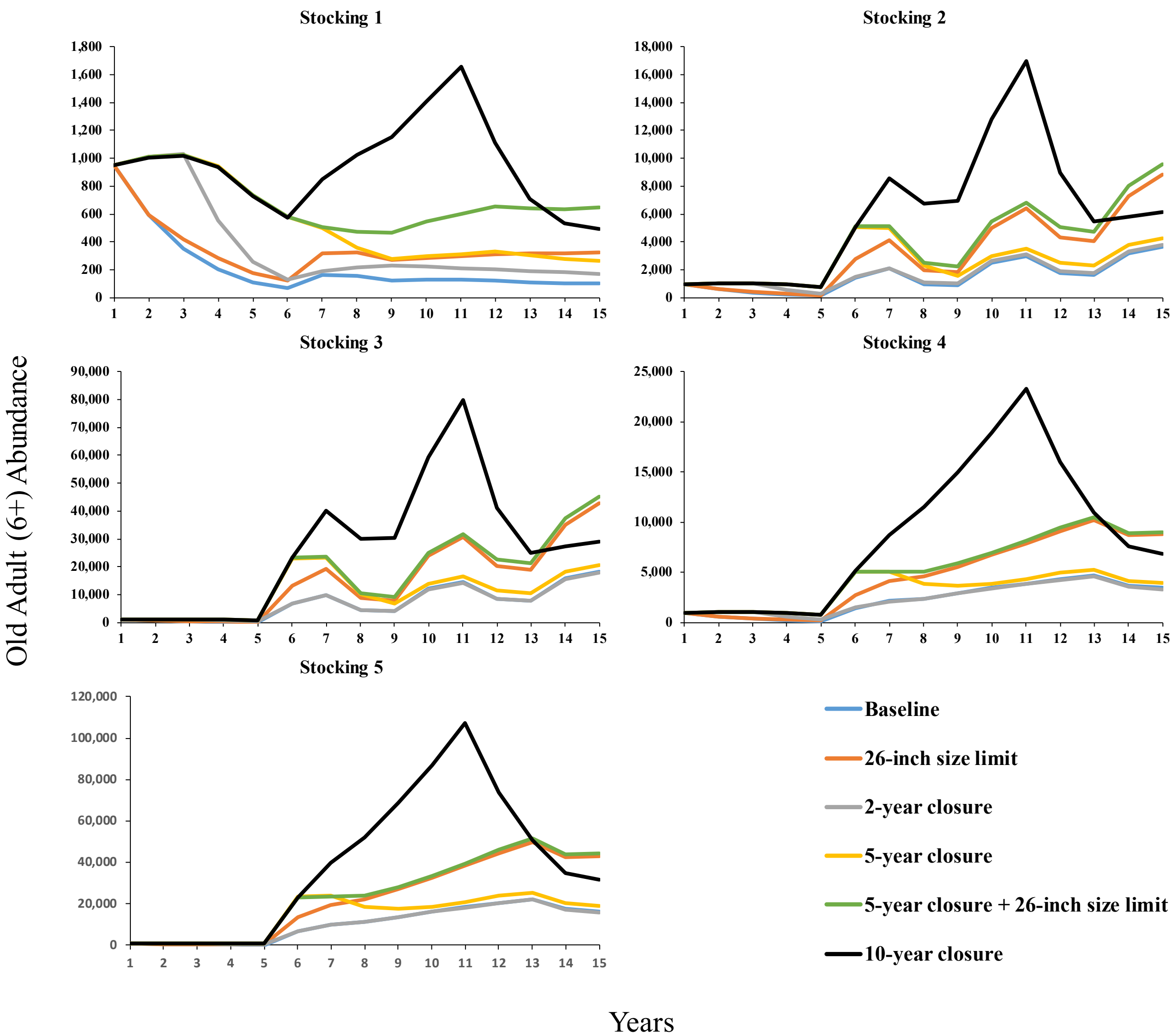


Figure 3.4. Abundance of old adults (age 6+) projected under five stocking strategies and six fishing strategies. Stocking 1 - no stocking; Stocking 2 - stocking 100,000 fish per year with 2-year stocking and 2-year no stocking alternating for 15 years (8 years of stocking in total); Stocking 3 - stocking 500,000 fish per year with 2-year stocking and 2-year no stocking alternating for 15 years (8 years of stocking in total); Stocking 4 - stocking 100,000 fish per year with 8-year continuous stocking; Stocking 5 - stocking 500,000 fish per year with 8-year continuous stocking. Lines show the median from 10,000 iterations.

Based on matrix model results, no level of fishing mortality is sustainable. Continuing the no-possession measure is important to increase the age structure and abundance of Tar-Pamlico and Neuse rivers striped bass, which should promote natural reproduction (Mathes et al. 2020). Fishing activities typically select larger fish, increasing fishing mortality disproportionally. Fishing activities impact the abundance of older fish, limiting the age structure of the population and reproductive contribution (Mathes et al. 2020). Past management measures may have maintained an artificially young age structure for a species documented to live up to age 30 (Greene et al. 2009).

An additional potential benefit of no-harvest in the CSMA is protection of A-R striped bass using juvenile and adult habitats in the Pamlico Sound and the Tar-Pamlico and Neuse rivers systems. Conventional tag return data has documented movement of smaller A-R stock striped bass into CSMA rivers (Callihan et al. 2014) and preliminary acoustic tag results from 30 adult (ages 4–5), non-hatchery origin striped bass tagged in the Tar-Pamlico and Neuse rivers indicates 63% were detected in the Albemarle Sound or on the Roanoke River spawning grounds in spring 2020 and 2021 (NCDMF unpublished data).

If the no-possession measure is discontinued in Amendment 2, alternative management strategies must be considered to manage harvest. Prior to 2019, management measures limited harvest seasons to cooler months to reduce discard mortality. Recreational fishers were subject to a two fish per person per day creel limit and commercial fishers were subject to a 10 fish per person per day limit with a maximum of two limits per commercial operation. Commercial and recreational fishers were subject to an 18-inch total length (TL) minimum size limit for striped bass, and a protective measure in joint and inland waters made it unlawful for recreational fishers to possess striped bass between 22- and 27-inches TL. In 2018, a 26-inch TL minimum size limit was established in inland waters. If harvest was allowed, changes to the size limits, or slot limits, could be considered to protect larger, older striped bass.

Among the six fishing strategies evaluated by the matrix model, a 5-year closure combined with a 26-inch TL minimum size limit was the second most effective strategy at increasing the abundance of older fish (Mathes et al. 2020). Additionally, commercial harvest was managed by an annual TAL of 25,000 pounds. With a goal of achieving self-sustaining populations in the Tar-Pamlico and Neuse rivers, lower harvest levels, alternative seasons, or area closures could be considered. Because striped bass populations in the CSMA are at an extent that sustainability is unlikely at any level of fishing mortality (Mathes et al. 2020), alternative management strategies beyond the harvest moratorium are unlikely to result in a self-sustaining stock.

Gear restrictions/limits

In 2004, DMF conducted a fishery independent study to test the effectiveness of various tie-down and gill net setting configurations in reducing striped bass bycatch. Results of these studies indicated distance from shore is a significant factor in striped bass catch rates, with up to a 60% reduction in striped bass catch when nets are set greater than 50 yards from shore (NCDMF 2013). Additionally, the use of tie-downs decreased striped bass catch by 85–99% in water depths greater than 3 feet, depending on season (NCDMF 2013). In 2008, the MFC approved requiring the use of 3-foot tie-downs in large mesh gill nets in internal coastal fishing waters and establishing a minimum setback distance from shore of 50 yards to effectively reduce striped bass discards (NCDMF 2013). After passing Supplement A, the MFC held a special meeting and passed a motion beyond what was contained in Supplement A instructing the DMF Director to issue a proclamation that prohibited the use of all gill nets upstream of the ferry lines on the Tar-Pamlico River and the Neuse River. The tie-down and distance from shore restrictions were maintained year-round for large mesh gill nets in the western Pamlico Sound and rivers below the ferry line (Figure 3.5). The gill net tie-down and distance from shore restrictions will remain in place as part of Amendment 2.

Rock et al. (2016) compared Tar-Pamlico and Neuse rivers striped bass dead discard estimates from observer data before and after the tie-down and distance from shore management measures were implemented (2004–2009 and 2011–2012). Average annual striped bass discards in the commercial gill net fishery were reduced by 75% following implementation. The persistent availability of striped bass within 50 yards of shore as indicated by fishery independent sampling and limited numbers of out of season observations from commercial gill nets indicate the setback and tie-down measures were effective in reducing gill net interactions with striped bass (Rock et al. 2016).

Relative annual variation in commercial gill net effort, commercial harvest, recreational effort, and recreational discards are significant factors contributing to the total mortality of striped bass in the Neuse River (Mathes et al. 2020). Reducing mortality, including dead discards, may increase spawning stock biomass and expand the age structure of spawning females (Rachels and Ricks 2018). Estimates of commercial striped bass total dead discards in the Tar-Pamlico River were greater than in the Neuse River (Mathes et al. 2020). From 2012 to 2018, commercial striped bass dead discards in these rivers averaged 1,606 fish per year; however, after the ferry line gill net closures were implemented, the average number of striped bass dead discards reduced to 522 fish per year (2019–2020; Table 3.1). In addition to the gill net closure above the ferry lines, there has also been an overall decline in large mesh gill net trips resulting from the adoption of Amendment 2 to the Southern Flounder FMP in 2019. Overall, relatively small estimates of dead discards are an indicator that distance from shore and tie-down requirements enacted in 2008 have been successful in reducing the number of striped bass discards in the commercial gill net fishery in the Tar-Pamlico and Neuse rivers (Rock et al. 2016). Lowering mortality on a stock that cannot sustain itself at any level of fishing mortality is likely to have benefits to the population.

Table 3.1. Recreational and commercial estimates of striped bass discards in Central Southern Management Area rivers, 2012–2020.

| Year | Recreational Dead Discard Numbers | Commercial Dead Discards Numbers |
|---|---|---|
| 2012 | 2,927 | 1,255 |
| 2013 | 2,263 | 1,797 |
| 2014 | 1,967 | 1,351 |
| 2015 | 2,158 | 1,536 |
| 2016 | 5,121 | 1,805 |
| 2017 | 8,657 | 2,429 |
| 2018 | 3,135 | 1,066 |
| 2019 | 2,150 | 371 |
| 2020 | 1,685 | 672 |
| Total | 30,063 | 12,282 |

Recreational measures to reduce discard mortality either through gear modifications or reduced angling effort could be considered as a management tool for the Tar-Pamlico and Neuse stocks due to the large number of fishing trips where anglers target striped bass in a catch and release fishery. From 2012 to 2020, recreational striped bass dead discards in the Tar-Pamlico and Neuse rivers averaged 3,340 fish per year. Over the past nine years, the number of recreational dead discards was more than double the number of commercial dead discards (Table 3.1). To reduce injury and stress-induced mortality in the upper Roanoke River, anglers are required to use a single barbless hook or lure from April 1 through June 30 while striped bass are concentrated near the spawning grounds. Similar measures, such as requiring non-offset circle hooks for natural bait and restricting the use of treble hooks, could be considered in the upper portions of the Tar-Pamlico and Neuse rivers. However, striped bass are not abundant in large numbers in the upriver sections of these systems, so the impact would likely be much smaller in magnitude when compared to the Roanoke River. Recreational gear restrictions could be required and focus by area and time of year. Gear restrictions that are targeted at one species in a multi-species fishery are difficult to enforce because one cannot prove intent (see section 11.3 of Amendment 1 to the NC Estuarine Striped Bass FMP).

Recreational angler education and outreach provide a viable option to improve survival of released fish. Practicing ethical angling techniques have been shown to improve survival (see NCDMF Ethical Angling brochure). Learning best management practices for ethical angling will give anglers confidence to release fish in a way that helps protect the resource for future generations. Increasing public awareness, through directed outreach and education will help anglers make informed decisions to minimize their impact to the striped bass population through catch and release mortality.

Anglers can minimize stress and exhaustion to fish by using appropriate tackle suited to the size of desired fish. Using barbless and non-offset circle hooks can increase the likelihood of jaw hooking a fish giving it a greater chance of survival at release. Additionally, handling can be minimized with rubberized landing nets and hook removal devices. When handling striped bass, it is very important to minimize the time out of water. If anglers must remove a fish from the water, return to the water as soon as possible. It's important to support the weight of the fish and never suspend it by the lip. Minimize handling and only touch fish with wet hands, avoiding contact with the eyes and gills. Anglers should resuscitate a sluggish fish by placing it into the water facing the current until it regains strength and can swim away on its own. High air and water temperatures create stressful environmental conditions for striped bass. Anglers should not target striped bass for catch and release on these days.

Commercial gear restrictions have been implemented that significantly reduce the impact of this gear on striped bass but also have other impacts. Year-round gill net closures above the ferry lines on the Tar-Pamlico and Neuse rivers impact commercial harvest of other species, such as hickory shad and American shad. The hickory shad commercial season in the Tar-Pamlico and Neuse rivers occurs from January 1–April 14. The American shad season occurs from February 15–April 14 and most American shad are harvested during the March striped bass gill net fishery. From 2012 –2017, an average of 16,805 pounds of American shad were harvested in the commercial fishery in January–March in the Tar-Pamlico and Neuse rivers (NCDMF 2013). After the gill net closure in March 2019, commercial landings and the number of trips were greatly reduced in both river systems (NCDMF 2020b). No American shad were harvested in 2019 and 125 pounds were harvested in 2020 in the Tar-Pamlico River. In the Neuse River, commercial harvest of American shad in 2019 was reduced to 1,539 pounds and 109 pounds in 2020.

Tie-downs and Distance from Shore

Proclamation M-6-2019 implemented year-round tie-down and distance from shore restrictions to reduce bycatch of striped bass. The restrictions remain in effect until Amendment 2 is adopted. Prior to the gill net closure, there were no tie-down or distance from shore measures during the commercial shad seasons, large mesh gill net tie-down and distance from shore restrictions were in place once the commercial striped bass season closed. On April 30 annually, or whenever the CSMA striped bass TAL was reached, the 3-foot tie-down and 50-yard distance from shore measures went into effect through December 31.

DMF commercial gill net observer data indicates few striped bass are caught in gill nets set greater than 25 yards from shore above the ferry lines in the Tar-Pamlico and Neuse rivers (Figure 3.6). Observer data indicates clear differences in the spatial distribution of American and hickory shad and striped bass at varying distance from shore. From 2012 to 2018 (Feb 15–April 14), hickory and American shad were caught in all trips observed above the ferry lines that were greater than 200 yards from shore, whereas only 26% of those observed trips caught striped bass. If the gill net closure is removed, requiring large mesh gill nets to be set a minimum distance of 200 yards from shore above the ferry lines would allow the commercial fisheries for hickory and American shad to operate without substantial increases in striped bass discards. Observer coverage would monitor interactions and adaptive management could be used to close the area if necessary.

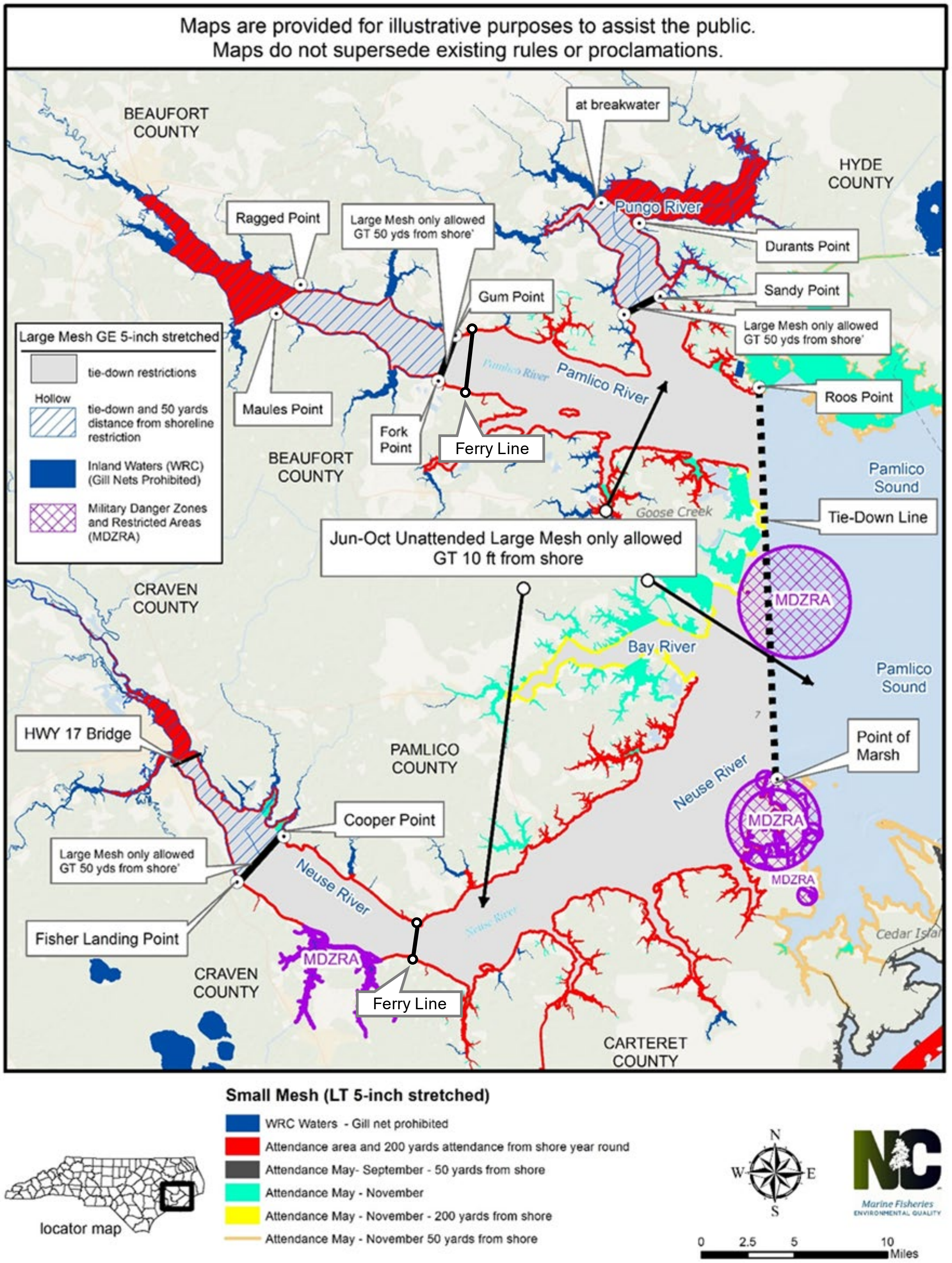


Figure 3.5. Gill net regulation map for various gill net types and seasons in the Central Southern Management Area.

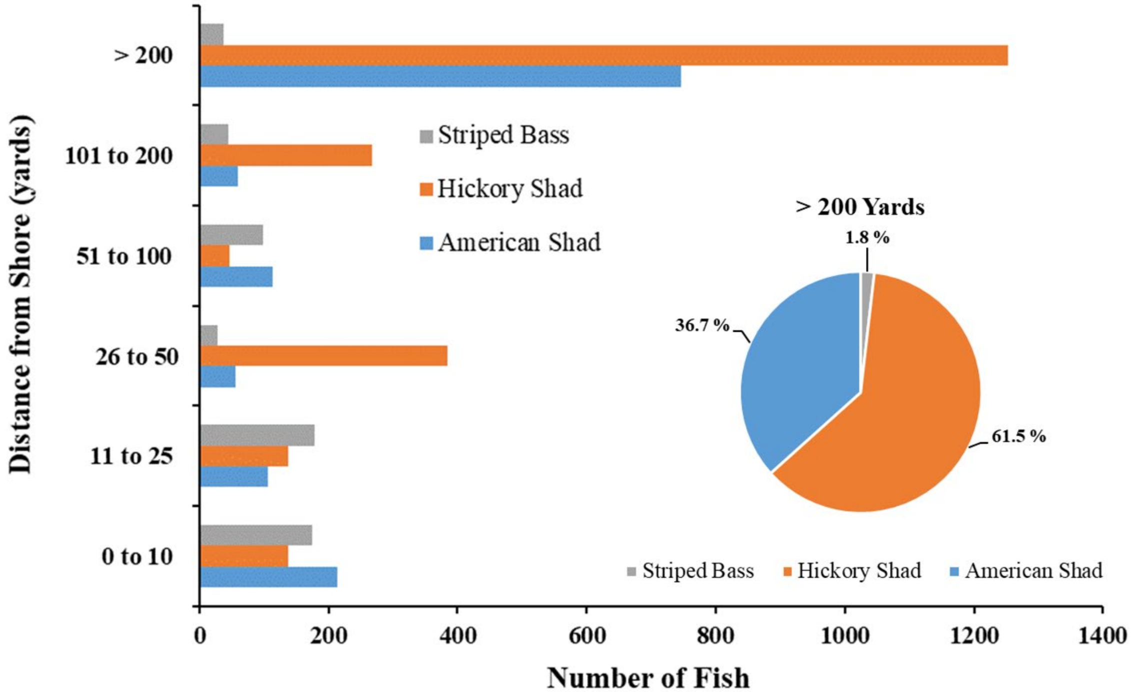


Figure 3.6. DMF observer data for striped bass, hickory shad, and American shad from gill nets set above the ferry lines on the Tar-Pamlico and Neuse rivers (2012–2020; Feb 15 – Apr 14; n=162 trips), separated by the distance from shore (yards). The insert shows the percentage of fish that were observed in gill net sets greater than 200 yards from shore (n=62 trips).

The decision in the Tar-Pamlico and Neuse rivers on opening or closing the striped bass fishery and establishing areas open or closed to gill netting is a tradeoff between providing additional protection to promote self-sustaining populations or providing opportunities to harvest limited numbers of striped bass. If the ferry line gill net closure was not carried forward, commercial gill net restrictions in place before the 2019 closure would be implemented, including the tie-down and distance from shore restrictions. Additionally, rules already in place would require year-round small mesh gill net attendance in the upper portions of the Tar-Pamlico, Pungo, Neuse, and Trent rivers and within 200 yards of shore in the lower portions of the rivers to the western Pamlico Sound. Attendance requirements for small mesh nets were put in place to reduce dead discards in the small mesh gill net fishery. If the harvest moratorium is not maintained, the rationale behind the gill net closure above the ferry lines should be reevaluated along with any additional measures that can potentially allow access to the resource while minimizing the impact on striped bass discards.

<u>Adaptive Management</u>

Adaptive management allows managers to adjust management measures as new information or data becomes available. Management options which are selected during FMP adoption take into account the most up to date data on the biological and environmental factors which affect the stock. After FMP adoption, data through 2024 will be reviewed in 2025 by the striped bass PDT. Trends in key population parameters like adult abundance, age structure, natural recruitment, and hatchery contribution will be evaluated to determine the impact of the 2019 no-possession provision on the stocks. Analysis will also consider environmental conditions (e.g., river flow), changes to stocking strategies, and new life history information. If the data review suggests continuing the no-possession provision is needed for additional stock recovery, no changes in harvest management measures will be recommended until the next FMP Amendment is developed. Adaptive management may be used to adjust management measures including area and time restrictions and gear restrictions if it is determined additional protections for the stocks are needed.

If analysis indicates the populations are self-sustaining and a level of sustainable harvest can be determined, recommendations for harvest strategies will be developed by the PDT. If analysis indicates biological and/or environmental factors prevent a self-sustaining population, then alternate management strategies will be developed that provide protection for and access to the resource.

## MANAGEMENT OPTIONS AND IMPACTS

(+ potential positive impact of action)
(- potential negative impact of action)

1. Striped Bass Harvest
   A. Continue the no-possession measure in Supplement A to Amendment 1

      + Provides an opportunity to evaluate the population response in the absence of fishing mortality.
      + Increases abundance and expands the age structure
      + Provides protection of A-R striped bass found in the Tar-Pamlico and Neuse rivers systems
      + Provides the best chance of achieving sustainable harvest
      - Does not allow for limited harvest of the resource by commercial and recreational fishers
      - May not achieve desired results if other factors negatively influence recruitment
      - Discards in commercial and recreational fishery will still occur

   B. Discontinue the no-possession measure in Supplement A to Amendment 1 after reviewing data in 2025 if it can be shown populations are self-sustaining and a level of sustainable harvest can be determined (open harvest)

      + Allows for limited harvest of the resource by commercial and recreational fishers
      + Reduces discards
      +/- Environmental and other factors may prevent natural recruitment from occurring regardless of stock condition
      - Cannot achieve goal of sustainable harvest at any level of fishing mortality

2. Gear Restrictions/Limits

A. Maintain gill net closure above the ferry lines and maintain the 3-foot tie-downs below the ferry lines

+ Reduces dead discards from the gill net fishery
+ Could help increase abundance and expand age structure
+ Maintains reduced protected species interactions
+ Makes it easier for managers to measure any potential impacts
- Impacts commercial harvest of many species, such as, American shad
- May not increase chances of achieving sustainable harvest

3. Adaptive Management

- In 2025, review data through 2024 to determine if populations are self-sustaining and if sustainable harvest can be determined

+ Adaptive management allows for management adjustments to any of the selected management options as new data becomes available
+ Will help achieve the goal of increased abundance and expanded age structure
+ Allow for scheduled review and adjusted of management measure between scheduled FMP reviews

- Creates management uncertainty if not clearly defined

**RECOMMENDATIONS**

See Appendix 6 for DMF, WRC, and advisory committees recommendations and a summary of online public.

NCMFC Preferred Management Strategy

Options: 1.A., 2.A., and 3.

In addition, the MFC asked that the DMF study the effects of the gill net closure and reevaluate it at the next full amendment review. This research will be conducted, preferably within two years, and this closure be addressed based on that study.

MFC Actions

At its February 2022 business meeting, the MFC approved a motion to send the draft Estuarine Striped Bass Fishery Management Plan Amendment 2 for review by the public and advisory committees with the change of deleting Options 2.B and 2.C. from Appendix 3, leaving only Option 2.A. These options, if selected, provided access above the ferry lines to commercial gill net operations during commercial shad season. Gear, season, and area limitations were included in the options as well as observer monitoring. These options were removed from the draft plan prior to public and advisory committee review.

## APPENDIX 4: ACHIEVING SUSTAINABLE HARVEST FOR THE CAPE FEAR RIVER STRIPED BASS STOCK

### ISSUE

Consider existing factors that prevent a self-sustaining population in the Cape Fear River and implement management measures that provide protection for and access to the striped bass resource.

The 2020 Central Southern Management Area (CSMA) matrix and tagging models show a consistent decline in abundance estimates for striped bass in the Cape Fear River from 2012 – 2018, even with a total harvest moratorium for striped bass in place since 2008. Population abundance is maintained through stocking efforts, but genetic testing and young-of-the-year (YOY) surveys suggest limited natural striped bass reproduction occurs in the system.

### ORIGINATION

North Carolina Division of Marine Fisheries (DMF) and North Carolina Wildlife Resources Commission (WRC).

### BACKGROUND

Historically the Cape Fear River system supported self-sustaining populations of multiple anadromous fish species, including striped bass (Yarrow 1874; Earl 1887). Multiple factors are attributed to declines in anadromous fish stocks, including overfishing, loss of habitat, declining water quality, and blockage of upstream spawning migrations (ASMFC 2007; Limburg and Waldman 2009). Construction of three locks and dams on the mainstem of the Cape Fear River between Riegelwood and Tar Heel, NC, was completed between 1915 and 1935 (Figure 4.1). These impediments to migration severely reduced the ability of striped bass to reach historic spawning areas near Smiley's Falls at the fall line in Lillington, NC (Nichols and Louder 1970). In an effort to enhance striped bass abundance in this system, hatchery reared fish have been stocked into the Cape Fear River by management agencies since at least the 1950s (Woodroffe 2011; *Stocking Information Paper*). In 1974, DMF began a study to document and protect critical spawning habitat for anadromous fishes, resulting in the designation of Anadromous Fish Spawning Areas throughout North Carolina. Spawning areas were identified in the Cape Fear River from the mouth of Town Creek upstream to Lillington, NC (Sholar 1977). As a response to low numbers of documented spawning adults and limited evidence of juvenile recruitment, the current commercial and recreational harvest moratorium of striped bass in the Cape Fear River was implemented in 2008.

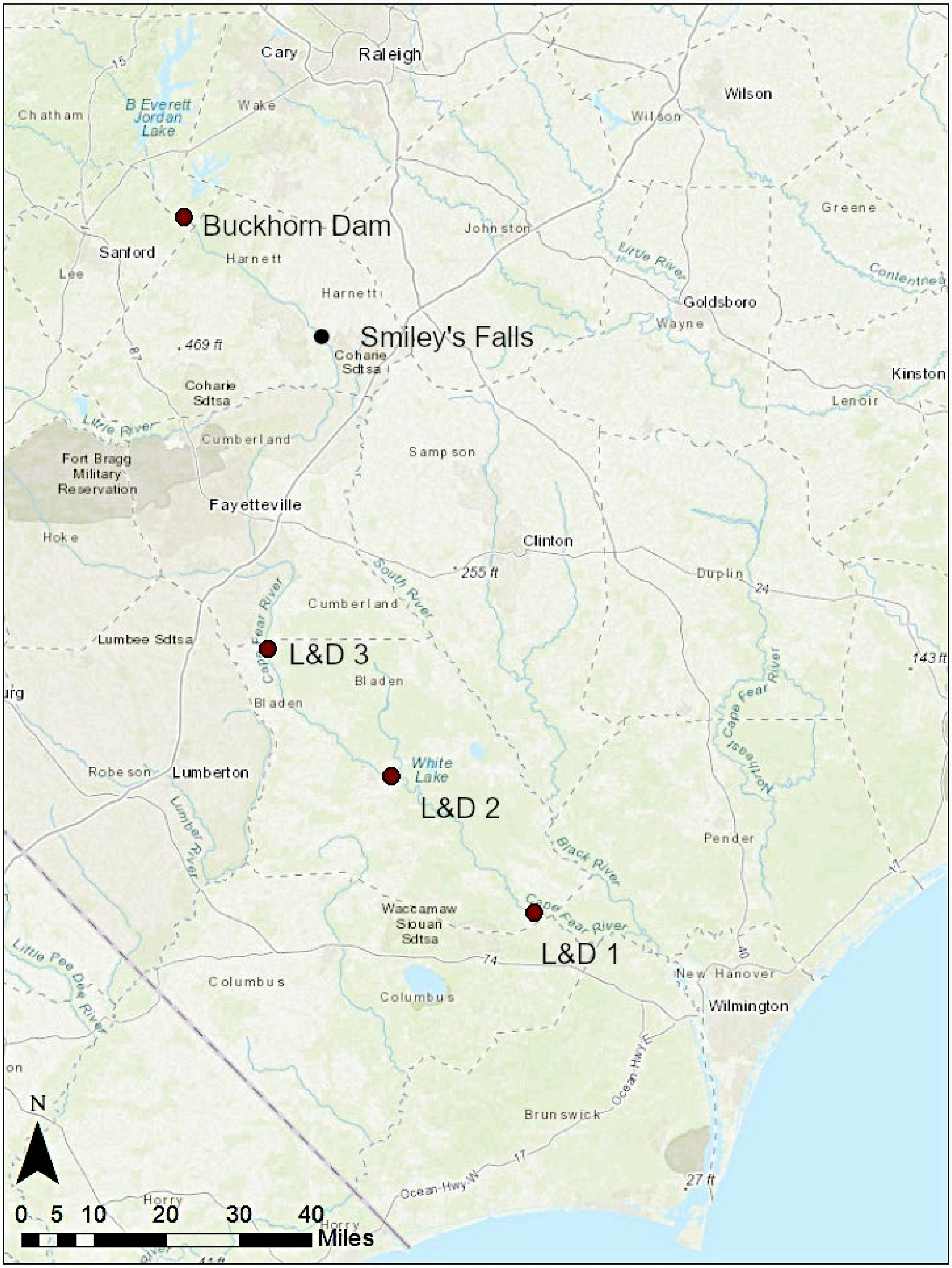


Figure 4.1. A map showing the locations of the three locks and dams on the mainstem of the Cape Fear River downstream of the historic spawning area near Smiley's Falls.

Although evidence of successful striped bass spawning in the Cape Fear River system has been documented by the collection of adult fish in spawning condition and eggs in the water column, few larvae or YOY juveniles have been observed (Hawkins 1980; Winslow et al. 1983; Smith 2009; Smith and Hightower 2012; Dial Cordy and Associates 2017; Morgeson and Fisk 2018; Rock et al. 2018). Limited natural reproduction of striped bass in the Cape Fear River Basin suggests the sustainable harvest of a self-sustaining population of wild fish is not possible at this time (Mathes et al. 2020). Evaluation of stocking efforts using parentage-based testing (PBT) analysis has shown most striped bass sampled in the Cape Fear River during spawning surveys are of hatchery origin (Boggs and Rachels 2021). Restricted access to historic spawning grounds in the mainstem Cape Fear River is likely the primary factor preventing striped bass population recovery in this system. A small amount of natural reproduction is likely occurring in the Northeast Cape Fear River, but the overall contribution to total possible production of striped bass remains unknown. Until passage of striped bass is achieved at all three locks and dams, it is unlikely sustainable harvest of wild fish will be attainable. While strategies are developed to meet passage goals, the potential for harvest of the hatchery supported population of striped bass in the Cape Fear River may be evaluated. For more information on stocking analysis see Appendix 1 Stocking in Coastal River Systems information paper.

**Cape Fear River Striped Bass Stock**

For a comprehensive review of striped bass life history in North Carolina, as well as the Cape Fear River, see Mathes et al. (2020) and Amendment 2 of the Estuarine Striped Bass Fishery Management Plan. Striped bass populations in the CSMA are generally considered to have an endemic riverine life history and typically do not make any oceanic migrations (Rulifson et al. 1982; Callihan 2012). Acoustic tagging studies in the Cape Fear River Basin show adult fish making seasonal migrations within the drainage and minimal emigration out of the system (Rock et al. 2018; Prescott 2019). Striped bass move upstream during the spawning season (March–May), then return to a core residency area (June–February) focused within 10 kilometers around the confluence of the Northeast and mainstem Cape Fear rivers (Rock et al. 2018; Prescott 2019). Striped bass are observed to show fidelity to either the Northeast or mainstem Cape Fear River for spawning migrations, making spring migrations up the same branch which they used the previous year before returning and mixing in the core residency area (Prescott 2019).

The WRC has conducted annual monitoring of the spawning stock of striped bass on the mainstem of the Cape Fear River since 2006. Sampling occurs weekly below each of the three locks and dams from late February through May. Adult abundance is typically much higher for the station below Lock and Dam #1 compared to the remaining stations, and peak abundance occurs in mid to late May (Figure 4.2). Very few striped bass eggs are collected above Lock and Dam #3 where the historic spawning area is located, with most eggs being collected below Lock and Dam #1 (Dial Cordy and Associates 2017). In 2017, DMF juvenile abundance trawl and seine survey stations were developed for the Cape Fear River system. Zero YOY striped bass have been collected in mainstem sampling. The last documented YOY striped bass collected in the mainstem Cape Fear River were in July 1977 (Hawkins 1980).

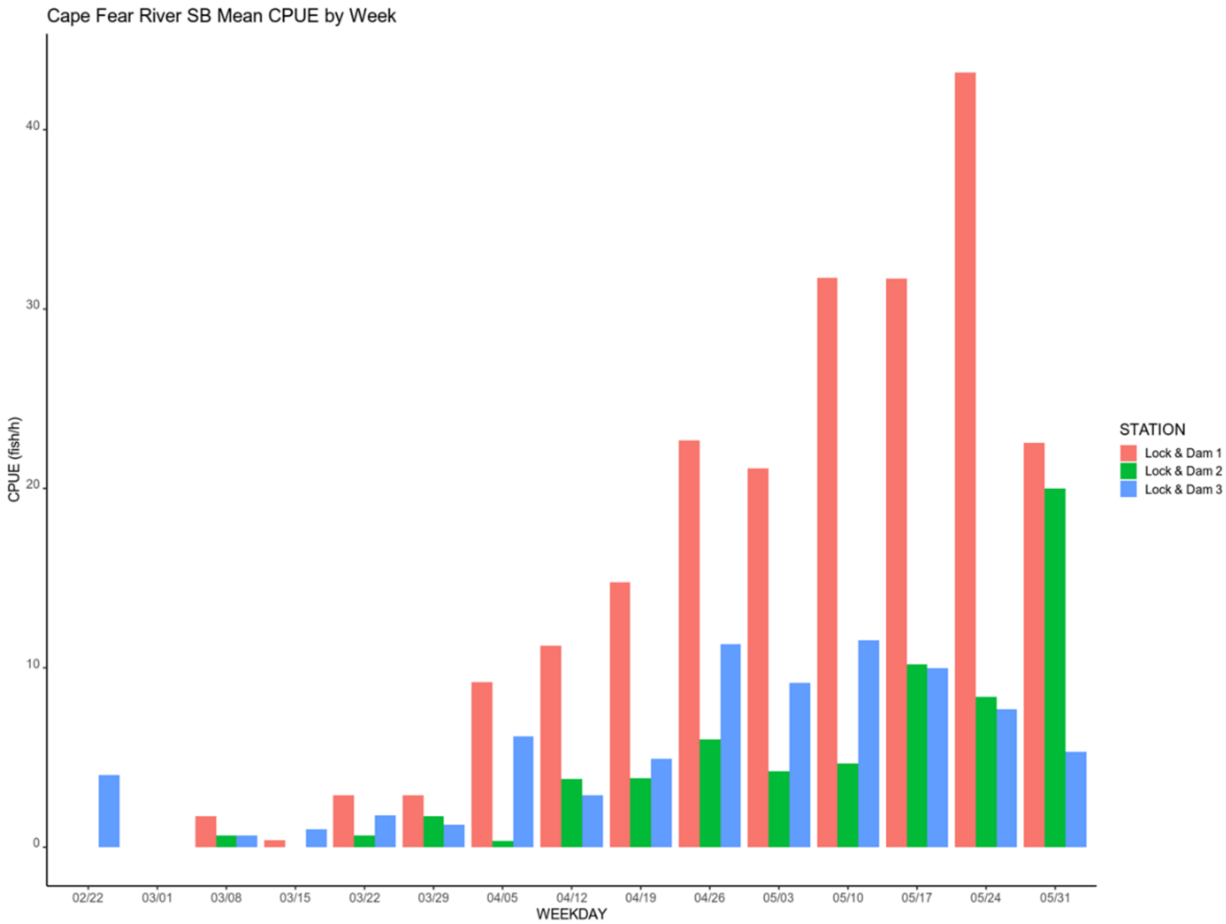


Figure 4.2. Weekly striped bass catch-per-unit-effort (CPUE) by sample site February through May 2008–2019.

In the Northeast Cape Fear River, adult striped bass have been captured and acoustically tagged during the spawning season (April – May) between White Stocking, NC, (kilometer 118) and Chinquapin, NC, (kilometer 168), with potential spawning occurring as far upstream as Hallsville, NC (kilometer 183; Rock et al. 2018). Winslow et al. (1983) documented small numbers of YOY striped bass in the lower Northeast Cape Fear River. DMF sampling collected 24 YOY striped bass in 2018, four were collected in 2019, and two were collected in 2020 at stations in the Northeast Cape Fear River (Darsee et al. 2020).

The first well documented stocking of hatchery origin striped bass into the Cape Fear system began in the 1950s (Wodroffe 2011). For a history of stocking in the Cape Fear River system see Appendix 1 Stocking in Coastal River Systems information paper. State and federal hatcheries have produced striped bass released into the system, and ongoing stocking efforts are made by a cooperative agreement between the USFWS, DMF, and WRC, which has been in place since 1986. Between 1980 and 2009, over 629,000 "phase-II" Roanoke River strain striped bass (approximately 5 – 7 inches total length), were stocked into the Cape Fear River system. Since 2010, an average of 144,000 phase-II striped bass were stocked into the system annually (Table 1.1 and 1.2). Starting in 2010, adult striped bass captured in the Cape Fear River were used as broodstock for stocking efforts into the system. No genetic difference was detected between Cape

Fear and Roanoke fish sampled between 2009–2011, and this was attributed to the previous stocking history of Roanoke hatchery origin fish into the Cape Fear system (Anderson et al. 2014). The extent of impacts from stocking striped bass originating in the Roanoke River into other striped bass populations remain relatively unknown (Rulifson and Laney 1999; Bergey et al. 2003). However, Anderson et al. (2014) suggested that, despite genetic similarity between Roanoke and Cape Fear River fish, natural reproduction of striped bass was likely occurring in the Cape Fear River.

Jordan Reservoir, a large impoundment in the Cape Fear River basin above the fall line and known historic spawning grounds for striped bass, was stocked with hybrid striped bass (*M. chrysops x M. saxatilis*) until the early 2000s. The WRC stopped stocking hybrid striped bass in Jordan Reservoir due to escapement of these fish into the lower Cape Fear River, and evidence that escaped fish would interfere with striped bass restoration efforts (e.g., interbreed with and/or outcompete for resources; Patrick and Moser 2001). Striped bass were stocked into Jordan Reservoir as a replacement for the hybrid striped bass recreational fishery from the mid-2000s until 2020. Evaluation of the stocked striped bass fishery in Jordan Reservoir suggested low survival and low angler participation, resulting in WRC discontinuing this reservoir stocking effort.

Parentage-based tagging (PBT) was implemented by the WRC as a means to determine percent hatchery contribution to the striped bass spawning populations in the CSMA systems starting in 2010. Using known genetic markers from parent brood stock, this method can determine if a fish was produced in a hatchery (Denson et al. 2012). In 2011, WRC analyzed all striped bass captured in their Cape Fear River spawning survey. In 2017, DMF began collecting additional samples in the lower portion of the Cape Fear River and in the Northeast Cape Fear River and mainstem mixing area. Additionally, a subset of the YOY captured in the Northeast Cape Fear River during 2018 and 2019 were tested, and all YOY analyzed were determined to not to be of hatchery origin and likely wild spawned. PBT results show hatchery origin fish comprise between 63% and 93% of the fish tested each year, and the percentage of fish determined to be of hatchery origin increasing annually (Table 1.4). Fish determined to be of unknown origin are not necessarily wild-spawned since parentage-based markers are only available back to the 2010 year-class of stocked fish. The 89% hatchery contribution indicated in 2018 PBT analysis is likely an accurate reflection of actual hatchery contribution to the 2018 Cape Fear River striped bass population, as striped bass aged in the system are typically less than 10 years old. Additionally, an increasing proportion of fish stocked into the upriver reservoirs are represented in the Cape Fear River system (Figure 4.3). The proportion of Jordan Reservoir stocked fish increases upriver and fish collected below Buckhorn Dam are entirely reservoir origin (Figure 4.4).

**Striped Bass Fisheries**

A total harvest moratorium on striped bass was enacted in 2008 as a management strategy in response to low numbers of documented spawning adults and limited evidence of juvenile recruitment in the Cape Fear River system (NCDMF 2013).

*Recreational*

Striped bass provide an important and popular recreational angling opportunity in the Cape Fear River. Despite a harvest moratorium, striped bass are targeted by anglers and support a catch-and-release fishery in the system. Recreational charter vessels hired by recreational fishers target Cape Fear River striped bass during the winter months; by April effort typically shifts to other fisheries.

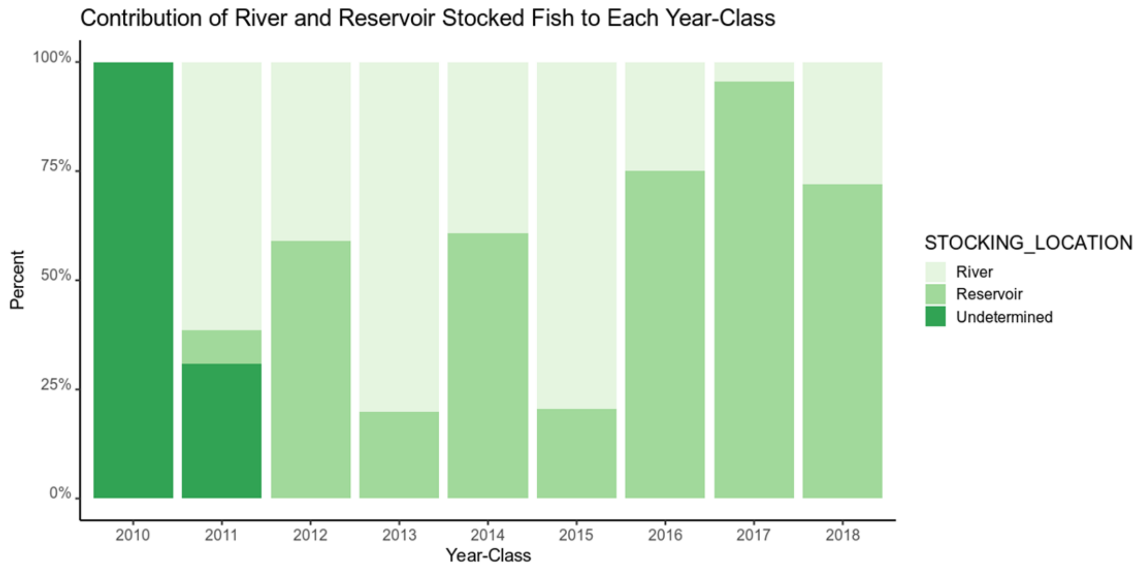


Figure 4.3. Relative contribution of hatchery-origin fish to the hatchery-origin year-class by stocking location of fish collected in WRC electrofishing surveys, 2010–2018.

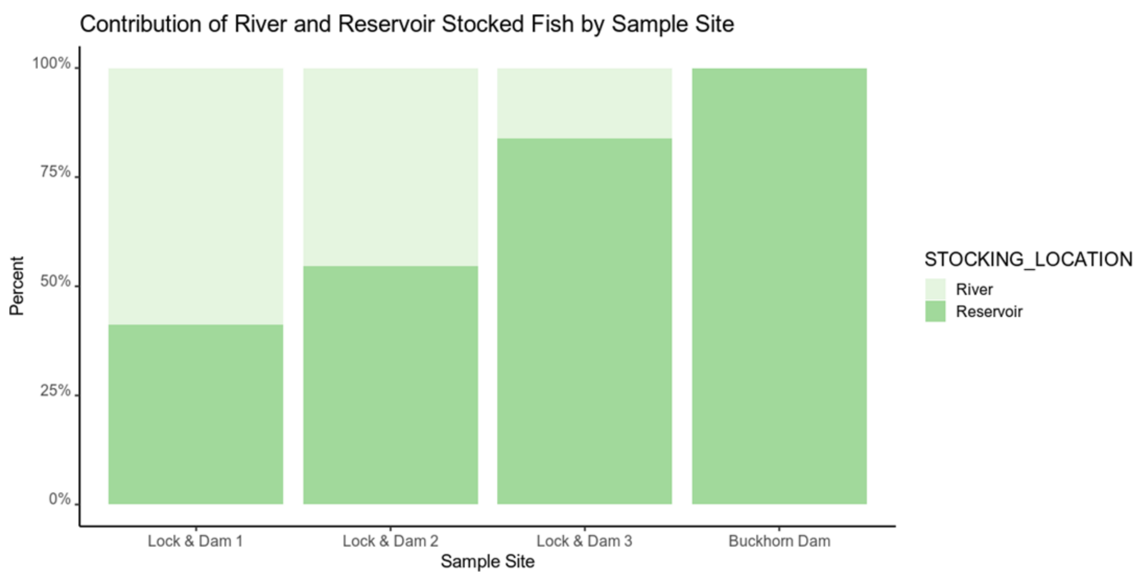


Figure 4.4. Relative contribution of hatchery-origin fish by stocking location to each WRC electrofishing sample site, 2015–2019.

Since 2013, the DMF Coastal Angling Program (CAP) has partnered with WRC on an anadromous creel survey to interview recreational anglers in the Cape Fear River for the purpose of producing effort and catch estimates for striped bass and American shad. Within the Cape Fear River, annual striped bass catch estimates are highly variable and imprecise, ranging between 14 and 1,551 fish from 2013 – 2018 (Table 4.1).

Striped bass in the Cape Fear River have been tagged using external anchor tags since 2011. These tags are highly visible and have instructions for anglers to report and return them to DMF for cash rewards. Beginning in 2015, striped bass were marked with both low ($5) and high reward tags ($100). As anglers may not report all tagged fish captured, the difference in tag returns between high (assumed to have a 100% reporting rate) and low reward tags can be used to calculate corrected low reward tag reporting rates. The percentage of tagged fish in a population which are reported by recreational anglers when taken into consideration with the tag reporting rate can be used to understand the overall recreational fishing catch. In the Cape Fear River from 2011 – 2020, 14.9% of the striped bass tagged with low reward tags were captured by recreational anglers and reported to the DMF and considering the calculated tag reporting rate this number likely represented 51.7% of the overall tagged striped bass caught by anglers during this time (Table 2.). Even though a harvest moratorium is in place, the overall proportion of high reward tagged striped bass caught and reported by recreational anglers in the Cape Fear River (28.9%) is similar to what was reported between 2020 and 2021 for high reward tags in other recreationally important species in North Carolina waters (spotted sea trout 33.3%, southern flounder 29.5%, striped bass statewide 22.4%; NCDMF 2021).

Table 4.1. Effort and catch estimates for Cape Fear River striped bass from Coastal Angling Program anadromous creel survey. PSE values are in parenthesis.

| Year | Number of Striped Bass Trips | Striped Bass Trip Hours | Total Striped Bass Catch |
|---|---|---|---|
| 2013 | 257 (48.6) | 870 (63.1) | 355 |
| 2014 | 433 (42.9) | 2140 (45.9) | 1,551 |
| 2105 | 209 (50.1) | 702 (53) | 199 |
| 2016 | 391 (46.4) | 1464 (44.4) | 628 |
| 2017 | 26 (100) | 159 (100) | 14 |
| 2018 | 24 (77.1) | 61 (71.5) | 140 |

*Commercial*

Between 1994 and 2008, annual commercial striped bass landings from the Cape Fear River averaged 1,206 pounds and ranged from 68 to 4,138 pounds (Table 4.2). Cape Fear River landings on average comprised less than 5% of the 25,000-pound CSMA Total Allowable Landings (TAL). Additionally, trips which contained striped bass comprised between 0.60% and 11.8% of total annual trips from the Cape Fear River which landed finfish during this time (Table 4.3). Gill nets accounted for 99.9% of the total landings of Cape Fear River striped bass, with the remainder of the landings from hook and line and crab pots (Table 4.4). Between 2011 and 2020, less than

0.01% of the reward tagged striped bass were captured and returned by commercial fishing operations.

Table 4.2. Numbers of striped bass tagged by DMF and then captured and reported by recreational anglers in the Cape Fear River by year and reward type ($5 for low reward, $100 for high reward). Low reward tag corrected reporting rate is calculated with the assumption that high reward tags are 100% reported.

| | Low Reward | | High Reward | | |
|---|---|---|---|---|---|
| Year | # Released | % Returned | # Released | % Returned | Low Reward Corrected Reporting Rate |
| 2011 | 286 | 4.9 | * | | |
| 2012 | 405 | 6.7 | * | | |
| 2013 | 491 | 9.4 | * | | |
| 2014 | 600 | 13.5 | * | | |
| 2015 | 640 | 18.1 | 49 | 36.7 | 49.3 |
| 2016 | 474 | 21.1 | 117 | 34.2 | 61.7 |
| 2017 | 349 | 18.3 | 9 | 33.3 | 55.0 |
| 2018 | 372 | 12.1 | 44 | 9.1 | ** |
| 2019 | 259 | 23.2 | 12 | 0.0 | ** |
| 2020 | 245 | 25.3 | 15 | 40.0 | 63.3 |
| Total | 4,121 | 14.9 | 246 | 28.9 | 51.7 |

*No high reward tags used

**Unable to be calculated

## Stock Concerns

In the 2020 Central Southern Management Area (CSMA) Striped Bass Stocks report, Cape Fear River striped bass abundance estimates ranged from 1,578 (2017) to 10,983 (2012) between 2012 and 2018 (Mathes et al. 2020). Abundance estimates consistently declined over this time period, and by 2018 striped bass abundance was reduced to less than 20% of what it was in 2012 (Mathes et al. 2020).

No legal recreational or commercial harvest of striped bass has occurred in the Cape Fear River system since the harvest moratorium was established in 2008, yet adult abundance estimates have continued to decline, indicating natural reproduction in the system has been limited and non-harvest related mortality is high. Specific estimates of discard mortality are unknown in this system.

Two non-native predatory catfish species Blue Catfish (*Ictalurus furcatus*), and Flathead Catfish (*Pylodictis olivaris*) are established in the Cape Fear River system. Both of these catfish have been documented to cause reductions in the abundance and composition of native fish in the systems where they have been introduced. In the Cape Fear River, these two species have been directly observed to prey on anadromous fish, including striped bass (Ashley and Buff 1988, Belkoski et al. 2021). Population level impacts to striped bass via direct predation by introduced catfish, or through competition for the same prey resources remains unquantified in the Cape Fear system.

Table 4.3. Cape Fear River striped bass annual commercial landings in pounds from all gears, percentage that striped bass contributed to the total annual Cape Fear River finfish commercial landings, and percentage of all finfish trips with striped bass landings 1994–2008. DMF Trip Ticket Program.

| Year | Landings (lbs.) | % of Total CFR Finfish Landings | % of CFR Finfish Trips With STB Landings |
|---|---|---|---|
| 1994 | 480 | 0.01 | 2.21 |
| 1995 | 264 | 0.26 | 1.85 |
| 1996 | 4,139 | 3.81 | 11.42 |
| 1997 | 2,187 | 2.21 | 8.38 |
| 1998 | 501 | 0.67 | 6.53 |
| 1999 | 1,001 | 1.72 | 8.35 |
| 2000 | 567 | 0.70 | 5.75 |
| 2001 | 129 | 0.18 | 2.15 |
| 2002 | 173 | 0.22 | 2.51 |
| 2003 | 68 | 0.08 | 0.60 |
| 2004 | 2,364 | 2.96 | 11.80 |
| 2005 | 2,721 | 3.36 | 10.86 |
| 2006 | 1,057 | 1.61 | 4.64 |
| 2007 | 1,601 | 2.02 | 8.59 |
| 2008 | 831 | 1.07 | 6.10 |

Table 4.4. Percentage of total Cape Fear River commercial striped bass landings (weight) by gear, 1994–2008.

| Gear | Percentage |
|---|---|
| Set sink gill net | 93.09% |
| Set float gill net | 3.58% |
| Drift gill net | 3.15% |
| Runaround gill net | 0.08% |
| Crab pot | 0.06% |
| Hook and line | 0.04% |

Water quality impacts in the Cape Fear River may contribute to poor recruitment of striped bass in this system. Striped bass require dissolved oxygen (DO) levels greater than 5 mg/L (Funderburk et al. 1991), and specific flow conditions are required for the survival of egg, larvae, and juvenile life stages (Rulifson and Manooch 1990). Impacts from urban and agricultural development in the Cape Fear River Basin can negatively impact water quality parameters, and the percentage of land developed for urban and agricultural uses is generally increasing in this system. Nearly 23% of the land in the basin is used for agriculture, such as pork and poultry production (Xian and Homer 2010). Conditions such as elevated temperatures combined with nutrient loading from agricultural and stormwater runoff creates high biological oxygen demand (BOD) and low DO (below 5 mg/L) conditions in the Cape Fear River (Mallin et al. 2006). Striped bass mass mortality caused by poor water quality in the Cape Fear River associated with large storm events have also been observed. In September 2018, water quality impacts from Hurricane Florence led to fish kills in the Cape Fear River. DMF staff observed dead striped bass at multiple locations from Lock and Dam #1 to the Cape Fear River inlet at Caswell Beach and 574 dead striped bass were recovered from Battleship Park (Wilmington, NC) in the week after the storm. Numerous chemical contaminants such as endocrine disrupting compounds (EDCs), heavy metals, per- and polyfluoroalkyl chemicals (PFAS), and other organic pollutants have been found in both the fish and the water of the Cape Fear River (Mallin et al. 2011; Black and Veatch 2018; Guillette et al. 2020). Guillette et al. (2020) found concentrations of PFAS to be 40 times higher in Cape Fear River striped bass than a control group, and these elevated levels were associated with changes to the liver and immune system of the fish.

The construction of the three locks and dams on the mainstem Cape Fear River has significantly reduced the ability of striped bass to reach historic spawning habitat at the fall line. The lowermost lock and dam (river kilometer 95) was completed in 1915 and is located approximately 160 river kilometers downstream of the striped bass spawning habitat at Smiley Falls. By 1935 two more locks and dams were completed above Lock and Dam #1, further restricting possible upriver access to spawning habitat. Fish ladders were constructed at each dam, but striped bass did not successfully use them, and passage over the dam was limited to extreme high flow or locking events (Nichols and Louder 1970). From 1962–2012, the United States Army Corps of Engineers (USACE) operated a daily locking schedule developed by WRC from March through May, with the goal of passing anadromous fish over the dams; however, studies have shown that a large proportion of fish below each dam are unable to pass using the lock chamber (Moser et al. 2000; Smith and Hightower 2012). Based on acoustic telemetry results while the USACE was operating the locking schedule, Smith and Hightower (2012) estimated 77% of striped bass could pass Lock and Dam #1, and only 25% were able to pass all three locks and dams.

In 2012, a rock arch ramp was constructed at Lock and Dam #1 to allow for continuous passage of anadromous fish over the dam without the need for locking. Success criteria for the rock arch ramp was set as 80% passage efficiency for target species by project biologists. Subsequent evaluation of passage at the rock arch ramp resulted in only 25% successful passage of striped bass (Raabe et al. 2019). Despite its failure to improve passage, USACE has not conducted anadromous fish locking at Lock and Dam #1 since construction of the fishway in 2012. Additionally, the lock structures at Lock and Dam #2 and #3 were damaged by Hurricanes Matthew and Florence and have been inoperable since 2018. The rock arch ramp design at Lock and Dam #1 did not meet physical design criteria (e.g., slope, pool dimensions, weir openings) later determined to be required for successful striped bass passage by Federal Interagency Nature-like Fishway Passage Design Guidelines for Atlantic Coast Diadromous Fishes (Turek and Haro 2016). Cape Fear River Watch received a Coastal Recreational Fishing License grant from DMF to modify the rock arch ramp to better meet the required passage criteria for striped bass, and construction was completed in November 2021.

The Cape Fear River Partnership is a coalition of 35 governmental, academic, and conservation organizations with a goal of restoring self-sustaining stocks of migratory fish in the Cape Fear

River. Since its formation in 2011, the Partnership has facilitated cooperation across member organizations to help achieve fish passage objectives through the construction and modification of the rock arch ramp at Lock and Dam #1 and to advance passage goals at the remaining locks and dams. Bladen County government and Cape Fear River Watch have led the efforts to engineer, design, and permit passage structures at Locks and Dams #2 and 3, securing over $3.1 M in necessary funding to date. In 2018, the USACE initiated a Disposition Study on the future of the locks and dams as they are no longer needed for their authorized purpose of maintaining commercial barge navigation between Wilmington and Fayetteville. The USACE released a draft of the Disposition Study in 2020 in which they recommend deauthorizing all three dams and transferring them to a non-federal entity. Removal of Locks and Dams #1 and #3 is unlikely, as they serve as structures to support storage and intake for the public water supplies of the Wilmington and Fayetteville areas. The NC General Assembly has enacted House Bill 2785, in which the State of North Carolina would accept the transfer of all of the locks and dams, however the structures would need to be “properly refurbished” and have fish passage structures in place for the transfer to occur. Both the NC Department of Environmental Quality and Fayetteville Public Works Commission have filed letters of intent with the USACE to take ownership of the three locks and dams if they are decommissioned. However, additional federal study and action are needed to determine the future of the dams.

In 2016 the Cape Fear River Basin was added to the Sustainable Rivers Program, a joint nationwide effort between the USACE and The Nature Conservancy (TNC) to improve the health of rivers by changing dam operations to enhance and protect ecosystems. A workshop of expert stakeholders considered biological flow needs and hydrologic conditions to make a series of environmental flow recommendations (TNC 2019). Beginning in 2020, the USACE adopted the workshop flow recommendations and modified dam release patterns during rainfall events to purposefully release flow from Jordan Reservoir during the anadromous fish migration period (March–April) to fully submerge all three locks and dams (Figure 4.5). With the dams submerged, it is believed that fish may pass without locking or the use of a fish passage structure. Preliminary evaluation of this new approach suggests that striped bass could time upstream movements with these pulsed flows and successfully migrate over the dams without a passage structure present (Bunch 2021). Additional monitoring is required to fully evaluate the efficacy of this passage strategy.

## AUTHORITY

North Carolina’s existing fisheries management system for striped bass is adaptive, with rulemaking authority vested in the MFC and the WRC within their respective jurisdictions. The MFC may delegate to the fisheries director the authority to issue public notices, called proclamations, suspending or implementing, in whole or in part, particular MFC rules that may be affected by variable conditions. Management of recreational and commercial striped bass regulations within the Cape Fear River are the responsibility of the MFC in Coastal and Joint Fishing Waters, and recreational regulations are the responsibility of the WRC in Joint and Inland Fishing Waters. It should also be noted that under the provisions of Amendment 1 to the North Carolina Estuarine Striped Bass FMP the DMF Director maintains proclamation authority to establish seasons, authorize or restrict fishing methods and gear, limit quantities taken or possessed, and restrict fishing areas as deemed necessary to maintain a sustainable harvest. The WRC Executive Director maintains proclamation authority to establish seasons.


Figure 4.5. Photos showing Lock and Dam #2 at lower flow during the spring anadromous fish migration period (upper image), and fully submerged during the modified dam release flow pulse which is intended to allow fish to pass over the dam without a passage structure present. Photo Credit: Aaron Bunch, Clemson University (Bunch 2021)

NORTH CAROLINA GENERAL STATUTES

*N.C. General Statutes*

| | |
|---|---|
| G.S. 113-132. | JURISDICTION OF FISHERIES AGENCIES |
| G.S. 113-134. | RULES |
| G.S. 113-182. | REGULATION OF FISHING AND FISHERIES |
| G.S. 113-182.1. | FISHERY MANAGEMENT PLANS |
| G.S. 113-221.1. | PROCLAMATIONS; EMERGENCY REVIEW |
| G.S. 113-292. | AUTHORITY OF THE WILDLIFE RESOURCES COMMISSION IN REGULATION OF INLAND FISHING AND THE INTRODUCTION OF EXOTIC SPECIES. |
| G.S. 143B-289.52. | MARINE FISHERIES COMMISSION—POWERS AND DUTIES |
| G.S. 150B-21.1. | PROCEDURE FOR ADOPTING A TEMPORARY RULE |

NORTH CAROLINA RULES

*N.C. Marine Fisheries Commission Rules 2020 and N.C. Wildlife Resources Commission Rules 2020* (15A NCAC)

| | |
|---|---|
| 15A NCAC 03H .0103 | PROCLAMATIONS, GENERAL |
| 15A NCAC 03M .0201 | GENERAL |
| 15A NCAC 03M .0202 | SEASON, SIZE AND HARVEST LIMIT: INTERNAL COASTAL FISHING WATERS |
| 15A NCAC 03M .0512 | COMPLIANCE WITH FISHERY MANAGEMENT PLANS |
| 15A NCAC 03Q .0107 | SPECIAL REGULATIONS: JOINT FISHING WATERS |
| 15A NCAC 03Q .0108 | MANAGEMENT RESPONSIBILITY FOR ESTUARINE STRIPED BASS IN JOINT FISHING WATERS |
| 15A NCAC 03Q .0109 | IMPLEMENTATION OF ESTUARINE STRIPED BASS MANAGEMENT PLANS: RECREATIONAL FISHING |
| 15A NCAC 03Q .0202 | DESCRIPTIVE BOUNDARIES FOR COASTAL-JOINT-INLAND WATERS |
| 15A NCAC 03R .0201 | STRIPED BASS MANAGEMENT AREAS |
| 15A NCAC 10C .0107 | SPECIAL REGULATIONS: JOINT WATERS |
| 15A NCAC 10C .0108 | SPECIFIC CLASSIFICATION OF WATERS |
| 15A NCAC 10C .0110 | MANAGEMENT RESPONSIBILITY FOR ESTUARINE STRIPED BASS IN JOINT FISHING WATERS |
| 15A NCAC 10C .0111 | IMPLEMENTATION OF ESTUARINE STRIPED BASS MANAGEMENT PLANS: RECREATIONAL FISHING |
| 15A NCAC 10C .0301 | INLAND GAME FISHES DESIGNATED |
| 15A NCAC 10C .0314 | STRIPED BASS |

## DISCUSSION

### Maintain Cape Fear River Harvest Moratorium

Despite a total harvest moratorium and annual hatchery support, the 2020 CSMA striped bass stock report shows continued decline in abundance estimates from 2012 – 2018. Passage efficiency has been demonstrated to be poor over the current configuration of the passage structure at the lowermost dam in the Cape Fear River (Raabe et al. 2019) and egg collection studies indicate most striped bass spawning activity in the mainstem occurs below Lock and Dam #1 (Dial Cordy and Associates 2017). PBT analysis suggests low successful recruitment from wild spawned fish and shows increasing proportions of reservoir stocked fish captured in the river, with fish collected below Buckhorn Dam entirely of reservoir origin. Limited upriver access to appropriate spawning habitat may be preventing stock recovery despite limiting fishing mortality via a moratorium. Modifications for the fish passage structure at Lock and Dam #1, designed to improve passage for striped bass (construction in 2021), will potentially allow striped bass to easily migrate an additional 90 river kilometers upstream before reaching Lock and Dam #2. Anecdotal evidence suggests that fish may be able to pass over Lock and Dam #2 during higher flow conditions. Through NGO and management agency partnerships, millions of dollars to construct passage at both Lock and Dams #2 and #3 have been secured and engineering and design options have been completed. However, USACE permits have not been acquired and the total funding to construct passage at both dams remains incomplete, resulting in an undetermined construction timeframe.

The Northeast Cape Fear River does not have blockages to fish passage. However, the importance of this river for striped bass reproduction has remained relatively unexamined. Acoustic telemetry has shown repeated spring spawning migrations and YOY have been captured in this tributary. Acoustic telemetry data also shows a contingent of fish which show fidelity for the Northeast Cape Fear for spawning migrations and return to the core residency area focused within 10 kilometers around the confluence of the Northeast and mainstem Cape Fear Rivers for the rest of the year (Rock et al. 2018; Prescott 2019). This suggests a small subset of striped bass in the Cape Fear River Basin are successfully spawning in the Northeast Cape Fear and are protected from harvest under the current moratorium.

High levels of PFAS have been found in Cape Fear River striped bass (Guillette et al. 2019). While the specific biological impacts to striped bass remain unknown, the consumption of fish is linked to human PFAS exposure (Haug et al. 2010). The Environmental Protection Agency has established the health advisory levels at 70 parts per trillion in drinking water, and the Great Lakes Consortium for Fish Consumption Advisories states for fish with concentrations of greater than 200 µg/kg as “DO NOT EAT”. Under a harvest moratorium, striped bass are not retained for consumption. However, DMF and WRC have not placed harvest restrictions on finfish due to consumption advisories, and no specific consumption advisory has been issued for PFOS in striped bass by the Occupational and Environmental Epidemiology Branch of the North Carolina Division of Public Health.

PBT analysis results demonstrate that most of the striped bass sampled in the Cape Fear River are of hatchery origin, and most of the fish sampled above Lock and Dam #1 are hatchery reared fish which have been stocked into the upriver reservoirs. Current WRC inland fishing regulations allow for harvest in the hatchery supported striped bass fisheries of the reservoirs in the Cape Fear basin above Buckhorn Dam. However, as the reservoir stocking of striped bass has been discontinued, the downriver migration of reservoir fish into the Cape Fear River will no longer occur.

WRC management has stated if a harvest moratorium remains in place, the continued allocation of substantial WRC resources to stock striped bass on an annual basis in the Cape Fear River cannot be justified. The North Carolina Interjurisdictional Fisheries annual stocking work plan may be modified in order to best use WRC hatchery resources for stocking other systems. For annual stocking to continue in the Cape Fear River, production of striped bass may need to be shifted to the federal partner.

**Allow Seasonal Harvest in All Cape Fear River Fishing Waters**

Removing the harvest moratorium for striped bass in the Cape Fear River would require a change to or suspension of MFC Rules 15A NCAC 03M .0202 (a)(b), and 15A NCAC 03Q .0107 (1)(d), as well as a change to WRC Rules 15A NCAC 10C .0107 (1)(d), and 15A NCAC 10C .0314 (h). The remaining MFC rule language would allow commercial or recreational harvest in Joint and Coastal Fishing Waters (Figure 4.6) between October 1 through April 30 and would cap the potential minimum size limit at no less than 18 inches. This rule would also allow for a recreational bag limit of no more than two fish per day. More conservative season dates, size or bag limits, and area restrictions may be specified by proclamation. Any commercial landings of striped bass from the Cape Fear River could count toward a TAL applicable to the CSMA, be managed under a separate TAL, or another strategy depending on other management actions adopted.

Allowing harvest under a hatchery supported striped bass fishery management strategy in the lower river would create equity in management throughout the system. Because very few striped bass in the Cape Fear basin appear to be of wild origin and current impediments to passage limit the ability of striped bass to reach appropriate spawning habitat in the mainstem Cape Fear, fishing mortality would likely have little impact on the amount of wild spawned fish in the system. However, an increase in fishing mortality may exacerbate the decline in abundance of striped bass observed in recent years and potentially further truncate the age structure of the population. Size and possession limits could be established to protect certain age or size classes and could potentially mitigate impacts to population demographics from increased fishing mortality. As strategies to improve passage at the locks and dams are implemented, maintaining sufficient spawning stock biomass with an expanded age structure available to migrate to the spawning grounds will be necessary for striped bass recovery efforts in the Cape Fear River.

Allowing recreational harvest of the predominantly hatchery supported striped bass in the Cape Fear River may be viewed by recreational anglers as a suitable use of the hatchery produced fishery resource. However, opening the Joint and Coastal Fishing Waters to the taking of striped bass would potentially allow for the commercial harvest of this hatchery supported population. Commercial harvest of hatchery supported fish may create user conflicts or be perceived as a poor use of the resource by recreational anglers. The potential harvest by commercial fishers could be accommodated by allocating a small quota to the commercial sector and by using contributions from commercial fishing license sales to help support the hatchery program. While striped bass from the Cape Fear River did not historically contribute much to the overall statewide commercial landings, they were a consistent component of finfish landings from the system. With increased regulation in other commercial fisheries, opening striped bass for commercial harvest in the Cape Fear River may result in a larger percentage of the finfish landings from this waterbody than before the harvest moratorium.

Allowing harvest of striped bass from all waters of the Cape Fear system would increase fishing mortality on the small and relatively unstudied contingent of potentially naturally reproducing fish in the Northeast Cape Fear River, possibly leaving them vulnerable to overharvest or depletion.

**Allow Seasonal Harvest in Joint and Inland Fishing Waters in the Mainstem Cape Fear River Above 140 Bridge**

Harvest area boundaries can be set with the goal of allowing harvest on hatchery supported striped bass in the Cape Fear River, while protecting the relatively small and unstudied contingent of fish that may spawn in the Northeast Cape Fear. Allowing harvest of striped bass only in the Joint and Inland Fishing Waters of the Cape Fear River above the Highway 140 Bridge (Figure 4.5), would limit the harvest of the Northeast Cape Fear contingent of fish. Opening Joint Fishing Waters above the Highway 140 Bridge to striped bass harvest could allow for the commercial harvest of striped bass in this section of river. A commercial shad drift gillnet fishery operates between February 20 and April 11 each year. Due to protected species interactions, set gill net gear has been prohibited in this section of river. Striped bass may be targeted in this fishery if harvest is allowed. A hook and line commercial fishery could be developed. For more information on hook and line as a potential commercial gear, see Appendix 5 Use of Hook and Line as a Commercial Gear in the Estuarine Striped Bass Fishery.

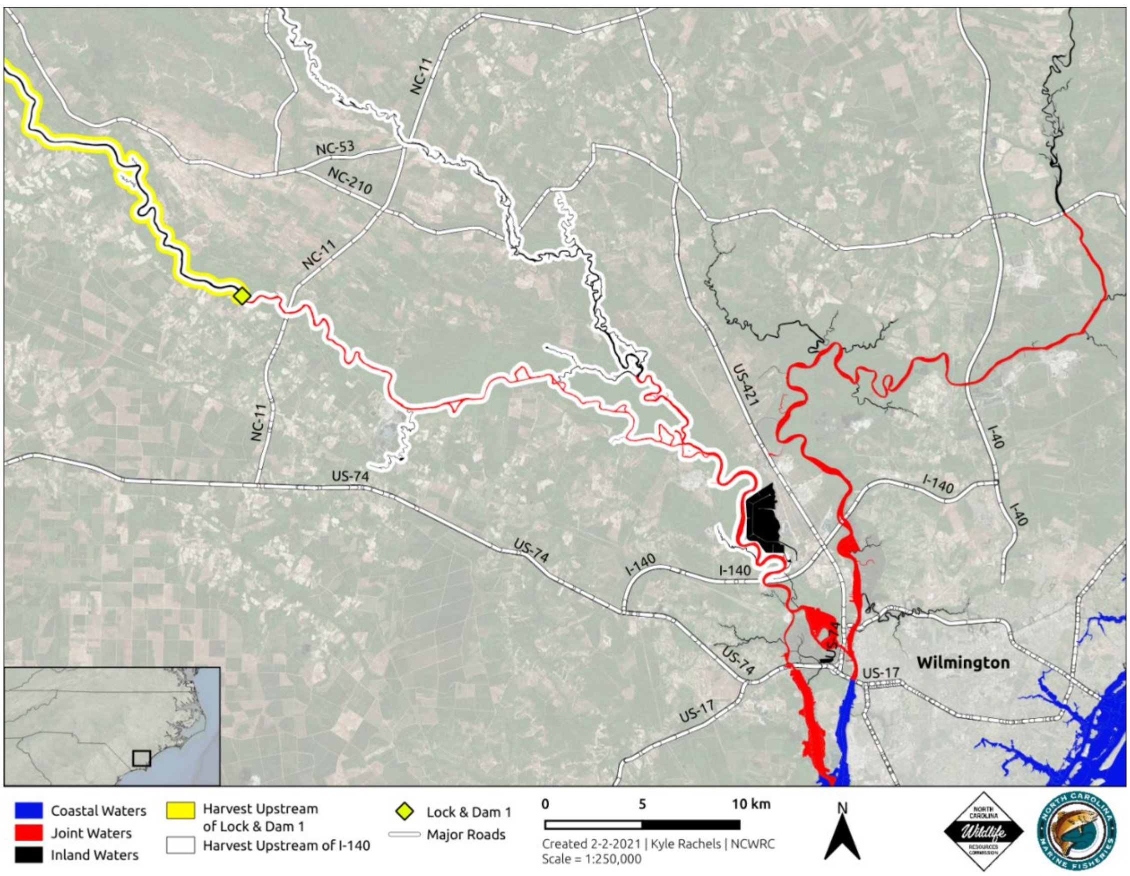


Figure 4.6. A map showing Inland, Joint, and Inland Fishing waters, as well as the harvest area boundaries for the proposed management options.

**Allow Seasonal Harvest in Inland Fishing Waters only above the Joint / Inland Fishing Waters boundary on the Mainstem of the Cape Fear River**

The Cape Fear River above Lock and Dam #1 is classified as Inland Fishing Waters and the commercial harvest of Inland Game Fish is prohibited in Inland Fishing Waters. Since striped bass is considered an Inland Game Fish, harvest above Lock and Dam #1 would be limited to recreational hook and line only, per inland fishing regulations. Most striped bass captured at stations above Lock and Dam #1 were determined to be hatchery origin fish which had moved down river from reservoirs. However, the discontinuation of striped bass stocking in Jordan Lake may reduce the number of fish in the Cape Fear River upstream of Lock and Dam #1. Stocking locations may be modified in the Cape Fear River to continue to supply hatchery origin fish to locations upriver of the locks and dams.

**Adaptive Management**

Adaptive management allows managers to change management strategies when new information or data becomes available. Management options, which are selected during the FMP process, take into account the most up to date data on the biological and environmental factors which affect the stock. After the implementation of the FMP, if additional data is available about a fishery or key factors change, adaptive management provides the flexibility to incorporate this new information to inform alternative and/or additional actions needed for sustainable fisheries management. A range of adaptive management actions, as well as criteria for their application can be established within the FMP management framework to improve both short- and long-term management outcomes.

Results from YOY juvenile abundance and distribution surveys, as well as PBT analysis can be used to evaluate natural reproduction of striped bass in the Cape Fear River system. The collection of YOY striped bass from the mainstem Cape Fear or Northeast Cape Fear rivers will be considered evidence for natural reproduction occurring in the branch where the juveniles were collected. The proportion of fish determined to be of unknown origin by PBT analysis will be used to determine the percentage of hatchery contribution to the Cape Fear River striped bass stock.

The proposed adaptive management framework for sustainable harvest of striped bass in the Cape Fear River system consists of the following:

1. Continue YOY surveys and PBT analysis after the adoption of the FMP.

a. If adopted management measures include allowing harvest of striped bass in any waters of the Cape Fear River, and YOY surveys and/or PBT analysis suggest levels of natural reproduction greater than observed up to the time of FMP adoption, then management measures may be re-evaluated and adjusted by proclamation using the authority granted to DMF and WRC directors. Rule changes or suspensions required to allow harvest.

b. If adopted management measures do not allow for harvest of striped bass in the Cape Fear River, and YOY surveys and/or PBT analysis suggest levels of natural reproduction less than observed up to the time of FMP adoption, then management measures may be re-evaluated, and harvest adjusted by proclamation using the authority granted to the DMF and WRC directors. Rule changes or suspensions required to allow harvest.

2. Management measures which may be adjusted include: means and methods, harvest area, as well as season, size and creel limit (as allowed for in rule).

3. Use of the DMF director's proclamation authority for adaptive management is contingent on evaluation of adaptive management measures by the Striped Bass Plan Development Team and consultation with the Finfish Advisory Committee.

## MANAGEMENT OPTIONS

(+ potential positive impact of action)
(- potential negative impact of action)

For management of commercial striped bass regulations within Coastal and Joint Fishing Waters of the Cape Fear River, the MFC adopts rules and implements management measures. For management of recreational striped bass regulations within Coastal Fishing Waters (that are not also Joint Fishing Waters) of the Cape Fear River, the MFC adopts rules and implements management measures. For management of recreational striped bass regulations within Inland Fishing Waters of the Cape Fear River, the WRC adopts rules and implements management measures.

For management of recreational striped bass regulations within Joint Fishing Waters of the Cape Fear River, the MFC and WRC have jointly adopted rules. MFC rule 15A NCAC 03Q .0107(d) and WRC rule 15A NCAC 10C .0107(d) state it "is unlawful to possess striped bass or striped bass hybrids taken from the joint fishing waters of the Cape Fear River." If the MFC and the WRC agree to change this management measure as part of final approval of the Estuarine Striped Bass FMP Amendment 2, the corresponding rules would be amended accordingly. If the MFC and the WRC do not agree to change this management measure, the current rules would remain in place for Joint Fishing Waters.

By law, those Coastal Fishing Waters in which are found a significant number of freshwater fish, as agreed upon by the MFC and the WRC, may be classified as Joint Fishing Waters. The MFC and WRC may make joint regulations governing the responsibilities of each agency and modifying the applicability of licensing and other regulatory provisions as may be necessary for rational and compatible management of the marine and estuarine and wildlife resources in Joint Fishing Waters (G.S. 113-132). Those joint rules are found in 15A NCAC 03Q .0100 (MFC) and 10C .0100 (WRC).

1. Striped Bass Harvest
   A. Status Quo: maintain Cape Fear River harvest moratorium
   + maintains protection for Northeast Cape Fear River wild spawning contingent
   + does not increase fishing mortality to population declining in abundance
   +/- no harvest of a primarily hatchery supported stock
   +/- continues current catch and release recreational fishery

B. Allow seasonal harvest in all Cape Fear River fishing waters (proposed season and limits: open season March 1–April 30; 18-inch TL minimum length limit; 2 fish daily creel limit)
+ equity in harvest regulation across the system and user groups
+/- allow harvest of a primarily hatchery supported stock
- potential user conflicts around hatchery supported stock
- allows harvest of Northeast Cape Fear River wild spawning contingent
- may increase fishing mortality to population declining in abundance

C. Allow seasonal harvest in joint and inland fishing waters in the mainstem Cape Fear River above the 140 Bridge (proposed season and limits: open season March 1–April 30; 18-inch TL minimum length limit; 2 fish daily creel limit)
+ offers protection to Northeast Cape Fear River wild spawning contingent
+/- allow harvest of a primarily hatchery supported stock
- creates additional management boundary and regulation complexity
- inequity in harvest regulation across the system by user groups
- potential user conflicts around hatchery supported stock
- may increase fishing mortality to population declining in abundance

D. Allow harvest in inland fishing waters only above the Joint/Inland Waters boundary on the mainstem of the Cape Fear River (proposed season and limits: no closed season; 20-inch TL minimum length limit; 4 fish per day)
+ offers protection to Northeast Cape Fear River wild spawning contingent
+/- allow harvest of a primarily hatchery supported stock
- creates additional regulation complexity using existing management boundary
- inequity in harvest regulation across the system by user groups
may increase fishing mortality to population declining in abundance

2. Adaptive Management
- Continue YOY surveys and PBT analysis after the adoption of the FMP
- If YOY surveys and/or PBT analysis suggest levels of natural reproduction have increased or decreased compared to what was observed up to the time of FMP adoption, then management measures may be re-evaluated using this new information and adjusted by proclamation using the authority granted to DMF and WRC directors. Rule changes or suspensions required to allow harvest.
- Management measures which may be adjusted include means and methods, harvest area, as well as season, size and creel limit (as allowed for in rule)
- Use of the DMF director's proclamation authority for adaptive management is contingent on evaluation of adaptive management measures by the Striped Bass Plan Development Team and consultation with the Finfish Advisory Committee

+ Adaptive management allows for management adjustments to any of the selected management options as new data becomes available

- Creates management uncertainty if not clearly defined

**RECOMMENDATIONS**

See Appendix 6 for DMF, WRC, and advisory committees recommendations and a summary of online public.

NCMFC Preferred Management Strategy

Options: 1.A. and 2.

## APPENDIX 5: THE USE OF HOOK AND LINE AS A COMMERCIAL GEAR IN THE ESTUARINE STRIPED BASS FISHERY

### ISSUE

Reevaluating the use of hook and line as a gear in the estuarine striped bass commercial fishery.

### ORIGINATION

North Carolina Marine Fisheries Commission (MFC) selected management strategy in Amendment 1 to the North Carolina Estuarine Striped Bass Fishery Management Plan (FMP).

### BACKGROUND

In response to a petition for rulemaking received in 2010, the MFC directed the North Carolina Division of Marine Fisheries (DMF) to examine the implications of allowing and promoting a commercial hook and line fishery statewide for all finfish species. An information paper was developed and concluded the use of hook and line as a commercial gear was feasible and should be managed on a fishery-by-fishery basis in conjunction with the FMP process (NCDMF 2010).

Amendment 1 to the North Carolina Estuarine Striped Bass FMP recommended not allowing hook and line as a commercial gear for striped bass unless future restrictions on the use of gill nets necessitate alternative commercial gears (NCDMF 2013). To facilitate the adaptive management aspect of the MFC selected management strategy, the portion of rule 15A NCAC 03M .0201 which prohibited the commercial sale of striped bass taken with hook and line gear was repealed. For more information, see the issue paper titled "Estuarine Striped Bass Fishery Commercial Hook-And-Line" in Amendment 1 of the Striped Bass FMP.

Since the adoption of Amendment 1 and subsequent rule change, the Fisheries Director has used proclamation authority granted in MFC Rule 15A NCAC 03M .0202 (4) to prohibit the use of hook and line in the commercial striped bass fisheries when they occur in the Albemarle Sound Management Area (ASMA) and the Central Southern Management Area (CSMA).

The striped bass fisheries in both the ASMA and CSMA are managed through proclamations or rules designed to keep overall harvest levels below the annual Total Allowable Landings (TAL) for each management area and fishing sector (commercial or recreational). The ASMA commercial striped bass gill net fishery is regulated as a "bycatch fishery", where striped bass landings cannot exceed 50 percent by weight of all other finfish species landed by trip. Most striped bass gill net harvest in the ASMA occurs in conjunction with the American shad *(Alosa sapidissima*), southern flounder (*Paralichthys lethostigma*), or the invasive blue catfish (*Ictalurus furcatus*) gill net fisheries. Increased gill net regulations implemented to meet sustainability objectives in the American shad and southern flounder fisheries have limited the amount of time gill nets can be set and reduced the opportunity to harvest striped bass in gill net fisheries.

The 2020 Albemarle-Roanoke striped bass benchmark stock assessment indicated the stock is overfished and overfishing is occurring (Lee et. al 2020). An evaluation of CSMA stocks indicates the striped bass populations are depressed to a point where no level of fishing mortality is sustainable (Mathes et al. 2020). As a response to poor stock conditions in the CSMA a no harvest provision has been in place for striped bass in the Cape Fear River since 2008 and in the remainder of the management area since 2019.

The only management area currently open to the commercial harvest of striped bass is the ASMA. The 2020 Revision to Amendment 1 reduced the TAL in the ASMA from 275,000 pounds to 51,216 pounds, with the goal of reducing fishing mortality and ending overfishing (NCDMF 2020). As of January 1, 2021, the commercial TAL for the ASMA was set at 25,608 pounds. The commercial fishery was open for only 16 days in the spring of 2021 and exceeded the TAL by approximately 2,000 pounds (preliminary data NC Quota Monitoring Program).

For more information on the ASMA or CSMA striped bass stocks and fisheries see: Lee et al. 2020, Mathes et al. 2020, as well as Appendices 2, 3, and 4.

Since the implementation of Amendment 1, management actions resulting in additional restrictions on the use of gill nets (e.g., area closures, shorter seasons) have prompted the need to explore the steps required for the implementation of the previously selected MFC adaptive management strategy to allow hook and line as an alternative commercial gear for striped bass. With the moratorium in the CSMA and the relatively small commercial TAL in the ASMA, commercial striped bass harvesters have not had difficulty landing all of the available striped bass TAL in recent years. However, as striped bass stocks recover, harvesters may not be able to take advantage of any future TAL increases given the increasing restrictions on the use of gill nets unrelated to striped bass. This issue paper evaluates the Amendment 1 adaptive management strategy of allowing hook and line as a commercial gear in the striped bass fishery. The proposed approach enhances the ability of DMF to monitor commercial landings, with the goal of maintaining harvest levels below the TAL needed to recover the stock.

Earlier issue papers have identified conflicts and concerns related to harvest and possession limits that arise when allowing hook and line as a commercial gear (NCDMF 2010, 2013). Based on these previously identified concerns, the DMF used the following to address management considerations required to allow hook and line gear in the commercial harvest of estuarine striped bass:

- Determine licensing requirements
- Determine harvest and possession limits
- Consider simultaneous use of hook and line with other gear types
- Distinguish commercial from recreational or for hire trips
- Tagging, landing, and reporting requirements

## AUTHORITY

North Carolina General Statutes

| | |
|---|---|
| GS 113-134 | RULES |
| GS 113-182 | REGULATION OF FISHING AND FISHERIES |
| GS 113-182.1 | FISHERY MANAGEMENT PLANS |
| GS 113-221.1 | PROCLAMATIONS; EMERGENCY REVIEW |
| GS 143B-289.52 | MARINE FISHERIES COMMISSION – POWERS AND DUTIES |

North Carolina Marine Fisheries Commission Rules

| | |
|---|---|
| 15A NCAC 03H .0103 | PROCLAMATIONS, GENERAL |
| 15A NCAC 03M .0201 | GENERAL, STRIPED BASS |
| 15A NCAC 03M .0202 | SEASON, SIZE AND HARVEST LIMIT: INTERNAL COASTAL WATERS |
| 15A NCAC 03M .0512 | COMPLIANCE WITH FISHERY MANAGEMENT PLANS |

## DISCUSSION

Determine licensing requirements

Standard Commercial Fishing License (SCFL) and Retired Standard Commercial Fishing License (RSCFL) holders are allowed to commercially harvest striped bass by any legal method when the season is open in each management area. No additional licensing requirements are necessary to use hook and line as a commercial gear. However, DMF recommends the creation and requirement of a no cost Hook and Line Striped Bass Permit for SCFL or RSCFL license holders wanting to participate in this fishery. This permit would be required for the commercial harvest of striped bass by hook and line methods and allows for the targeted collection of effort and participation data for this gear type.

**Summary:** Require SCFL or RSCFL with Striped Bass Hook and Line Permit.

DETERMINE HARVEST AND POSSESSION LIMITS

If striped bass TAL is available for commercial harvest in a management area, the Fisheries Director may use proclamation authority to designate hook and line as a legal commercial gear. The hook and line daily individual limit should be at least the same as the daily commercial limit for gill nets, to not disincentivize this gear as a substitute for gill nets. Additionally, the daily individual limit for the commercial harvest of striped bass by hook and line may be set higher than the gill net limit as a means to encourage the use of hook and line as an alternative gear. A vessel should be limited to two daily hook and line commercial limits when two or more permit holders are on board to align with current gill net limits, both for ease of enforcement and compliance. Having commercial limits that are higher than recreational limits may incentivize latent or dual recreational and commercial license holders to use hook and line to harvest the higher commercial limits, even if these fish were not to be sold. This concern is addressed in the following sections of this paper.

**Summary:** The Fisheries Director may use proclamation authority to designate hook and line as a legal commercial harvest gear in a management area and set the individual harvest limit to be at least the same for both hook and line and gill net. Commercial hook and line vessels will be restricted to the proclaimed limit of two commercial license holders when two Striped Bass Permit holders are on the vessel.

CONSIDER SIMULTANEOUS USE OF HOOK AND LINE WITH OTHER GEAR TYPES

Current restrictions limit the total weight of striped bass landed in a commercial operation to not exceed 50 percent of the combined weight of the total daily catch of all species. The purpose of managing harvest in this manner is to allow commercial gill net operations targeting other species to land striped bass, reducing discards and maintaining landings below the TAL. Any hook and line only commercial trips for striped bass (no other commercial harvest gear onboard) would not be subject to a 50 percent bycatch provision.

If an area is simultaneously open to the use of commercial hook and line and gill net, both gears could be used simultaneously. This makes it challenging for law enforcement to determine which fish were captured by what gear. Any vessel that has a gill net onboard will be subject to the catch limits and harvest restrictions for gill nets (including requiring the 50 percent bycatch provision) and will be considered a gill net trip regardless of whether the gill net was used.

**Summary:** If an area is open to both commercial hook and line harvest and the use of gill nets, and a vessel has a gill net onboard, the vessel is subject to the catch limits and regulations governing the use of gill nets.

DISTINGUISH COMMERCIAL FROM RECREATIONAL OR FOR-HIRE TRIPS

Some individuals hold for-hire, commercial, and/or recreational fishing licenses. The use of hook and line has typically been sufficient to delineate commercial participants from recreational and for-hire sectors. A concern of allowing hook and line gear to be used both recreationally and commercially is latent SCFL or RSCFL holders and for-hire vessel captains who also hold commercial licenses using hook and line gear to land higher commercial trip limits for recreational purposes.

The number of participants landing striped bass in the commercial fishery has steadily declined in the ASMA and CSMA since the late 1990s. The number of participants peaked at 449 in the ASMA in 1999 and declined to 155 in 2020, while the number of participants peaked at 297 in the CSMA in 1997 and fell to 95 in 2018. However, the number of commercial license holders residing in counties surrounding the ASMA and CSMA that could legally participate in the fishery is much higher. In 2020, there were 1,632 SCFL/RSCFL licenses held by individuals residing in counties adjoining the ASMA and 5,282 in counties adjoining the CSMA.

Allowing hook and line as a commercial harvest gear provides individuals who hold multiple license types the ability to retain commercial limits on what would otherwise be recreational or for-hire hook and line trips. Striped bass harvested in this manner would not be sold and not reported in the NC Trip Ticket Program (TTP), resulting in an underestimate of commercial harvest from the stock. To mitigate this scenario, commercial hook and line only trips for striped bass will be restricted to no more than two people per vessel. Appropriately licensed and permitted vessels with two people or less may harvest striped bass commercially in a manner and amount defined by proclamation, and landings concerns will be addressed by reporting requirements.

**Summary:** Commercial hook and line harvest for striped bass will be limited to no more than two persons per vessel.

**Landing and reporting requirements**

It is a requirement that all striped bass landed commercially be tagged. The purpose of this tagging requirement is to minimize the illegal harvest and sale of striped bass. North Carolina requires commercially harvested striped bass to be tagged by the dealer at the point of sale. Dealers are required to report to DMF daily the number and pounds of striped bass tagged. This daily reporting requirement allows DMF to monitor harvest in near real-time which aids in ensuring the annual TAL is not exceeded.

Fish kept for personal consumption by SCFL and RSCFL holders are not sold and accounted for as landings. Without a record of sale, this harvest would not be captured in the TTP, leading to an underestimate of total removals from the stock. An accurate estimate of total removals is important information for stock assessments to estimate population abundance and determine stock status. There is no evidence that unreported landings are occurring in any significant amount with the current harvest methods allowed in the estuarine striped bass fishery. However, without additional reporting requirements the use of hook and line as a commercial gear could increase uncertainty in stock removal estimates. To minimize the uncertainty in these removal estimates, SCFL or RSCFL holders using hook and line as a commercial gear could be required to report the disposition of all retained striped bass catch (sold or kept for personal use) through the TTP. The establishment of a reporting requirement for all retained striped bass catch by commercial license holders is an option that can pursued by DMF and MFC, however enacting this requirement would need legislative action and a change to the North Carolina General Statutes.

**Summary:** Maintain established tagging and reporting requirements for all landed striped bass and explore options for additional reporting requirements for all commercial license holders on the disposition of all retained striped bass catch (sold or kept for personal use) through the TTP.

The ASMA is the only management area currently open to the commercial harvest of striped bass, and this stock has been determined to be overfished. To recover this stock, harvest must remain at or below the established TAL. This relatively low TAL was reached and exceeded in 16 days in 2021, with only the amount of effort and participation occurring under the current regulatory structure. By allowing the use of hook and line as gear, there is the potential for additional effort to occur in the commercial fishery. Given the current low TAL, any increase in effort may make it more difficult to constrain commercial landings within the current TAL and impact the sustainable management of this fishery. However, immediately allowing hook and line as a means of commercial harvest concurrent with the use of gill nets, even under the current low TAL, could be a proactive approach providing additional means to harvest striped bass. This additional gear may become necessary as striped bass stocks recover and the TAL increases, assuming current gill net restrictions remain in place.

Implementation of the use of hook and line gear in the commercial fishery could be delayed again until potential future restrictions or prohibitions on the use of gill nets prevent commercial striped bass harvest with this gear, or the stocks have recovered to a point where any increase in effort will not potentially impact the ability to sustainably manage harvest in the fishery. However, an additional management tool which may be necessary to consider given current stock status and the very low TAL, is limited entry. North Carolina General Statute 113-182.1 states the MFC can only recommend the General Assembly limit participation in a fishery if the commission determines sustainable harvest in the fishery cannot otherwise be achieved. In North Carolina General Statute 143B-289.52 (d1) the MFC can already regulate participation in a federal fishery, subject to a federal fishery management plan, if that plan imposes a quota on the State for the harvest and landing of fish in the fishery. As both the ASMA and CSMA striped bass stocks are in poor condition, maintaining sustainable harvest is a concern. Because the ASMA striped bass stock is overfished the MFC can consider whether the only way to achieve sustainable harvest goals in this fishery is by limiting participation.

**Adaptive Management**

Adaptive management allows managers to change management strategies when new information or data becomes available. Management options, which are selected during the FMP process, account for the most recent data on the biological and environmental factors that affect the stock. After implementation of the FMP, if additional data are available about a fishery or key factors change, adaptive management provides the flexibility to incorporate this new information to inform alternative and/or additional actions needed for sustainable fisheries management. A range of adaptive management actions, as well as criteria for their application, can be established within the FMP management framework to improve both short- and long-term management outcomes.

Targeted data collected from the Striped Bass Hook and Line Permit, Marine Patrol enforcement activity, as well as DMF License and Statistics TTP and Quota Monitoring data will be used to evaluate effort, participation, and striped bass hook and line landings.

The proposed adaptive management framework for the use of hook and line as a commercial gear in the estuarine striped bass fishery consists of the following:

1. Allow hook and line as a commercial gear for the harvest of striped bass.
    a. If hook and line is allowed for the commercial harvest of striped bass and TTP and Quota Monitoring data indicate the TAL will <u>either</u> be quickly exceeded <u>or</u> unable to be met during the potential striped bass season, then management measures may be re-evaluated and adjusted by the proclamation authority granted to the Fisheries Director (as is currently occurring under the existing management strategy).
    b. If hook and line is allowed for the commercial harvest of striped bass and Marine Patrol enforcement activity or License and Statistics data suggest significant amounts of unreported commercial striped bass catch is occurring, then additional tagging or reporting requirements may be developed and implemented.

2. Management measures that may be adjusted include means and methods, harvest area, as well as season, size, and quantity.
3. Implementation of adaptive management measures to enact additional increased tagging or reporting requirements is contingent on evaluation of these measures by the Striped Bass Plan Development Team and consultation with the MFC.

## MANAGEMENT OPTIONS

+ (Potential positive impact of the action)
- (Potential negative impact of the action)

1. Hook and Line as a Commercial Gear
   - A. Do not allow hook and line as a commercial gear in the estuarine striped bass fishery at this time
     - + No incentive for increased effort on overfished/overfishing stock
     - + No additional regulatory burden to harvesters (additional TTP reporting)
     - - Does not provide an alternate gear for harvest with increasing regulation on gill nets
     - - Does not provide DMF additional harvest data collection (via permits and TTP)
   - B. Allow hook and line as a commercial gear in the estuarine striped bass fishery at this time
     - + Provides an alternate gear for harvest with increasing regulation on gill nets
     - + Provides DMF additional harvest data collection (via permits and TTP)
     - - Incentive for increased effort on overfished/overfishing stock

2. Adaptive Management
   - If hook and line is allowed for the commercial harvest of striped bass and NC TTP and Quota Monitoring data indicate the TAL will <u>either</u> be quickly exceeded <u>or</u> unable to be met during the potential striped bass season, then management measures may be re-evaluated and adjusted by the proclamation authority granted to the Fisheries Director (as is currently occurring under the existing management strategy).
   - If hook and line is allowed for the commercial harvest of striped bass and Marine Patrol enforcement activity or License and Statistics data suggest significant amounts of unreported commercial striped bass catch is occurring, then additional tagging or reporting requirements may be developed and implemented.
   - Management measures that may be adjusted include means and methods, harvest area, as well as season, size and limit.
   - Implementation of adaptive management measures to enact additional increased tagging or reporting requirements is contingent on evaluation of these measures by the Striped Bass Plan Development Team and consultation with the Marine Fisheries Commission.

## RECOMMENDATIONS

See Appendix 6 for DMF, WRC, and advisory committees recommendations and a summary of online public.

NCMFC Preferred Management Strategy

Options: 1.A. and 2.

## APPENDIX 6: SUMMARY OF DMF, WRC, MFC ADVISORY COMMITTEE RECOMMENDATIONS, AND ONLINE SURVEY RESPONDENTS FOR ISSUE PAPERS IN THE NORTH CAROLINA ESTUARINE STRIPED BASS FMP AMENDMENT 2

Table 6.1. Summary of DMF, WRC, MRC standing and regional Advisory Committee recommendations, and summary of online survey respondents for management options in the North Carolina Estuarine Striped Bass FMP Amendment 2.

| Issue Paper | DMF and WRC Recommendations | Northern Regional Advisory Committee Recommendation | Southern Regional Advisory Committee Recommendation | Finfish Standing Advisory Committee Recommendation | Online Questionnaire Summary of Support * |
|---|---|---|---|---|---|
| **APPENDIX 2: ACHIEVING SUSTAINABLE HARVEST FOR THE ALBEMARLE SOUND-ROANOKE RIVER STRIPED BASS STOCK** | DMF: Option 1.A.<br><br>WRC: Option 1.A. | No recommendation passed | Support the DMF and WRC staff initial recommendation, Option 1.A. | Support the DMF and WRC staff initial recommendation, Option 1.A. | 53% Option 1.B.<br>41% Option 1.A.<br><br>If a moratorium was in place 56% would still target striped bass for recreational catch-and-release |
| | DMF: Option 2.A.<br><br>WRC: Option 2.A. | Support the DMF and WRC staff initial recommendation, Option 2.A. | Support the DMF and WRC staff initial recommendation, Option 2.A. | Support the DMF and WRC staff initial recommendation, Option 2.A. | 70% Option 2.A.<br>8% Option 2.B. |
| | DMF: Option 3.D.<br><br>WRC: Do not support any options as written; support the following modified option: | Support the DMF recommendation, Option 3.D. | Support the DMF recommendation, Option 3.D. | Support the DMF recommendation, Option 3.D. | 68% single fishery payback above TAL<br>9% divide across all fisheries<br>8% single fishery pay back a portion of landings above TAL (buffer)<br>5% no payback |
| | WRC language: If the landings in any one of the three fisheries (RRMA recreational, ASMA recreational, and ASMA commercial) exceed their allocated TAL by 5% in a calendar year, any landings in excess of their allocated TAL and 5% buffer will be deducted from that fishery's allocated TAL the next calendar year. If the payback for a fishery exceeds the next year's allocated TAL, the fishery will be closed the subsequent year with no additional payback required. | | | | |
| | DMF: Options 4.C. and 4.E.<br><br>WRC: Options 4.C. and 4.E. | Support the DMF and WRC staff initial recommendation, Options 4.C. and 4.E. | Support the DMF and WRC staff initial recommendation, Options 4.C. and 4.E. | Support the DMF and WRC staff initial recommendation, Options 4.C. and 4.E. | 83% size limit changes to increase older fish<br><br>71% Options 4.C. and 4.E.<br>11% status quo. |

Table 6.1. Continued.

| Issue Paper | DMF and WRC Recommendations | Northern Regional Advisory Committee Recommendation | Southern Regional Advisory Committee Recommendation | Finfish Standing Advisory Committee Recommendation | Online Questionnaire Summary of Support * |
|---|---|---|---|---|---|
| APPENDIX 2: CONTINUED | DMF: Options 5.A. and 5.E.<br><br>WRC: Options 5.A. and 5.E. | Support the DMF and WRC staff initial recommendation, Options 5.A. and 5.E. | Support the DMF and WRC staff initial recommendation, Options 5.A. and 5.E. | Support the DMF and WRC staff initial recommendation, Options 5.A. and 5.E. | 49% Option 5.B.<br>19% Option 5.D.<br>17% Option 5.E.<br>11% Option 5.C. |
| | DMF: Support all Adaptive Management measures<br><br>WRC: Support all Adaptive Management measures | Support the DMF and WRC staff initial recommendation to support all Adaptive Management measures | Support the DMF and WRC staff initial recommendation to support all Adaptive Management measures | Support the DMF and WRC staff initial recommendation to support all Adaptive Management measures | N/A |
| APPENDIX 3: ACHIEVING SUSTAINABLE HARVEST FOR THE TAR-PAMLICO AND NEUSE RIVERS STRIPED BASS STOCKS | DMF: Option 1.A.<br><br>WRC: Option 1.A. | Recommend to end no-possession measure. | Support the DMF and WRC staff initial recommendation, Option 1.A. | Support the DMF and WRC staff initial recommendation, Option 1.A. | 59% Option 1.A.<br>32% Option 1.B. |
| | DMF: No recommendation<br><br>WRC: Option 2.A. | Ask the MFC to end the gill net closure above the ferry lines and return to NCDMF regulations prior to the 2019 closure. | Recommend to MFC to remove the gill net moratorium above the ferry lines and re-implement the management measures prior to the 2019 closure. | No recommendation. | 60% support maintaining closure above ferry lines and 3-foot tie down use below ferry lines<br>12% opposed |
| | DMF: Support all Adaptive Management measures<br><br>WRC: Support all Adaptive Management measures with additional language | Support the DMF and WRC staff initial recommendation to support the Adaptive Management measure | Support the DMF and WRC staff initial recommendation to support the Adaptive Management measure | Support the DMF and WRC staff initial recommendation to support the Adaptive Management measure | N/A |

Table 6.1. Continued.

| Issue Paper | DMF and WRC Recommendations | Northern Regional Advisory Committee Recommendation | Southern Regional Advisory Committee Recommendation | Finfish Standing Advisory Committee Recommendation | Online Questionnaire Summary of Support * |
|---|---|---|---|---|---|
| APPENDIX 4: ACHIEVING SUSTAINABLE HARVEST FOR THE CAPE FEAR RIVER STRIPED BASS STOCK | DMF: Option 1.A.<br><br>WRC: Option 1.B. | Support the DMF initial recommendation, Option 1.A. | Support the DMF initial recommendation, Option 1.A. | Support the DMF initial recommendation, Option 1.A. | 65% Support continued harvest moratorium<br>14% opposed |
| | DMF: Support all Adaptive Management measures<br><br>WRC: Support all Adaptive Management measures | Support the DMF and WRC staff initial recommendation to support all Adaptive Management measures | Support the DMF and WRC staff initial recommendation to support all Adaptive Management measures | Support the DMF and WRC staff initial recommendation to support all Adaptive Management measures | N/A |
| APPENDIX 5: THE USE OF HOOK AND LINE AS A COMMERCIAL GEAR IN THE ESTUARINE STRIPED BASS FISHERY | DMF: Option 1.A.<br><br>WRC: Option 1.A. | Support the DMF initial recommendation, Option 1.A. | Support the DMF initial recommendation, Option 1.A. | Support the DMF initial recommendation, Option 1.A. | 65% Option 1.A<br><br>If harvest is allowed:<br>15% Option 1.B.<br>16% Option 1.C.<br>16% Option 1.D.<br>54% uncertain or no opinion. |
| | DMF: Support all Adaptive Management measures<br><br>WRC: Support all Adaptive Management measures | Support the DMF initial recommendation to support all Adaptive Management measures | Support the DMF initial recommendation to support all Adaptive Management measures | Support the DMF initial recommendation to support all Adaptive Management measures | N/A |

***Breakdown of respondents:*** Recreational Fishing (84%), Charter/For-Hire (5%), Seafood Consumer (4%), Other (4%), Commercial Fishing (2%), NGO (2%), Seafood Dealer/Retail/Restaurant (0%), and Academic (0%).

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# FISHERY MANAGEMENT PLAN UPDATE
# STRIPED MULLET
# AUGUST 2022

## STATUS OF THE FISHERY MANAGEMENT PLAN

### Fishery Management Plan History

| | | |
|---|---|---|
| Original FMP Adoption: | April 2006 | |
| Amendments: | Amendment 1 | November 2015 |
| Revisions: | None | |
| Supplements: | None | |
| Information Updates: | None | |
| Schedule Changes: | None | |
| Comprehensive Review: | July 2020 | |

The North Carolina Striped Mullet Fishery Management Plan (FMP) was adopted in April 2006. The management plan established minimum and maximum commercial landings triggers of 1.3 and 3.1 million pounds (NCDMF 2006). If annual landings fall below the minimum trigger, the North Carolina Division of Marine Fisheries (NCDMF) would determine whether the decrease in landings is attributed to stock decline, decreased fishing effort, or both. If annual landings exceed the maximum trigger, NCDMF would determine whether harvest is sustainable and what factors are driving the increase in harvest. The striped mullet FMP established a daily possession limit of 200 mullets (white and striped in aggregate) per person per day in the recreational fishery.

Amendment 1 to the FMP was adopted in November 2015, and the subsequent rules were implemented in April 2016. Amendment 1 resolved issues with Newport River gill net attendance, mitigated known user group conflicts, updated the management framework, and updated minimum and maximum commercial landings triggers to 1.13 and 2.76 million pounds (NCDMF 2015). Amendment 1 maintains the 200-mullet possession limit per person in the recreational fishery.

Commercial landings in 2016 were 965,198 pounds, which is below the minimum landings trigger of 1.13 million pounds (Figure 3A). As required by the FMP, the NCDMF initiated data analysis in July 2017 to determine whether the decrease was attributed to a stock decline, decreased fishing effort, or both. The NCDMF presented preliminary findings and recommendations to the North Carolina Marine Fisheries Commission (NCMFC) during its November 2017 business meeting. It was determined by the NCDMF that no management actions were necessary at that time, but a more comprehensive analysis with data through 2017 was needed.

The NCDMF presented results of their comprehensive analysis at the February 2018 NCMFC business meeting and concluded the stock had likely declined since completion of the 2013 stock assessment, which had a terminal year of 2011. The NCDMF recommended updating the 2013 stock assessment model to include data through 2017 prior to taking management action. As an assessment update, there were no changes to model parameters and peer review was not required, as the configuration of the model that previously passed peer review was maintained. Results of the stock assessment indicated overfishing was not occurring through 2017 but could not determine if the stock was overfished (NCDMF 2018).

Subsequent management options were developed by the NCDMF and presented to the Finfish, Southern, and Northern advisory committees in July 2018 to receive input prior to finalizing the NCDMF recommendation. Recommendations were then presented to the NCMFC at its August 2018 business meeting. The NCDMF and the advisory committees recommended no management action be taken since the stock assessment update indicated overfishing was not occurring. The NCDMF would, however, continue to monitor trends in the commercial fishery and fishery-independent indices. The recommendation was approved by the NCMFC.

Review of the 2021 commercial landings indicate neither the maximum or minimum triggers have been exceeded. Review of the FMP was initiated in 2020, following the FMP review schedule.

**Management Unit**

Coastal and joint waters of North Carolina.

**Goal and Objectives**

The goal of Amendment 1 to the North Carolina Striped Mullet FMP is to manage the striped mullet fishery to preserve the long-term viability of the resource, maintain sustainable harvest, maximize social and economic value, and consider the needs of all user groups. The following objectives will be used to achieve this goal:

- Use a management strategy that provides for conservation of the striped mullet resource and promotes sustainable harvest while considering the needs of all user groups.
- Promote the protection, enhancement, and restoration of habitats and water quality necessary for the striped mullet population.
- Minimize conflict among user groups, including non-fishing user groups and activities.
- Promote research to improve the understanding of striped mullet population dynamics and ecology to improve management of the striped mullet resource.
- Initiate, enhance, and/or continue studies to collect and analyze the socio-economic data needed to properly monitor and manage the striped mullet fishery.
- Promote public awareness regarding the status and management of the North Carolina striped mullet stock.

## DESCRIPTION OF THE STOCK

### Biological Profile

Striped mullet are found in a wide range of depths and habitats but primarily inhabit freshwater to estuarine environments until migrating to the ocean to spawn in the fall (Able and Fahay 1998; Pattillo et al. 1999; Cardona 2000; Whitfield et al. 2012). Striped mullet serve as an ecological link between some of the smallest aquatic organisms and the highest-level predators in the marine food chain. Striped mullet feed on microorganisms such as bacteria and single-celled algae found on aquatic plants, in mud, silt, sand and decaying plant material (Odum 1968; Moore 1974; Collins 1985a; Larson and Shanks 1996; Torras et al. 2000). In turn, striped mullet are prey to top predators such as birds, fish, sharks, and porpoises (Breuer 1957; Thomson 1963; Collins 1985a; Barros and Odell 1995; Fertl and Wilson 1997).

The male and female maximum ages for striped mullet in North Carolina are 14 and 13 years old and a 15-year-old striped mullet of unknown sex was observed in 2017 by NCDMF (NCDMF 2022). The maximum size of striped mullet in North Carolina is recorded at 27.5 inches' total length (NCDMF 2022).

Striped mullet are highly fecund (upwards of 4 million eggs for a large female: Bichy 2000) and spawn in large aggregations near inlets to offshore areas (Collins and Stender 1989). Spawning individuals have been reported from September to March; however, peak spawning activity occurs from October to early December (Bichy 2000). Skipped spawning has been exhibited by striped mullet on the east coast of Florida (Myers et al. 2020) and on the eastern coast of Australia (Fowler et al. 2016). Striped mullet in North Carolina appear to mature at a younger age and larger size than other striped mullet populations (Bichy 2000). Length at 50 percent maturity occurs at 11.1 inches fork length for males (Bichy 2000) and 12.6 inches fork length for females (NCDMF 2021a).

### Stock Status

The 2022 North Carolina striped mullet stock assessment (NCDMF 2022) indicated the striped mullet stock in North Carolina is overfished and overfishing is occurring.

### Stock Assessment

The North Carolina striped mullet stock was modeled using stock synthesis version 3.30, an integrated statistical catch-at-age, forward-projecting, length based, age-structured model using data from 1950 to 2019. Input data included commercial landings, recreational harvest, fisheries-independent survey indices (Program 915), and biological data collected.

Both the observed data and the model predictions suggest a decreased presence of larger, older striped mullet in the population. The model has estimated declining trends in age-0 recruitment and female spawning stock biomass (SSB) over the last several decades. Estimates of fishing mortality (F) exhibit an increasing trend. Model results also indicate consistent overestimation of biomass and the highest risk for overfishing.

A fishing mortality threshold of $F_{25\%}$ and a fishing mortality target of $F_{35\%}$ were maintained from the prior assessment since the fishery continues to target mature female fish during the spawning season and the ecological importance of striped mullet. Complementary reference points for stock size were adopted based on female SSB, $SSB_{25\%}$ and $SSB_{35\%}$. The stock assessment model estimated a value of 0.37 for $F_{25\%}$ and a value of 0.26 for $F_{35\%}$. These estimates represent numbers-weighted values for ages 1 through 5. Predicated F in 2019 is 0.42, which is larger than the $F_{25\%}$ threshold and so suggests that overfishing is occurring (Figure 1). The model estimated a value of 1,364,895 (619 metric tons) for the $SSB_{25\%}$ threshold and a value of 2,238,075 (1,015 metric tons) for the $SSB_{35\%}$ target. Female SSB in 2019 was estimated at 579,915 pounds (263 metric tons), which is smaller than the $SSB_{25\%}$ threshold and so suggests the stock is overfished (Figure 2).

An external peer review was held in April 2022. The panel concluded the assessment model and results ae suitable for providing management advice for at least the next five years. The Panel considers the current model a substantial improvement from the previous assessment, representing the best scientific information available for the stock.

## DESCRIPTION OF THE FISHERY

### Current Regulations

There are no size restrictions, but as of July 1, 2006, there is a 200 mullet (white and striped aggregate) daily possession limit per person in the recreational fishery and the mutilated finfish rule was modified in 2006 to exempt mullet from the requirements of the rule to continue allowing mullet to be used for cut bait.

### Commercial Fishery

Historically, beach seines and gill nets are the two primary gear types used in the striped mullet commercial fishery, with most commercial landings prior to 1978 coming from the beach seine fishery. Gill nets (runaround, set, and drift) replaced seines as the dominant commercial gear type in 1979. Because the commercial fishery primarily targets striped mullet for roe, the fishery is seasonal with the highest demand and landings occurring in the fall when large schools form during their spawning migration to the ocean and females are ripe with eggs. Striped mullet are primarily targeted commercially using runaround gill nets in the estuarine and ocean waters of North Carolina. The striped mullet beach seine fishery primarily occurs in conjunction with the Bogue Banks stop net fishery. The stop net fishery has operated under fixed seasons and net and area restrictions since 1993. Stop nets are limited in number (four), length (400 yards), and mesh sizes (minimum eight inches outside panels, six inches middle section). Stop nets are only permitted along Bogue Banks (Carteret County) in the Atlantic Ocean from October 1 to November 30. However, the stop net season was extended to include December 3 to December 17 in 2015 due to minimal landings of striped mullet (Proclamation M-28-2015). In 2020 and 2021, the stop net fishery was open from October 15 through December 31 (Proclamations M-17-2020 and M-21-2021). Due to the schooling nature of striped mullet, the beach seine fishery has the potential to be, and historically has been, a high-volume fishery with thousands of pounds landed during a single trip. In addition, the use of cast nets in the striped mullet commercial fishery has been increasing since around 2003.

Since 1991, commercial landings have ranged from a low of 965,198 pounds in 2016 to a high 3,063,853 pounds in 1993 (Table 1; Figure 3A). From 2003 to 2009, landings were stable between 1,598,617 and 1,728,607 pounds before increasing to 2,082,832 pounds in 2010. Landings fluctuated annually between 1.5 and 2.0 million pounds from 2010 to 2014 before declining in 2015 and again in 2016, dropping below the minimum commercial landings trigger established by Amendment 1. Commercial landings in 2021 increased to 2,135,952 pounds, which is 1,005,952 pounds above the minimum commercial landings trigger.

**Recreational Fishery**

The federal Marine Recreational Information Program (MRIP) is primarily designed to sample anglers who use rod and reel as the mode of capture. Since most striped mullet are caught with cast nets for bait, striped mullet recreational harvest data are imprecise. In addition, angler misidentification between striped mullet and white mullet is common, and bait mullet are usually released by anglers before visual verification by creel clerks is possible. As such, mullets are not identified to the species level in the MRIP data (Catch Type B). Beginning in 2002, MRIP began deferring to mullet genus to classify unobserved type B1 (harvested/unavailable catch) and B2 (released/unavailable catch) catch. As a result, the magnitude of recreational harvest for mullet genus in units of numbers far exceeds that of both striped mullet and white mullet. This methodological improvement served to greatly increase the precision of estimates albeit without species level resolution. As such, estimates of recreational harvest for mullet prior to 2002 are considered unreliable.

The 2022 striped mullet stock assessment used the sum of recreational striped mullet harvest and a proportion of the recreational harvest of mullet genus for removals by the recreational fleet (NCDMF 2022). The proportion of mullet genus assumed to be striped mullet in the recreational harvest was 29%, a value derived from a study by the NCDMF of cast net recreational harvest for striped mullet (NCDMF 2006).

Recreational harvest peaked in 2002 and 2003 at greater than four million fish harvested (Table 1, Figure 3B). From 2004 to 2017 recreational harvest remained stable at around one million fish before declining in 2018, 2019 and 2020 to around 500,000 fish. This decline was likely related to decreased abundance of striped mullet and regulations that drastically shortened the recreational fishing season for southern flounder, a fishery where live mullet is a popular bait. Recreational harvest in 2021 was 1,484,850 fish.

The length-frequency distributions collected in North Carolina’s MRIP survey are considered to be an inaccurate representation of the recreational fishery. This is due to biases in the methodology of the program and angler behavior. Lengths collected in North Carolina’s MRIP survey are recorded at the dock and therefore only represent fish brought back to be kept by the angler. Anglers typically only keep the largest mullet, whether it be for personal consumption, or to be saved for use as cut bait. This bias toward keeping only the largest striped mullet has caused them to be disproportionately represented in the MRIP data. The vast majority of striped mullet harvested in the recreational fishery are used as live bait for other fisheries. For this type of fishing, “finger mullet”, or age-0 fish, approximately four inches in total length are used.

Striped mullet harvest data from the Recreational Commercial Gear License (RCGL) were collected from 2002 to 2008. The program was discontinued in 2009 due to a lack of funding and the minimal contributions from RCGL to overall harvest. From 2002 through 2008, an average of 41,512 pounds of striped mullet were harvested per year using a RCGL (NCDMF 2021b).

## MONITORING PROGRAM DATA

### Fishery-Dependent Monitoring

The number of striped mullet measured per year in fishery-dependent programs between 1994 and 2021 ranged from 123 to 13,212 with the lowest number measured in 1996 (Table 2). In 2021, 7,239 striped mullet were measured from commercial catches; a more than 70% increase from the previous year. Variation in mean length was low, usually falling between 12.0- and 14.5-inches fork length (FL), with the lowest mean length occurring in 1997 (12.8 inches FL). Minimum and maximum lengths fell within a small range with maximum length ranging from 20.0 to 28.0 inches fork length, though in 1994 and 1996, maximum length was below 20.0 inches (Table 3).

From 1994 through 2021 the size range of striped mullet captured in the commercial fishery as determined from commercial fish house samples ranged from 6.0 to 28.0 inches FL (Figure 4). Modal length generally falls between 11.0 and 15.0 inches. In all years there are few striped mullet over 18.0 inches present in the catch.

### Fishery-Independent Monitoring

The Fishery-Independent Gill-Net Survey (Program 915), began in 2001 and included sampling in the Pamlico Sound along the Hyde and Dare County shorelines. In July 2003, sampling was expanded to include the Neuse, Pamlico, and Pungo rivers. Additional areas in the Southern District including the New and Cape Fear rivers were added in April 2008. A stratified random sampling design is used based on area and water depth. Sampling occurs from mid-February to mid-December using an array of gill nets with stretched mesh sizes ranging from 3.0 inches to 6.5 inches.

To provide the most relevant indices for use in the 2022 stock assessment, Program 915 data were limited to those collected from shallow water during August through December. A combined index, with a starting year of 2008 and data collected from the Pamlico Sound, Pamlico River, Pungo River, Neuse River, and New River was calculated. Relative abundance increased through 2011 before declining to its lowest point in 2015 (Figure 5). Since 2015, abundance has increased with peaks in 2018 and 2021.

From 2008 to 2021, the size of striped mullet captured during the August to November portion of Program 915 in the Pamlico Sound, Pamlico River, Pungo River, Neuse River, and New River ranged from 7.0 to 26.0 inches FL (juveniles excluded, see NCDMF 2022 for juvenile length cut offs; Figure 6). Modal length ranged from 11.0 to 13.0 inches FL and was 12.0 inches FL in most years. Few striped mullet less than 10.0 inches FL and greater than 15.0 inches FL are captured in this survey.

During 2020 no indices of abundance are available for striped mullet from Program 915. Sampling in this program was suspended in February 2020 due to COVID-19 restrictions and protected species interactions but resumed July 2021.

Striped mullet age samples are collected from numerous NCDMF fishery independent and dependent sources. Modal age was two in all years except 1996, 1999, 2001, 2003 and 2005 when modal age was one, and 2017 when modal age was 1-2 (Table 3). Minimum age was zero in every year except 2010 when the minimum age was one. Maximum age ranged from six in 1996, 2012, 2014, and 2015 to 15 in 2017. There is substantial overlap in length at age for striped mullet (Figure 7). Striped mullet grow quickly from age 0 to age 2 before growth slows after age 3.

## RESEARCH NEEDS

The following research needs were compiled from those listed in the 2022 Striped Mullet Stock Assessment (NCDMF 2022). Improved assessment and management of striped mullet is dependent upon research needs being met. Research needs are broken into high, medium, and low priority.

### High

- Increase sampling of recreational mullet catches to determine the proportion of striped versus white mullet and improve estimates of recreational landings.
- Improve characterization of the length and age structure of recreational fisheries removals by increasing the number of age samples and number of trips sampled for lengths and ages from fisheries-dependent sources.
- Develop a reliable fisheries-independent abundance index for larger juveniles to characterize trends in recruitment.
- Consider expanding Program 915 to include the northern part of the state (Albemarle sound and major tributaries).
- Evaluate the current sampling methodology of Program 146 and effectiveness for sampling striped mullet; since this survey was not considered useful for the assessment of striped mullet, consider dropping this survey and focusing effort elsewhere if it is not contributing to management of other species.
- Consider running a simpler, single-sex version of the stock assessment model.

### Medium

- Consider a tagging program to provide estimates of stock size, F, and M.
- Consider genetic and/or tagging studies to examine extent of the unit stock on a regional basis for the south Atlantic as well as the Gulf of Mexico.
- Expand ichthyoplankton survey to other inlets throughout the state.
- Conduct an age validation study of known age fish to provide estimates of ageing error.

- Consider alternative weighting of data sources in future stock assessments.
- Develop estimates of fecundity for North Carolina striped mullet.

**Low**

- Perform an acoustic tagging study to evaluate spatial and temporal variation in habitat use to more effectively design and conduct fisheries-independent surveys.
- Investigate the predation impact on striped mullet; striped mullet is widely believed to be an important forage species but there is little evidence to support this claim in the North Carolina stock.
- Investigate environmental factors that influence the spatial and temporal distribution of larval striped mullet.

## MANAGEMENT STRATEGY

The management strategy for the striped mullet fisheries in North Carolina is to: 1) optimize resource utilization over the long-term; 2) reduce user group conflicts; 3) promote public education. The first strategy will be accomplished by protecting critical habitats and monitoring stock status. To address user group conflicts, a rule change was made to limit how much of a waterway may be blocked by runaround, drift, or other non-stationary gill nets. Specific user group conflicts will continue to be dealt with on a case-by-case basis and management actions will be implemented to address specific fishery-related problems. Issues addressed in formulating Amendment 1 of the management plan for North Carolina's striped mullet fishery included: 1) resolution of the Newport River gill net attendance; 2) user group conflicts; 3) updating the management framework for the N.C. striped mullet stock.

Minimum and maximum landings triggers of 1.13 and 2.76 million pounds have been established to monitor the striped mullet fishery. If landings fall below the minimum landings trigger or exceed the maximum landings trigger, the NCDMF will determine if a new stock assessment and/or interim management action is needed. The management strategy is under review as part of the scheduled review of the plan and the overfished and overfishing stock status determined from the most recent stock assessment.

## FISHERY MANAGEMENT PLAN SCHEDULE RECOMMENDATIONS

Striped mullet commercial landings in 2021 were 2,135,952 pounds, which is above the minimum and below the maximum commercial landing triggers established in Amendment 1. Review of the plan is underway. Results of the 2022 striped mullet stock assessment (NCDMF 2022) indicate the North Carolina striped mullet stock is overfished and overfishing is occurring through the terminal year of 2019. As statutorily required, management measures will be developed through Amendment 2 to end overfishing and rebuild spawning stock biomass.

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# TABLES

Table 1. Recreational harvest (number of fish landed and weight in pounds) and releases (number of fish) and commercial harvest (weight in pounds) of spotted seatrout from North Carolina, 1991–2021. Number released and weight landed cannot be determined because of uncertainty in reported species identification.

| | Recreational | | | Commercial | |
|---|---|---|---|---|---|
| Year | Number Landed | Number Released | Weight Landed (lb) | Weight Landed (lb) | Total Weight (lb) |
| 1991 | . | . | . | 1467448 | 1467448 |
| 1992 | . | . | . | 1820494 | 1820494 |
| 1993 | . | . | . | 3063853 | 3063853 |
| 1994 | . | . | . | 1726242 | 1726242 |
| 1995 | . | . | . | 2298446 | 2298446 |
| 1996 | . | . | . | 1756863 | 1756863 |
| 1997 | . | . | . | 2442657 | 2442657 |
| 1998 | . | . | . | 2218108 | 2218108 |
| 1999 | . | . | . | 1460850 | 1460850 |
| 2000 | . | . | . | 2829086 | 2829086 |
| 2001 | . | . | . | 2317655 | 2317655 |
| 2002 | 5967684 | . | . | 2596304 | 2596304 |
| 2003 | 4090368 | . | . | 1629314 | 1629314 |
| 2004 | 1394707 | . | . | 1598617 | 1598617 |
| 2005 | 1312234 | . | . | 1620394 | 1620394 |
| 2006 | 1059444 | . | . | 1728607 | 1728607 |
| 2007 | 1766373 | . | . | 1668804 | 1668804 |
| 2008 | 1191633 | . | . | 1675859 | 1675859 |
| 2009 | 1167086 | . | . | 1685615 | 1685615 |
| 2010 | 1319070 | . | . | 2082832 | 2082832 |
| 2011 | 1139786 | . | . | 1627894 | 1627894 |
| 2012 | 1369975 | . | . | 1859587 | 1859587 |
| 2013 | 1453038 | . | . | 1549157 | 1549157 |
| 2014 | 1352690 | . | . | 1828351 | 1828351 |
| 2015 | 1420378 | . | . | 1247044 | 1247044 |
| 2016 | 1491533 | . | . | 965337 | 965337 |
| 2017 | 1537183 | . | . | 1366351 | 1366351 |
| 2018 | 489321 | . | . | 1314385 | 1314385 |
| 2019 | 562089 | . | . | 1362217 | 1362217 |
| 2020 | 531875 | . | . | 1299464 | 1299464 |
| 2021 | 1484850 | . | . | 2135952 | 2135952 |
| Total | 1671366 | . | . | 1803594 | 1803594 |

Table 2. Mean, minimum, and maximum lengths (fork length, inches) of striped mullet measured from the commercial fisheries, 1994–2021.

| Year | Mean Length | Minimum Length | Maximum Length | Total Number Measured |
|---|---|---|---|---|
| 1994 | 13.0 | 6.1 | 19.1 | 302 |
| 1995 | 14.5 | 9.3 | 21.6 | 255 |
| 1996 | 13.5 | 10.0 | 18.5 | 123 |
| 1997 | 12.8 | 9.2 | 22.8 | 2,048 |
| 1998 | 13.1 | 8.6 | 25.4 | 1,600 |
| 1999 | 13.4 | 8.7 | 23.9 | 1,759 |
| 2000 | 13.4 | 8.3 | 23.5 | 7,522 |
| 2001 | 14.1 | 8.1 | 20.9 | 5,726 |
| 2002 | 13.2 | 5.9 | 21.3 | 10,989 |
| 2003 | 13.2 | 6.3 | 24.5 | 7,170 |
| 2004 | 13.1 | 7.6 | 24.4 | 12,778 |
| 2005 | 13.5 | 7.8 | 22.6 | 10,270 |
| 2006 | 13.7 | 7.8 | 22.2 | 12,108 |
| 2007 | 13.5 | 7.1 | 27.5 | 12,141 |
| 2008 | 14.1 | 8.4 | 24.1 | 13,212 |
| 2009 | 14.1 | 8.0 | 22.4 | 8,241 |
| 2010 | 13.9 | 8.1 | 22.7 | 10,991 |
| 2011 | 13.9 | 6.5 | 22.1 | 7,750 |
| 2012 | 14.0 | 7.9 | 22.2 | 12,833 |
| 2013 | 14.2 | 8.3 | 24.3 | 8,535 |
| 2014 | 13.8 | 7.7 | 24.0 | 6,517 |
| 2015 | 14.2 | 8.1 | 24.9 | 5,923 |
| 2016 | 14.3 | 8.9 | 24.1 | 5,661 |
| 2017 | 14.2 | 7.8 | 28.6 | 4,480 |
| 2018 | 14.5 | 8.3 | 22.5 | 4,111 |
| 2019 | 14.6 | 8.7 | 22.8 | 4,922 |
| 2020 | 13.8 | 8.3 | 21.9 | 4,246 |
| 2021 | 14.3 | 8.8 | 24.7 | 7,239 |

Table 3. Modal age, minimum age, maximum age, and number aged for striped mullet collected through NCDMF sampling programs, 1996–2021. Age data from 2021 are preliminary.

| Year | Modal Age | Minimum Age | Maximum Age | Total Number Aged |
|---|---|---|---|---|
| 1996 | 1 | 0 | 6 | 163 |
| 1997 | 2 | 0 | 7 | 344 |
| 1998 | 2 | 0 | 7 | 717 |
| 1999 | 1 | 0 | 8 | 753 |
| 2000 | 2 | 0 | 10 | 1,122 |
| 2001 | 1 | 0 | 11 | 705 |
| 2002 | 2 | 0 | 7 | 625 |
| 2003 | 1 | 0 | 13 | 765 |
| 2004 | 2 | 0 | 9 | 1,142 |
| 2005 | 1 | 0 | 10 | 654 |
| 2006 | 2 | 0 | 10 | 685 |
| 2007 | 2 | 0 | 10 | 699 |
| 2008 | 2 | 0 | 10 | 771 |
| 2009 | 2 | 0 | 13 | 349 |
| 2010 | 2 | 1 | 8 | 748 |
| 2011 | 2 | 0 | 14 | 633 |
| 2012 | 2 | 0 | 6 | 873 |
| 2013 | 2 | 0 | 7 | 850 |
| 2014 | 2 | 0 | 6 | 855 |
| 2015 | 2 | 0 | 6 | 769 |
| 2016 | 2 | 0 | 8 | 956 |
| 2017 | 1-2 | 0 | 15 | 695 |
| 2018 | 2 | 0 | 10 | 770 |
| 2019 | 2 | 0 | 13 | 827 |
| 2020 | 2 | 0 | 7 | 269 |
| 2021 | 2 | 0 | 10 | 933 |

## FIGURES

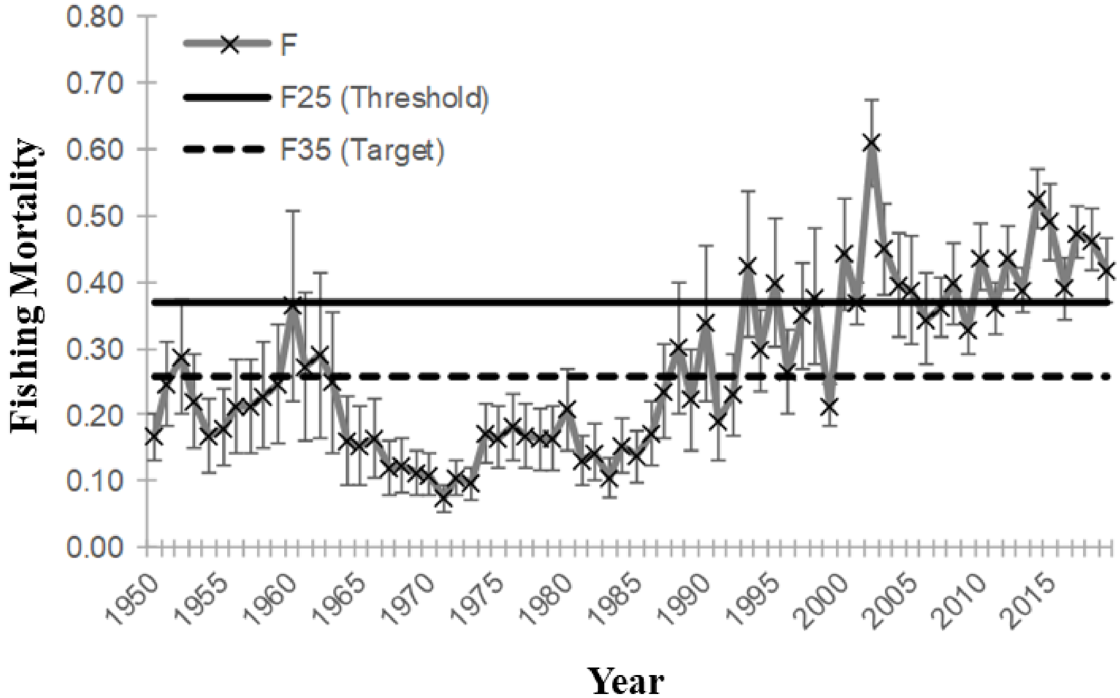


Figure 1. Annual predicted fishing mortality rates (numbers-weighted, ages 1–5) compared to estimated FThreshold (F25%) and FTarget (F35%), 1950–2019. 2019 is the terminal year for the most recent striped mullet stock assessment (NCDMF 2022).

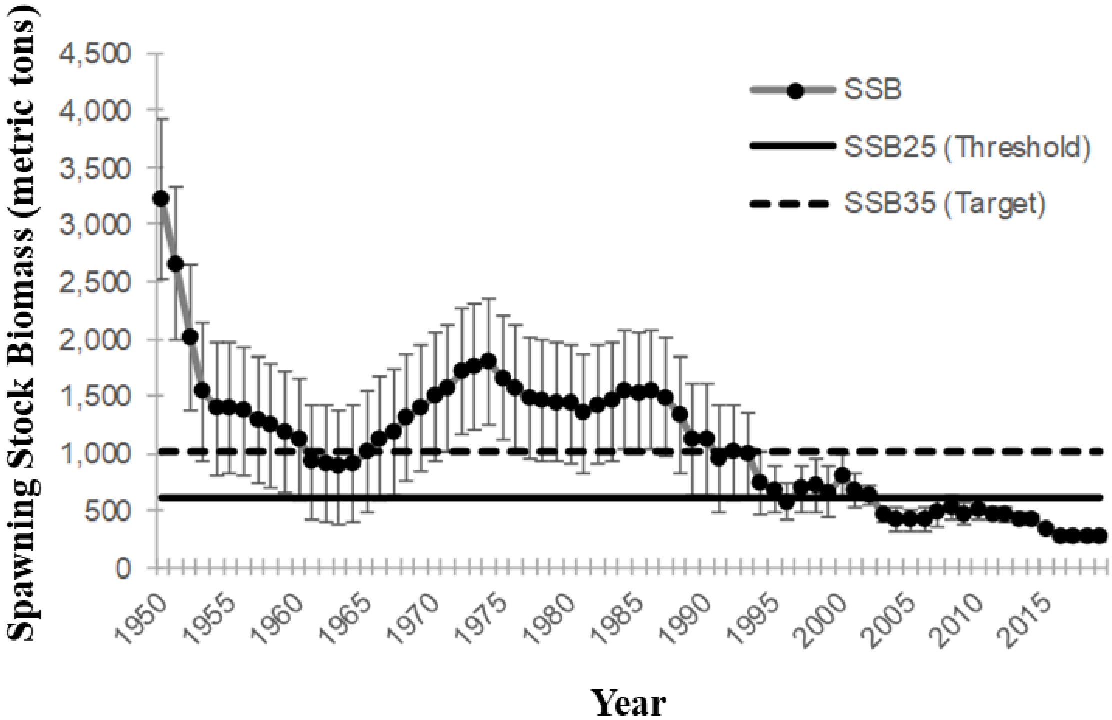


Figure 2. Annual predicted spawning stock biomass in metric tons, compared to estimated SSBThreshold (SSB25%) and SSBTarget (SSB35%), 1950–2019. 2019 is the terminal year for the most recent striped mullet stock assessment (NCDMF 2022).

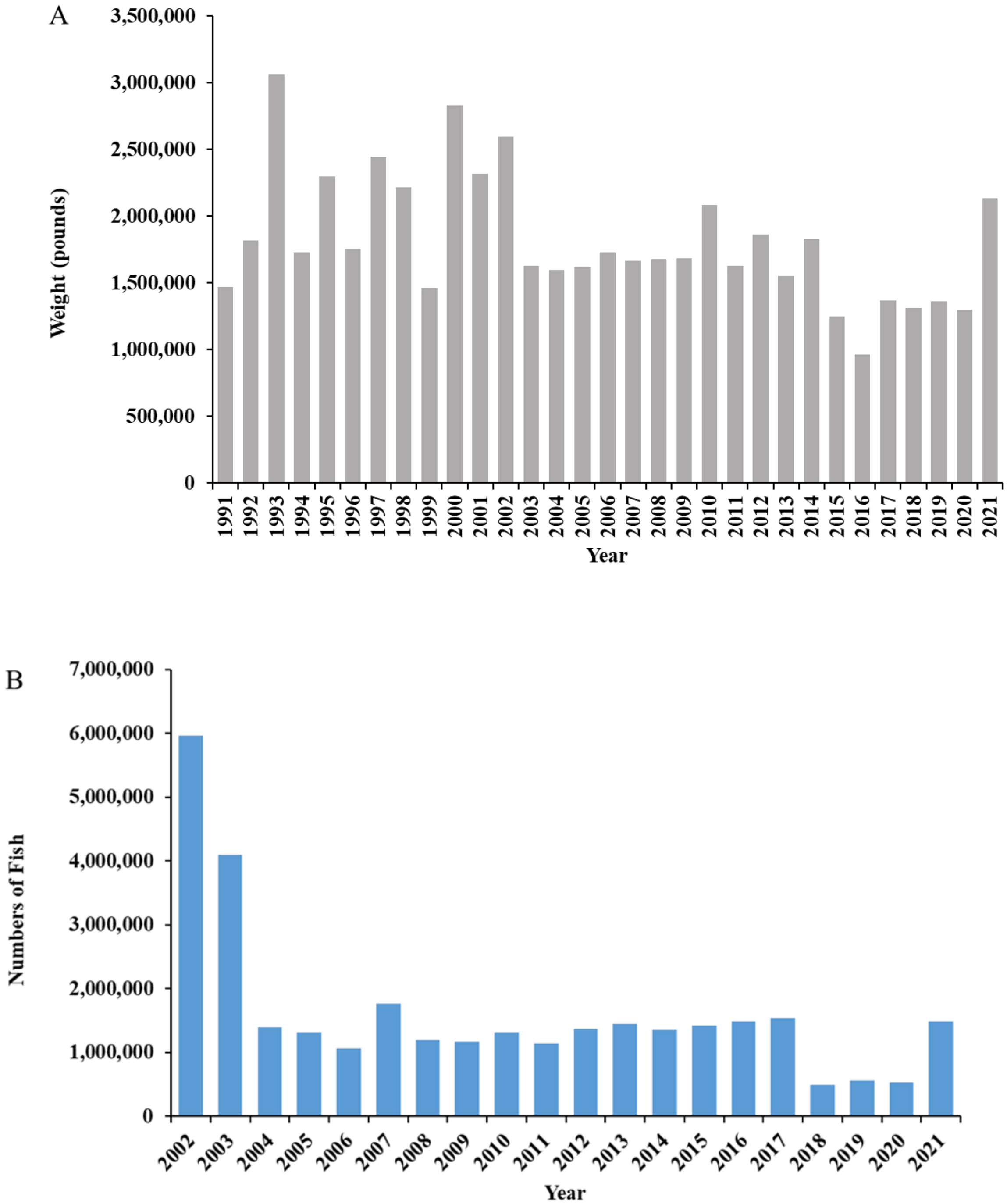


Figure 3. Striped mullet commercial landings (pounds) reported through the North Carolina Trip Ticket Program (A), 1991–2021. Recreational landings (Type A + B1; numbers of fish) includes estimates of striped mullet plus 29% of the mullet genus harvest from the Marine Recreational Information Program survey for North Carolina, 2002–2021 (B).

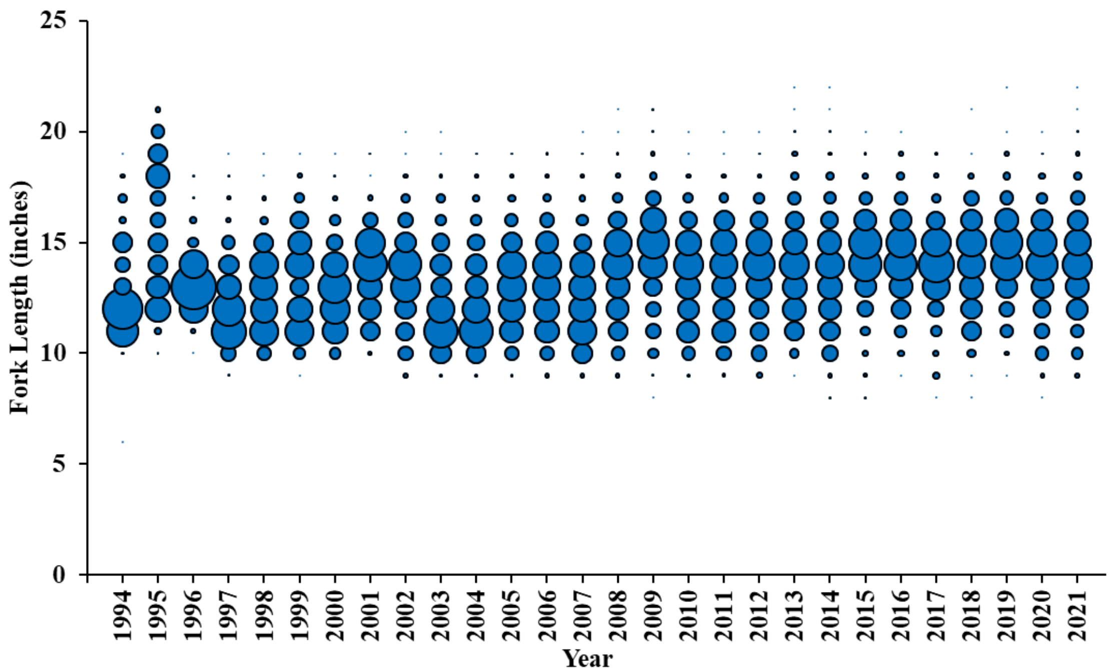


Figure 4. Commercial length frequency (fork length, inches) of striped mullet harvested, 1994–2021. Bubbles represent fish harvested at length and the size of the bubble is equal to the proportion of fish at that length.

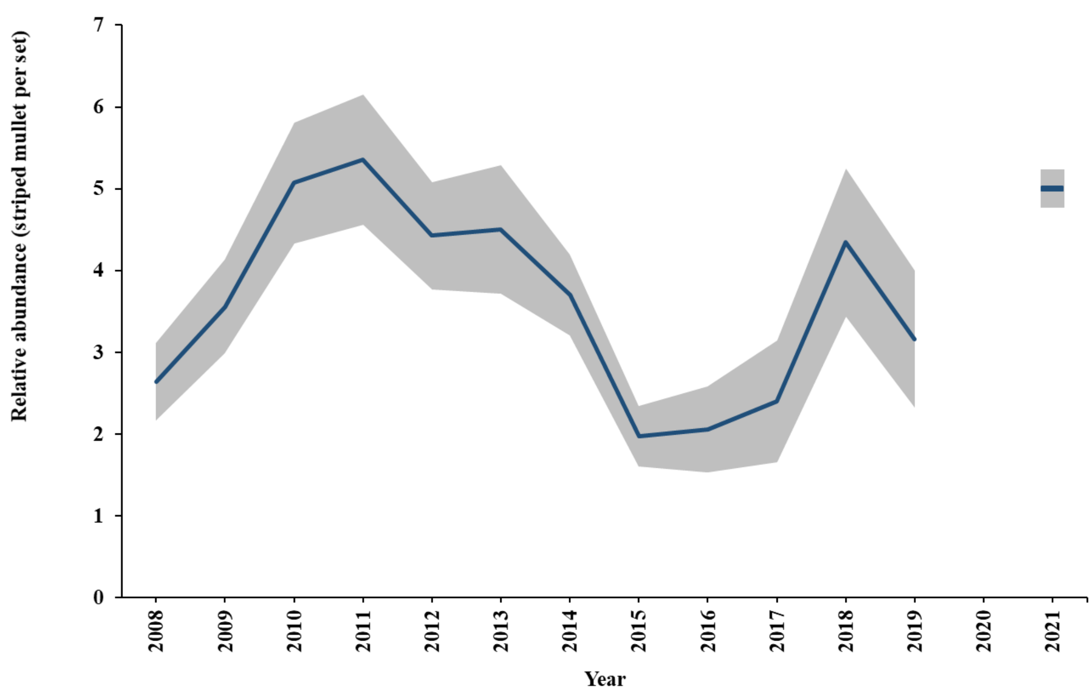


Figure 5. Relative Abundance index (fish per set) of striped mullet collected from Program 915 in Pamlico Sound, Pamlico, Pungo, Neuse and New rivers from August-December 2008–2021. Gray shading represent ± 1 standard error. Sampling was not conducted in 2020.

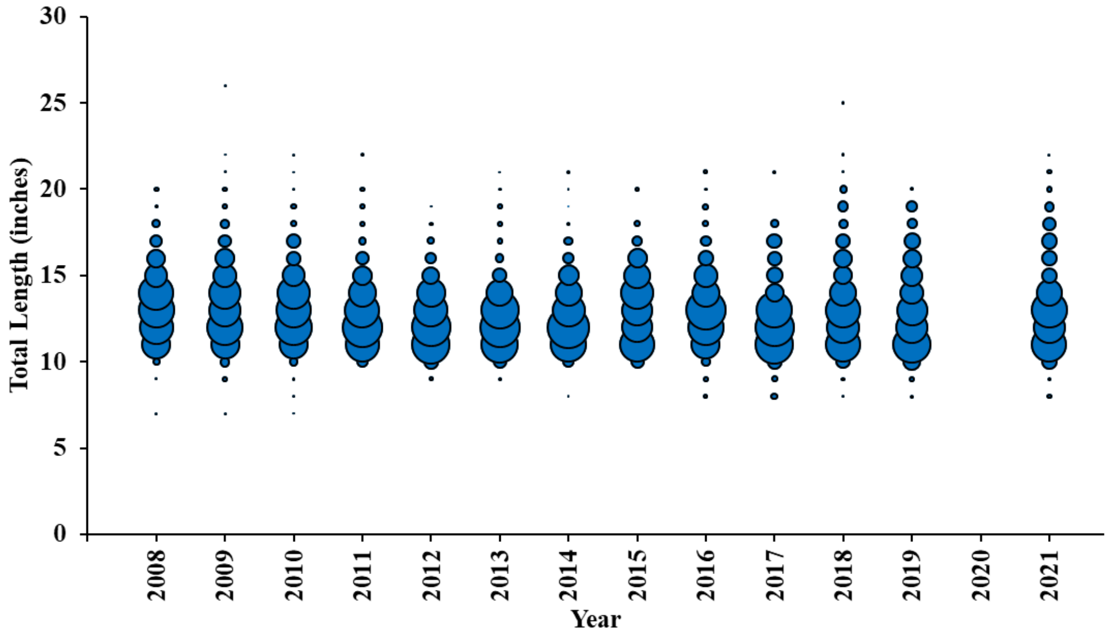


Figure 6. Length frequency (fork length, inches) of striped mullet collected from Program 915 in Pamlico Sound, Pamlico, Pungo, Neuse and New rivers from August-December (juveniles excluded), 2008–2021. Sampling was not conducted in 2020.

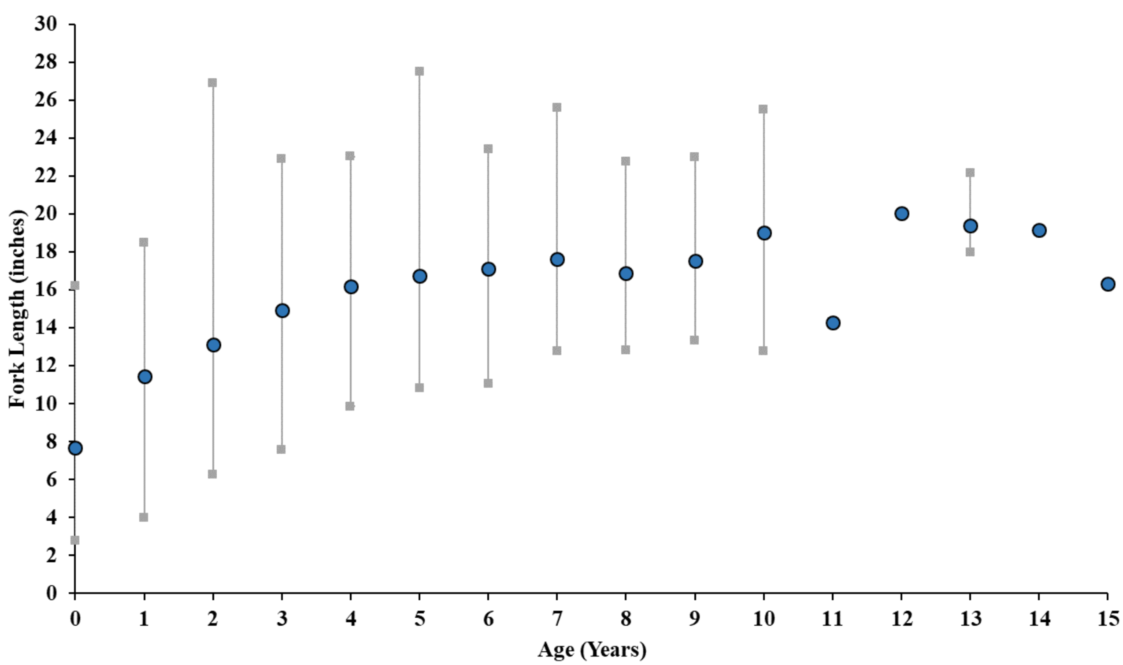


Figure 7. Striped mullet length at age based on all age samples collected, 1996–2021. Blue circles represent the mean size at a given age while the grey squares represent the minimum and maximum observed size for each age.

# DRAFT – SUBJECT TO CHANGE

## SUPPLEMENT A TO AMENDMENT 1 TO THE N.C. STRIPED MULLET FISHERY MANAGEMENT PLAN

**November 2022**

ISSUE

Consideration of Supplement A to Amendment 1 to the N.C. Striped Mullet Fishery Management Plan (FMP) to implement temporary management measures to immediately address overfishing of the striped mullet stock while Amendment 2 is developed.

ORIGINATION

The North Carolina Division of Marine Fisheries (DMF).

BACKGROUND

The North Carolina striped mullet stock is overfished and overfishing is occurring in 2019, the terminal year of the stock assessment (NCDMF 2022). As statutorily required, management measures will be developed through Amendment 2 to end overfishing and rebuild spawning stock biomass. Development of Amendment 2 is underway, with final adoption and implementation tentatively scheduled for 2024. Because of the timeline of FMP development, there will be four-years between the terminal year of the stock assessment and implementation of management measures to address the stock status. The supplement allows for implementation of temporary management measures to supplement Amendment 1 until Amendment 2 is adopted.

General Statute 113-182.1 provides a mechanism to supplement management under a Fishery Management Plan (FMP) between scheduled reviews when the Secretary of the Department of Environmental Quality (DEQ) determines it is in the interest of the long-term viability of the fishery. The draft supplement contains analysis of the proposed management change, projected outcomes, and proposed rules or proclamation measures necessary to implement the management change. The North Carolina Marine Fisheries Commission (MFC) may only consider a single management issue for each draft supplement. The supplement allows for implementation of temporary management measures to supplement Amendment 1 until Amendment 2 is adopted. NCMFC Rule 15A NCAC 03M .0502 provides the Director proclamation authority to implement restrictions in the taking of mullet. In accordance with the MFC FMP Guidelines, the MFC will review the draft supplement and reject (end of process), approve, or modify and approve it for public comment.

The North Carolina Striped Mullet FMP was adopted in April 2006 and established minimum and maximum commercial landings triggers of 1.3 and 3.1 million pounds (NCDMF 2006). If annual landings fall below the minimum trigger, the DMF would determine whether the decrease in landings is attributed to stock decline, decreased fishing effort, or both. If annual landings exceed the maximum trigger, DMF would determine whether harvest is sustainable and what factors are driving the increase in harvest. The Striped Mullet FMP established a daily possession limit of 200 mullets (white and striped combined) per person per day in the recreational fishery, through NCMFC Rule 15A NCAC 03M .0502.

The Striped Mullet FMP Amendment 1 was adopted in November 2015. The associated rules from Amendment 1 were implemented in April 2016; to resolve issues with Newport River gill net attendance and mitigate known user group conflicts. Amendment 1 also updated the management framework and updated minimum and maximum commercial landings triggers to 1.13 and 2.76 million pounds (NCDMF 2015). Amendment 1 maintains the recreational fishery limit. Other than the recreational daily possession limit there are no management measures directly limiting harvest of striped mullet.

Stock assessments for the North Carolina striped mullet stock were conducted by the DMF in 2006 (NCDMF 2006), 2013 (NCDMF 2015), 2018 (NCDMF 2018), and 2022 (NCDMF 2022). In each assessment, a fishing mortality threshold of $F_{25\%}$ was used to determine if overfishing was occurring. The 2022 assessment also used a spawning stock biomass (SSB) threshold of $SSB_{25\%}$ to determine if the stock was overfished. Stock assessments in 2006, 2013, and 2017 determined overfishing was not occurring but could not determine whether the stock was overfished. While these assessments concluded overfishing was not occurring, each noted concerning trends, data uncertainty, and the potential impact of future poor recruitment events. Given this concern, the commercial landings triggers and adaptive management framework were approved in the Striped Mullet FMP and updated in Amendment 1.

Commercial landings in 2016 were 965,198 pounds, less than the minimum commercial landings trigger. As required under the FMP, the DMF initiated data analysis and ultimately recommended updating the 2013 stock assessment with data through 2017 prior to considering any management action. As an assessment update, there were no changes to model parameters and peer review was not required, as the configuration of the model that previously passed peer review was maintained. The 2018 stock assessment concluded overfishing was not occurring in 2017 but indicated declining spawning stock biomass, declining recruitment, and increasing fishing mortality. A major concern in the 2017 assessment was lack of contrast in commercial landings data and lack of contrast and high variability associated with fishery-independent indices including the Fishery-Independent Gill Net Survey (Program 915), the Striped Mullet Electrofishing Survey (Program 146), and the Striped Bass Independent Gill Net Survey (Program 135). Also of concern were the poor fits to survey data and length compositions.

At its August 2018 business meeting, the DMF presented its recommendation along with recommendations from the Northern, Southern, and Finfish Advisory Committees to the NCMFC that no management action be taken since the stock assessment update indicated overfishing was not occurring. The DMF would, however, continue to monitor trends in the commercial fishery and fishery-independent indices. The recommendation was approved by the MFC.

For the 2022 striped mullet stock assessment, a F threshold of $F_{25\%}$ and a target of $F_{35\%}$ were maintained from the prior assessment since the commercial fishery continues to target mature female fish during the spawning season and the ecological importance of striped mullet. Complementary reference points for stock size were adopted based on female SSB, with a threshold of $SSB_{25\%}$ and a target of $SSB_{35\%}$. The stock assessment model estimated a value of 0.37 for the $F_{25\%}$ threshold and a value of 0.26 for the $F_{35\%}$ target. In 2019, the terminal year of the assessment, F was 0.42, higher than the $F_{25\%}$ threshold, indicating overfishing is occurring (Figure 1). The model estimated a value of 1,364,895 pounds for the $SSB_{25\%}$ threshold and a value of 2,238,075 pounds for the $SSB_{35\%}$ target. Female SSB in 2019 was estimated at 579,915 pounds, smaller than the $SSB_{25\%}$ threshold, indicating the stock is overfished (Figure 2).

An external peer review workshop was held in April 2022. The panel concluded the assessment model and results are suitable for providing management advice for at least the next five years. The panel considers the current model a substantial improvement from the previous assessment, representing the best scientific information available for the stock.

# DRAFT – SUBJECT TO CHANGE

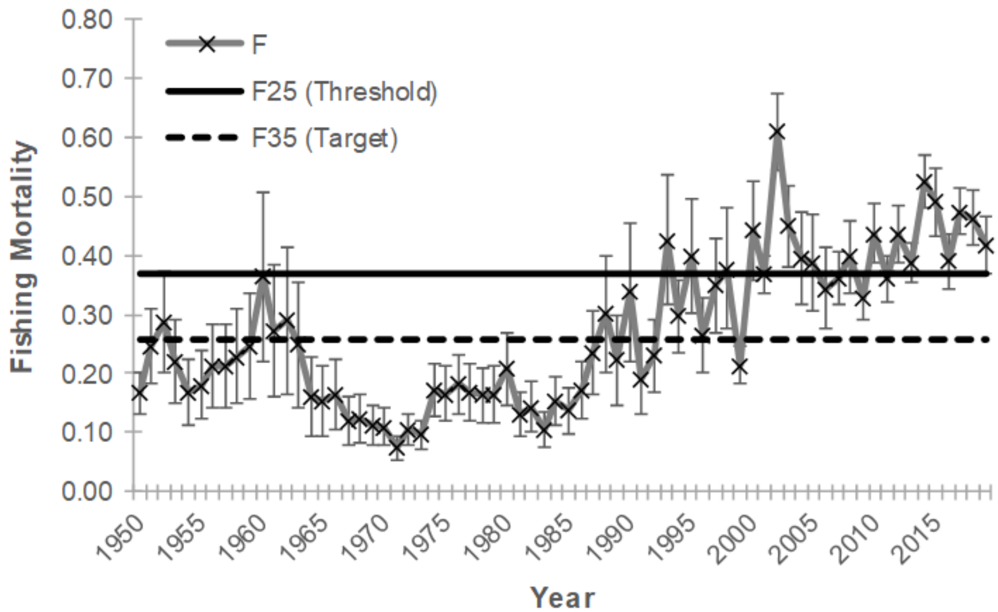


Figure 1. Comparison of annual estimates of fishing mortality (numbers weighted, ages 1-5) to the fishing mortality target (F35%) and threshold (F25%). Error bars represent ± 2 standard deviations.

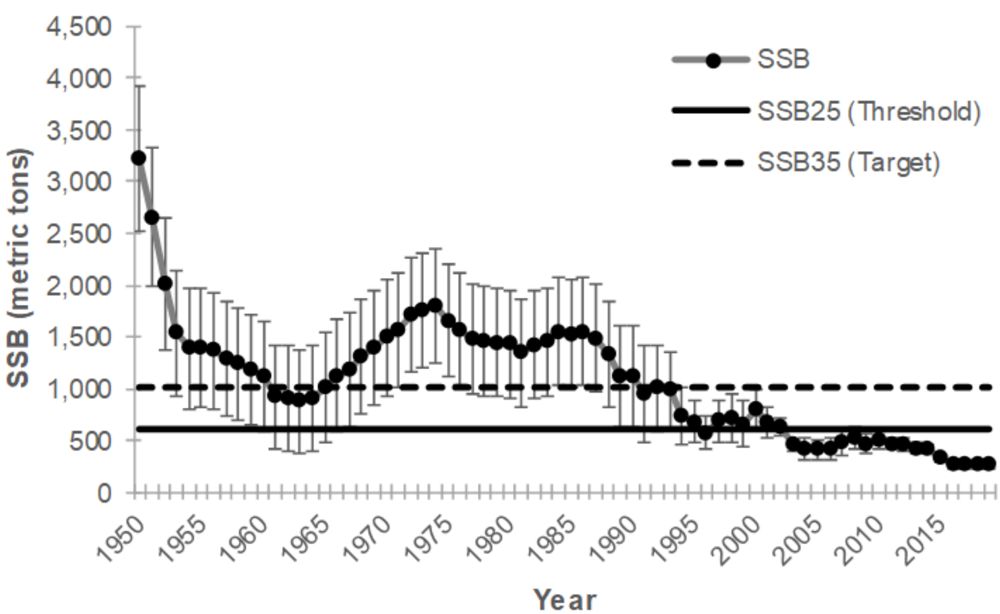


Figure 2. Comparison of annual estimates of female spawning stock biomass (SSB) to the SSB target (SSB35%) and threshold (SSB25%). Error bars represent ± 2 standard deviations.

AUTHORITY

G.S. 113-134 RULES
G.S. 113-182 REGULATION OF FISHING AND FISHERIES
G.S. 113-182.1 FISHERY MANAGEMENT PLANS
G.S. 113-221.1. PROCLAMATIONS; EMERGENCY REVIEW
G.S. 143B-289.52 MARINE FISHERIES COMMISSION-POWERS AND DUTIES
15A NCAC 03M .0502 MULLET
15A NCAC 03H .0103 PROCLAMATIONS, GENERAL

DISCUSSION

The 2022 stock assessment (NCDMF 2022) indicates recruitment has not only declined but has been below average since 2009 (Figure 3). The decline in recruitment coincides with declining spawning stock biomass while fishing mortality has increased (Figures 1-2).

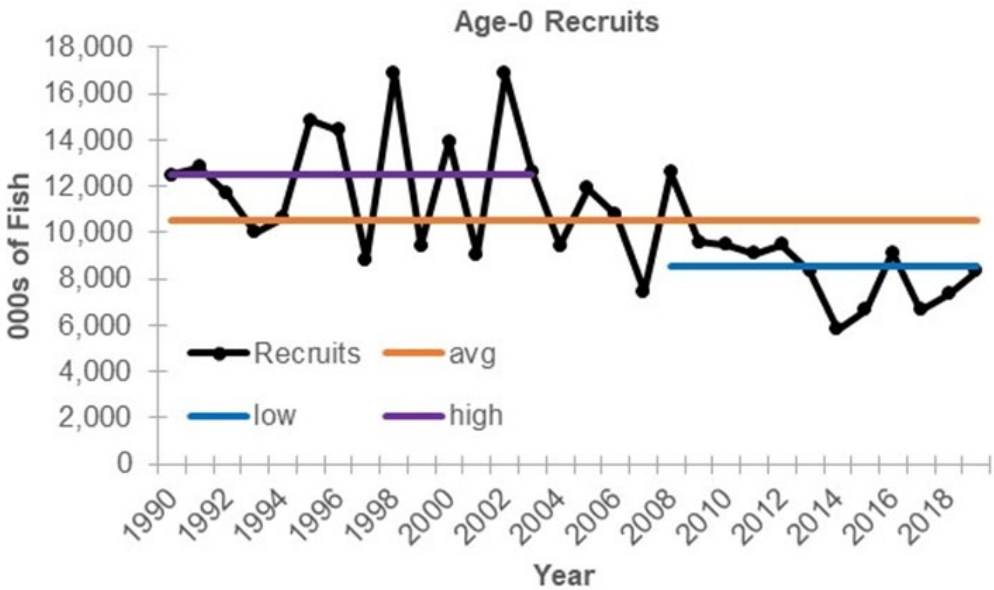


Figure 3. Estimates of striped mullet recruitment from the 2022 striped mullet stock assessment (NCDMF 2022). Average recruitment is the average number of recruits from 1990 to 2019, high recruitment is the average number of recruits from 1990 to 2003, and low recruitment is the average number of recruits from 2008 to 2019.

A 9.3% reduction in total removals relative to landings in 2019 is needed to reduce fishing mortality to the threshold and a 33% reduction is needed to reach the target. Amendment 1 to the Striped Mullet FMP included adaptive management allowing for implementation of management measures if commercial landings exceeded or fell below commercial landings triggers. Because neither the minimum or maximum commercial landings triggers were exceeded in 2022, adaptive management cannot be used to immediately implement management measures. A supplement to Amendment 1 is the only option to immediately implement management measures to end overfishing of the striped mullet stock. Given the stock is overfished and overfishing is occurring, ending overfishing immediately is in the long-term interest of the fishery because it begins rebuilding spawning stock biomass and meets the statutory requirement to end overfishing in two years. Measures addressing sustainable harvest and stock recovery will be explored and implemented through Amendment 2.

Implementation of quotas, seasons, size limits, area closures, gear restrictions, and harvest limits were discussed in Amendment 1 (NCDMF 2015). However, because management measures implemented through a supplement are intended to address a single issue, in this case ending overfishing, size limits, area closures, and gear restrictions are not considered viable options, and are not recommended, because they are unlikely to result in necessary harvest reductions without other measures in being place. A harvest quota would result in necessary harvest reductions and should be considered as a practical long-term option for management of the striped mullet fishery. However, because of the time needed to develop a quota monitoring framework and update infrastructure it is not considered a practical option through the supplement process and is not recommended. Trip limits, in conjunction with other options, could result in necessary reductions but given the high-volume nature of the striped mullet fishery may result in excessive dead discards. Trip limits should be explored during Amendment 2 but are not recommended for the supplement.

Given the inherent seasonality of the striped mullet fishery and life history characteristics that make striped mullet more vulnerable to the fishery during certain times of year, season closures are considered the most effective and efficient method to achieve the necessary reductions that can be implemented immediately through a supplement. Striped mullet are highly fecund (upwards of 4 million eggs for a large female; Bichy 2000) and spawn in large groups near inlets and in offshore areas (Collins and Stender 1989). Spawning individuals have been reported from September to March; however, peak spawning activity occurs from October to early December (Bichy 2000). Prior to spawning, striped mullet form large schools in estuaries and can be easily spotted near the surface making them particularly vulnerable to harvest. Closing a portion of the fall season to possession of striped mullet would reduce landings in the targeted striped mullet fishery, where most effort occurs. Targeting a season closure to the period of peak striped mullet harvest minimizes the length of the closure and the numbers of discards that might occur in other fisheries.

## Characterization of the Fishery

*Recreational Fishery*

The federal Marine Recreational Information Program (MRIP) is primarily designed to sample anglers who use rod and reel as the mode of capture. Since most striped mullet are caught with cast nets for bait, striped mullet recreational harvest data are imprecise. In addition, angler misidentification between striped mullet and white mullet is common, and bait mullet are usually released by anglers before visual verification by creel clerks is possible. As such, mullets are not identified to the species level in MRIP data (Catch Type B). Beginning in 2002, MRIP began deferring to mullet genus to classify unobserved type B1 (harvested/unavailable catch) and B2 (released/unavailable catch) catch. As a result, the magnitude of recreational mullet genus harvest far exceeds that of both striped mullet and white mullet. This methodological improvement increased the precision of mullet harvest estimates albeit without species level resolution. As such, estimates of recreational harvest for mullet prior to 2002 are considered unreliable.

The 2022 striped mullet stock assessment used the sum of recreational striped mullet harvest and a proportion of the recreational harvest of mullet genus to estimate removals by the recreational fleet (NCDMF 2022). The proportion of mullet genus assumed to be striped mullet in the recreational harvest was 29%, a value derived from a DMF striped mullet recreational cast net harvest study (NCDMF 2006).

Recreational harvest peaked in 2002 and 2003 at greater than four million fish harvested (Table 1). From 2004 to 2017 recreational harvest remained stable at around one million fish before declining in 2018, 2019 and 2020 to around 500,000 fish. This decline was likely related to decreased abundance of striped mullet and regulations that drastically shortened the recreational fishing season for southern flounder, a fishery where live mullet is a popular bait. Recreational harvest in 2021 was 1,484,850 fish.

Generally, most recreational striped mullet harvest occurs during the late summer and early fall. From 2017 to 2021 most recreational harvest occurred during September/October with some harvest during July/August (Figure 4). Based on MRIP harvest estimates very few, if any, striped mullet are harvested recreationally during the January/February or March/April waves (Table 2).

Striped mullet harvest data from the Recreational Commercial Gear License (RCGL) were collected from 2002 to 2008. The program was discontinued in 2009 due to a lack of funding and the minimal contributions from RCGL to overall harvest. From 2002 through 2008, an average of 41,512 pounds of striped mullet were harvested per year using a RCGL (Table 3).

Table 1. Recreational harvest (number of fish landed) of striped mullet and mullet genus estimated from MRIP sampling, 2002-2021. Based on results of a DMF cast net study (NCDMF 2006), 29% of the mullet genus harvested are assumed to be striped mullet.

| | Striped Mullet | | Mullet Genus | | Striped Mullet from Mullet Genus (29%) | Striped Mullet + Mullet Genus |
|---|---|---|---|---|---|---|
| Year | Harvest (A+B1) | PSE | Harvest (B1) | PSE | Harvest (B1) | Striped Mullet Total Harvest |
| 2002 | 4,668,427 | 18.0 | 4,480,197 | 36.3 | 1,299,257 | 5,967,684 |
| 2003 | 3,368,881 | 29.6 | 2,487,885 | 20.4 | 721,487 | 4,090,368 |
| 2004 | 5,496 | 101.7 | 4,790,382 | 16.1 | 1,389,211 | 1,394,707 |
| 2005 | 10,795 | 61.5 | 4,487,719 | 21.4 | 1,301,439 | 1,312,234 |
| 2006 | 15,706 | 63.5 | 3,599,098 | 21.4 | 1,043,738 | 1,059,444 |
| 2007 | 301,004 | 81.3 | 5,052,995 | 22.3 | 1,465,369 | 1,766,373 |
| 2008 | 3,458 | 65.0 | 4,097,156 | 14.4 | 1,188,175 | 1,191,633 |
| 2009 | 83,480 | 90.6 | 3,736,571 | 14.3 | 1,083,606 | 1,167,086 |
| 2010 | 126,250 | 44.7 | 4,113,171 | 14.3 | 1,192,820 | 1,319,070 |
| 2011 | 80,267 | 28.6 | 3,653,514 | 14.3 | 1,059,519 | 1,139,786 |
| 2012 | 351,960 | 79.5 | 3,510,395 | 16.3 | 1,018,015 | 1,369,975 |
| 2013 | 150,020 | 53.9 | 4,493,166 | 20.5 | 1,303,018 | 1,453,038 |
| 2014 | 50,381 | 67.0 | 4,490,722 | 26.2 | 1,302,309 | 1,352,690 |
| 2015 | 142,696 | 64.5 | 4,405,800 | 21.5 | 1,277,682 | 1,420,378 |
| 2016 | 29,965 | 50.6 | 5,039,891 | 55.6 | 1,461,568 | 1,491,533 |
| 2017 | 37,791 | 43.9 | 5,170,318 | 55.2 | 1,499,392 | 1,537,183 |
| 2018 | 35,565 | 59.3 | 1,564,676 | 31.7 | 453,756 | 489,321 |
| 2019 | 324,986 | 52.0 | 817,596 | 25.3 | 237,103 | 562,089 |
| 2020 | 323,102 | 43.2 | 719,908 | 23.2 | 208,773 | 531,875 |
| 2021 | 1,194,213 | 73.6 | 1,002,195 | 31.6 | 290,637 | 1,484,850 |

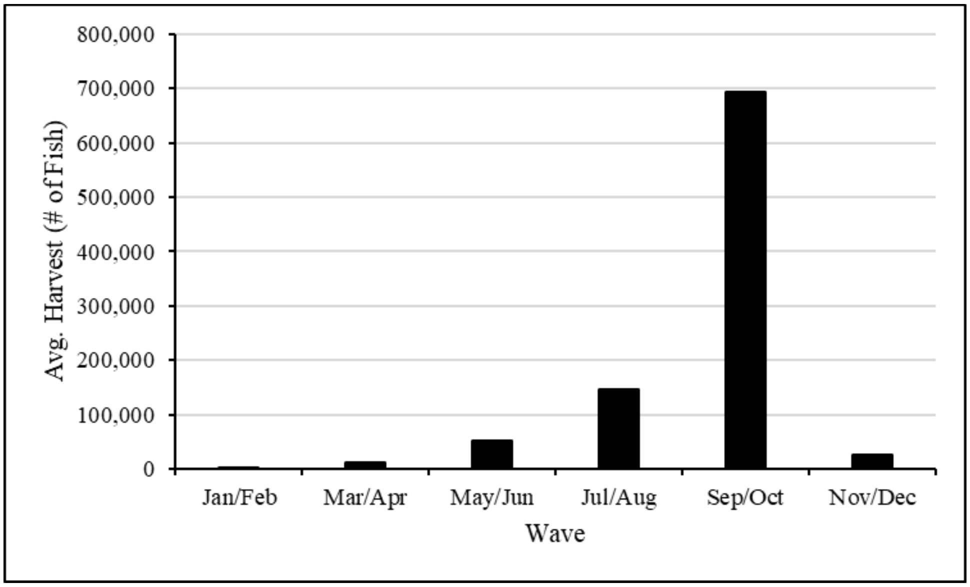


Figure 4. Average number of striped mullet harvested by the recreational fishery by wave based on MRIP estimates, 2017-2021.

# DRAFT – SUBJECT TO CHANGE

Table 2. Recreational harvest (number of fish landed) of striped mullet and mullet genus by wave estimated from MRIP sampling, 2002-2021. Striped mullet assumed as 29% of mullet genus.

| | | Striped Mullet | Mullet Genus | Striped Mullet from Mullet Genus (29%) | Striped Mullet + Mullet Genus |
|---|---|---|---|---|---|
| Year | Wave | Harvest (A+B1) | Harvest (B1) | Harvest (B1) | Striped Mullet Total Harvest |
| 2017 | January/February | . | . | . | . |
| 2017 | March/April | . | 82,931 | 24,050 | 24,050 |
| 2017 | May/June | 27,708 | 284,430 | 82,485 | 110,193 |
| 2017 | July/August | 8,505 | 354,629 | 102,842 | 111,347 |
| 2017 | September/October | 1,579 | 4,432,737 | 1,285,494 | 1,287,073 |
| 2017 | November/December | . | 15,590 | 4,521 | 4,521 |
| 2018 | January/February | . | . | . | . |
| 2018 | March/April | . | . | . | . |
| 2018 | May/June | 2,239 | 136,595 | 39,613 | 41,852 |
| 2018 | July/August | 18,993 | 750,891 | 217,758 | 236,751 |
| 2018 | September/October | 13,505 | 457,709 | 132,736 | 146,241 |
| 2018 | November/December | 828 | 219,480 | 63,649 | 64,477 |
| 2019 | January/February | . | . | . | . |
| 2019 | March/April | . | 32,700 | 9,483 | 9,483 |
| 2019 | May/June | 11,773 | 86,637 | 25,125 | 36,898 |
| 2019 | July/August | 82,801 | 280,921 | 81,467 | 164,268 |
| 2019 | September/October | 217,317 | 367,020 | 106,436 | 323,753 |
| 2019 | November/December | 13,096 | 50,318 | 14,592 | 27,688 |
| 2020 | January/February | 1,648 | 1,540 | 447 | 2,095 |
| 2020 | March/April | . | 21,050 | 6,105 | 6,105 |
| 2020 | May/June | 6,308 | 78,303 | 22,708 | 29,016 |
| 2020 | July/August | 40,470 | 239,694 | 69,511 | 109,981 |
| 2020 | September/October | 274,675 | 370,617 | 107,479 | 382,154 |
| 2020 | November/December | . | 8,704 | 2,524 | 2,524 |
| 2021 | January/February | . | 6,340 | 1,839 | 1,839 |
| 2021 | March/April | 7,087 | . | . | 7,087 |
| 2021 | May/June | 1,336 | 144,319 | 41,853 | 43,189 |
| 2021 | July/August | 21,670 | 292,846 | 84,925 | 106,595 |
| 2021 | September/October | 1,164,119 | 558,690 | 162,020 | 1,326,139 |
| 2021 | November/December | . | . | . | . |

Table 3. North Carolina Recreational Commercial Gear License (RCGL) survey estimates of the number of striped mullet harvested, pounds harvested, number released, and total number caught. The survey was discontinued in 2009.

| Year | Number Harvested | Pounds Harvested | Number Released | Total Number |
|---|---|---|---|---|
| 2002 | 66,305 | 64,213 | 6,549 | 72,854 |
| 2003 | 28,757 | 24,774 | 3,514 | 32,270 |
| 2004 | 34,736 | 35,947 | 2,875 | 37,611 |
| 2005 | 35,888 | 36,314 | 3,492 | 39,380 |
| 2006 | 38,175 | 37,385 | 5,352 | 43,527 |
| 2007 | 35,472 | 40,168 | 7,449 | 42,921 |
| 2008 | 51,465 | 51,785 | 9,207 | 60,672 |

*Commercial Fishery*

Since 1972, striped mullet commercial landings have ranged from a low of 965,198 pounds in 2016 to a high of 3,063,853 pounds in 1993 (Figure 5). From 2003 to 2009, landings were stable between 1,598,617 and 1,728,607 pounds before increasing to 2,082,832 pounds in 2010. Landings fluctuated annually between 1.5 and 2.0 million pounds from 2010 to 2014 before declining in 2015 and again in 2016, dropping below the minimum commercial landings trigger established by Amendment 1. Commercial landings in 2021 increased to 2,135,952 pounds, which is 1,005,952 pounds above the minimum commercial landings trigger.

Historically, beach seines and gill nets were the two primary gear types used in the striped mullet commercial fishery, with most commercial landings prior to 1978 coming from the beach seine fishery. Gill nets (runaround, set, and drift) replaced seines as the dominant commercial gear type in 1979 and since 2017 runaround gill nets have accounted for most (>70%) striped mullet commercial landings (Figure 6).

Because the commercial fishery primarily targets striped mullet for roe, the fishery is seasonal with the highest demand and landings occurring in October and November when large schools form during their spawning migration to the ocean and females are ripe with eggs (Figures 7-8). Striped mullet are primarily targeted commercially using runaround gill nets in the estuarine and ocean waters of North Carolina. The striped mullet beach seine fishery primarily occurs in conjunction with the Bogue Banks stop net fishery. The stop net fishery has operated under fixed seasons and net and area restrictions since 1993. Currently, stop nets are limited in number (four), length (400 yards), and mesh sizes (minimum eight inches outside panels, six inches middle section). Stop nets have typically been permitted along Bogue Banks (Carteret County) in the Atlantic Ocean from October 1 to November 30. However, the stop net season was extended to include December 3 to December 17 in 2015 due to minimal landings of striped mullet (Proclamation M-28-2015). In 2020 and 2021, the stop net fishery was open from October 15 through December 31 (Proclamations M-17-2020 and M-21-2021). Due to the schooling nature of striped mullet, the beach seine fishery has the potential to be, and historically has been, a high-volume fishery with thousands of pounds landed during a single trip. In addition, the use of cast nets in the striped mullet commercial fishery has been increasing since around 2003.

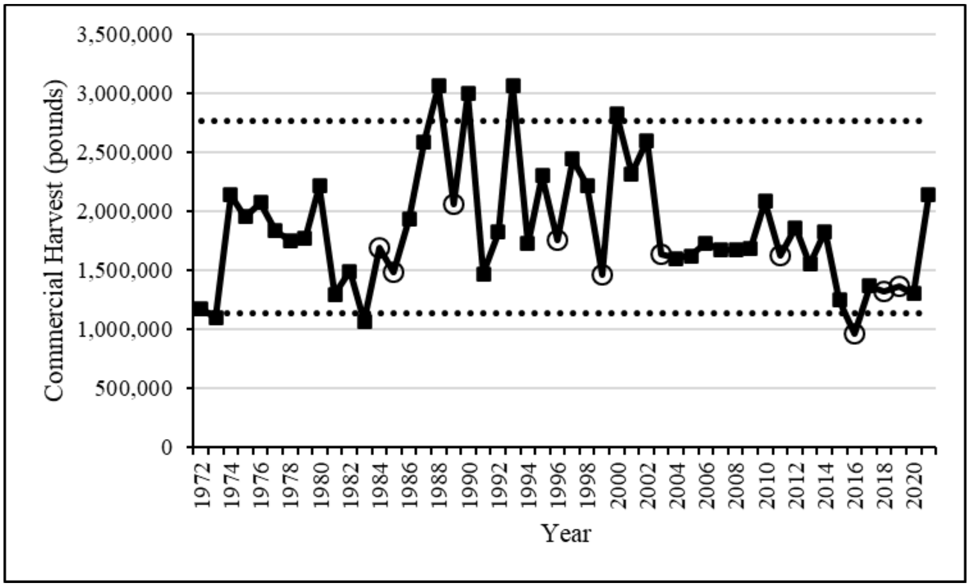


Figure 5. Striped mullet commercial landings (pounds) reported through the North Carolina Trip Ticket Program, 1972–2021 Lower dashed line (1.13 million lb.) and upper dashed line (2.76 million lb.) represent landings limits that trigger closer examination of data. Open circles represent years with significant hurricanes of storms.

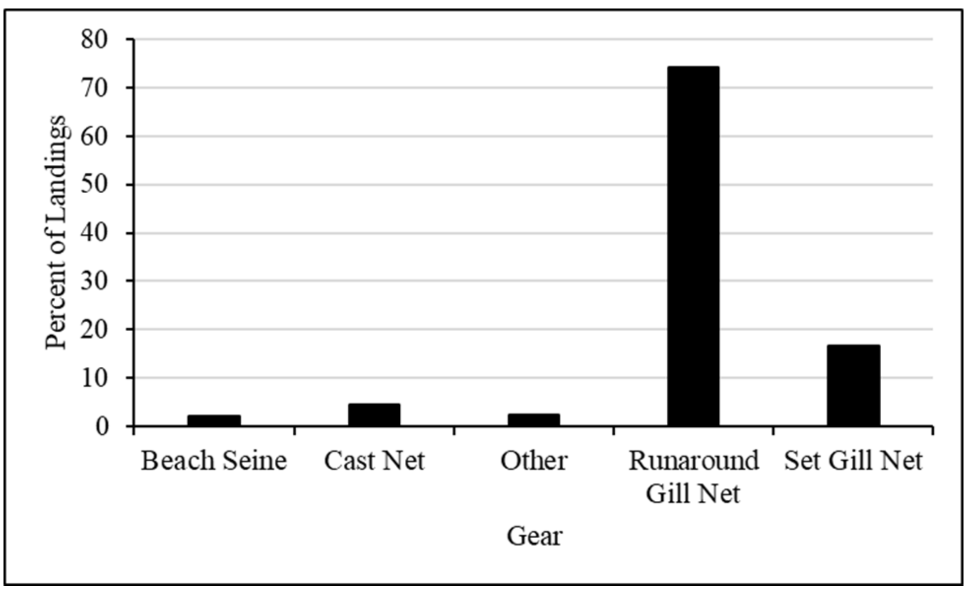


Figure 6. Percent of striped mullet commercial landings reported through the North Carolina Trip Ticket Program by gear, 2017–2021.

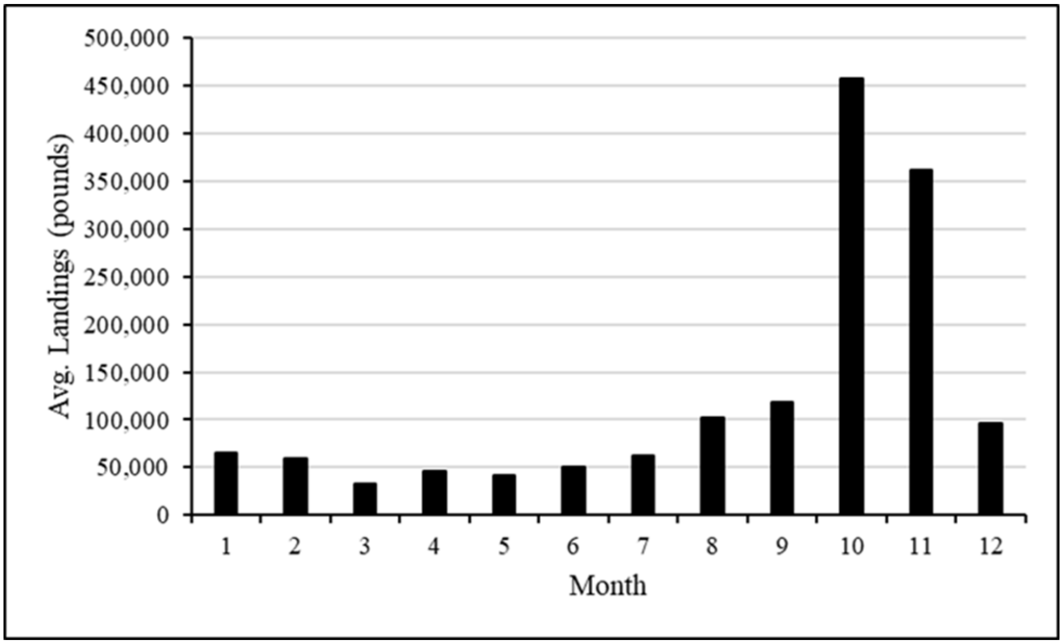


Figure 7. Average commercial landings of striped mullet by month, 2017-2021.

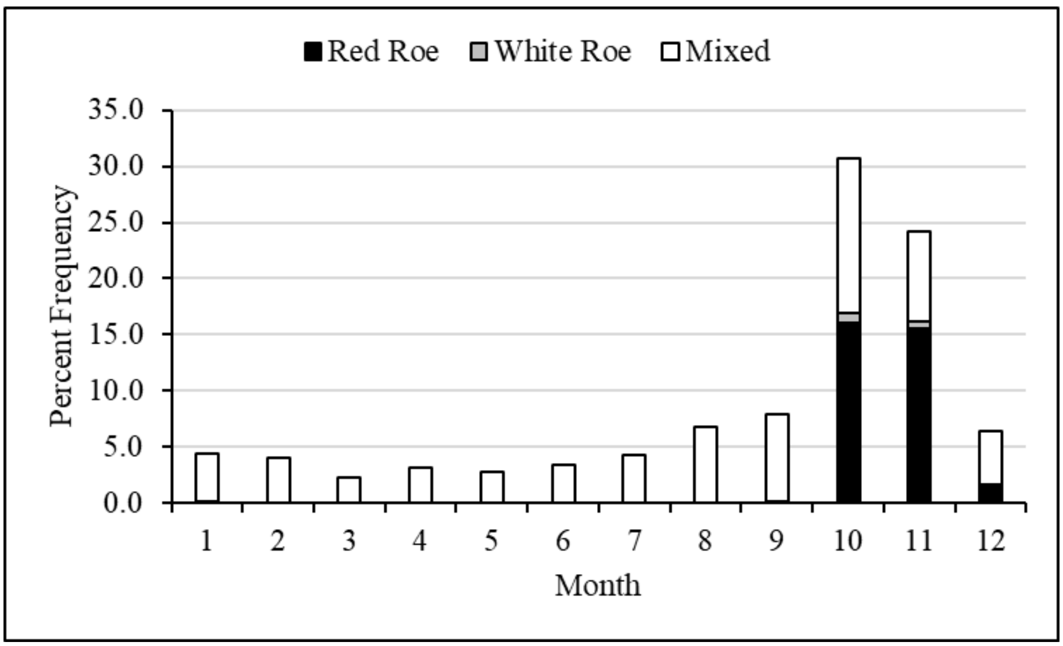


Figure 8. Percent frequency of striped mullet commercial landings by market grade and month, 2017-2021. Red Roe includes striped mullet graded as Red Roe and Roe. White Roe includes striped mullet graded as White Roe. Mixed includes striped mullet graded as Jumbo, Large, Medium, Mixed, Small, and X-Small.

PROPOSED MANAGEMENT OPTIONS

The goal of this supplement is to reduce fishing mortality and end overfishing with simple quantifiable measures as quickly as possible. A 9.3% reduction in total removals relative to landings in 2019 is needed to reduce fishing mortality to the threshold and a 33% reduction is needed to reach the target. The Division recommends harvest reductions of 20-33% to exceed the F threshold and either reach or approach the F target. This level of reduction increases the probability of, at a minimum, ending overfishing even if there is variability in fishing effort, market demand, striped mullet availability to the fishery, or recruitment.

Non-quantifiable measures such as gear restrictions, area closures, size limits, and recreational specific measures were not considered because they may not quantifiably reduce harvest. A quota system was not considered because the infrastructure is not in place to quickly implement this type of management. Management strategies such as daily trip limits, day of the week closures, and early or mid-season closures were not considered because the risk of recouped catches would likely limit the realized reductions of these management measures. Rather than reduce harvest, measures like early season closures would likely just act to delay harvest.

End of year season closures are considered the most effective and efficient management option that can be implemented through the supplement process and be expected to successfully limit striped mullet harvest. An end of year season closure would be implemented as no possession across both commercial and recreational sectors with no additional modification or prohibition of gears. Despite the closure occurring across all sectors, reductions cannot be quantified for the recreational sector due to data limitations. Therefore, overall reduction calculations are based solely on striped mullet landings from the commercial fishery. A 9.3% overall reduction equates to a 9.9% reduction in commercial harvest, and a 20-33% overall reduction equates to a 21.3-35.4% reduction in commercial harvest. All management options are presented as percent reductions to the commercial harvest relative to commercial landings in 2019 (terminal year of the stock assessment).

*End of Year Closures*

Historically, peak striped mullet roe landings have occurred in October-November, with most landings occurring from approximately October 15-November 15. An end of year season closure during this time provides the greatest reduction over the shortest period. The closure occurring at the end of the year, does not allow for recoupment of catch that year, increasing the probability of successfully reducing harvest, and ending overfishing. The closure must occur during the peak fall roe harvest season, which impacts the most economically valuable segment of the striped mullet fishery. An end of year closure also creates regulatory discards associated with fisheries that do not target striped mullet during the closed period. However, much of the striped mullet harvest during this time comes from directed trips where runaround gill nets are used to capture visible, schooling striped mullet so discards in other fisheries are unlikely to be excessive. A wrap-around end of year closure extending into January was not considered because of the minimal benefit to striped mullet and to avoid creating striped mullet discards in other fisheries. A closure extending into January would not yield any significant extension to the fall striped mullet season and would likely increase pressure on other fisheries, like spotted seatrout. An end of year closure is most likely to achieve the necessary reductions because recoupment would be less significant than other management options not considered in this supplement.

*Summary of Economic Impacts*

Modeling software, IMPLAN, is used to estimate the economic impacts of an industry to the state at-large, accounting for revenues and participation. For a detailed explanation of the methodology used to estimate the economic impacts please refer to DMF's License and Statistics Section Annual Report on the Fisheries Statistics page (NCDMF 2021). Due to the management options being considered, this analysis focuses on the commercial industry.

Commercial landings and effort data collected through the DMF Trip Ticket Program are used to estimate the economic impact of the commercial fishing industry. For commercial fishing output, total impacts are estimated by incorporating modifiers from NOAA's Fisheries Economics of the United States report (NMFS 2022), which account for proportional expenditures and spillover impacts from related industries. By assuming the striped mullet fishery's contribution to expenditure categories at a proportion equal to its contribution to total commercial ex-vessel values, it is possible to generate an estimate of the total economic impact of striped mullet statewide.

From 2011 to 2021 striped mullet ex-vessel value has been about $1 million dollars and impacts about 800 jobs annually (Table 4). Annual sales impacts have varied but averaged $3.6 million from 2011 to 2021. In general, these estimates demonstrate the striped mullet fishery contributes to about 1% of commercial fishing sales impact statewide.

Table 4. Annual commercial estimates of annual economic impact to the state of North Carolina from striped mullet harvest, 2011-2021. Economic impacts are reported in 2020 dollars.

| Year | Pounds Landed | Ex-Vessel Value | Job Impacts | Income Impacts | Value-Added Impacts | Sales Impacts |
|---|---|---|---|---|---|---|
| 2021 | 2,135,952 | $ 1,333,475 | 714 | $ 1,860,564 | $ 3,503,122 | $ 4,004,336 |
| 2020 | 1,299,464 | $ 651,104 | 658 | $ 1,330,677 | $ 2,257,282 | $ 2,912,396 |
| 2019 | 1,362,212 | $ 929,282 | 673 | $ 1,502,372 | $ 2,344,706 | $ 3,475,378 |
| 2018 | 1,312,121 | $ 953,667 | 731 | $ 1,502,185 | $ 2,686,226 | $ 3,303,076 |
| 2017 | 1,366,338 | $ 1,037,526 | 802 | $ 1,571,518 | $ 2,564,816 | $ 3,559,251 |
| 2016 | 965,337 | $ 669,843 | 716 | $ 1,006,728 | $ 1,739,854 | $ 2,240,287 |
| 2015 | 1,247,044 | $ 804,675 | 784 | $ 1,203,068 | $ 2,086,467 | $ 2,663,251 |
| 2014 | 1,828,351 | $ 1,112,465 | 912 | $ 1,735,047 | $ 3,293,379 | $ 3,936,322 |
| 2013 | 1,549,157 | $ 1,402,914 | 1,042 | $ 2,318,409 | $ 3,902,777 | $ 5,173,187 |
| 2012 | 1,859,587 | $ 1,041,659 | 948 | $ 1,957,469 | $ 3,167,843 | $ 4,390,261 |
| 2011 | 1,627,894 | $ 1,015,852 | 885 | $ 1,890,316 | $ 3,371,858 | $ 4,175,332 |
| Average | 1,504,860 | $ 995,678 | 806 | $ 1,625,305 | $ 2,810,757 | $ 3,621,189 |

Table 5. Monthly commercial estimates of annual economic impact to the state of North Carolina from striped mullet harvest over five years, 2017-2021. Economic impacts are reported in 2020 dollars.

| Month | Pounds Landed | Ex-Vessel Value | Job Impacts | Income Impacts | Value Added Impacts | Sales Impacts |
|---|---|---|---|---|---|---|
| 1 | 65,170 | $ 36,107.03 | 130 | $ 53,057.71 | $ 98,355.14 | $ 114,549.45 |
| 2 | 59,618 | $ 33,227.53 | 129 | $ 49,108.96 | $ 90,877.25 | $ 106,053.22 |
| 3 | 32,731 | $ 18,569.84 | 122 | $ 28,460.61 | $ 52,101.53 | $ 61,568.49 |
| 4 | 45,885 | $ 25,851.76 | 141 | $ 39,856.46 | $ 72,837.04 | $ 86,245.48 |
| 5 | 41,826 | $ 23,508.17 | 121 | $ 35,221.68 | $ 64,912.23 | $ 76,114.04 |
| 6 | 50,157 | $ 28,058.94 | 131 | $ 43,466.77 | $ 79,323.84 | $ 94,077.95 |
| 7 | 62,675 | $ 36,047.32 | 139 | $ 54,151.74 | $ 99,720.97 | $ 117,036.20 |
| 8 | 101,967 | $ 60,393.25 | 179 | $ 91,585.84 | $ 168,184.68 | $ 198,027.77 |
| 9 | 118,860 | $ 69,487.04 | 210 | $ 103,726.30 | $ 191,374.87 | $ 224,109.33 |
| 10 | 458,246 | $ 328,837.30 | 361 | $ 485,746.18 | $ 899,026.44 | $ 1,048,966.80 |
| 11 | 362,172 | $ 261,014.19 | 297 | $ 357,945.86 | $ 688,459.22 | $ 766,383.96 |
| 12 | 95,910 | $ 59,908.44 | 176 | $ 83,266.89 | $ 157,024.20 | $ 179,263.56 |

To further understand the dynamics of the striped mullet fishery the monthly economic impacts over the last five years are reported in Table 5. The striped mullet commercial fishery is driven by seasonal changes in population availability. The estimated change in job impacts and sales impacts reflect the availability of striped mullet throughout the year. Most of the harvest and economic impacts are concentrated in October and November of each year.

*Management Option Scenarios*

Management options for consideration include end of year closures that end December 31 (Table 6). All options provided in Table 6 meet the statutory requirement to end overfishing.

Table 6. Management options that satisfy the 9.9% commercial harvest reduction to end overfishing. All reductions are calculated from 2019 commercial harvest levels (terminal year of stock assessment).

| Single Management Measures that Satisfy Reduction | Management Measure | Estimated Commercial Harvest Reduction (%) |
|---|---|---|
| | Season Closures | |
| 1 | October 29 – December 31 | 33.7 |
| 2 | November 7 – December 31 | 22.1 |
| 3 | November 13 - December 31 | 10.9 |

*End of Year Season Closure (options 1 and 2)*

(+ potential positive impact of action)
(- potential negative impact of action)

+ No additional resources required to implement
+ No additional reporting burden on fishermen or dealers
+ Reduces effort from current level
+ High likelihood of ending overfishing
+ Increases probability of ending overfishing stock or fishery conditions are variable
– Weather may prevent fishing during open periods
– Effort may increase during the open period reducing the effectiveness of the closure
– Reduction in fishing mortality may not be achieved
– Overfishing may still occur if recruitment is low
– May adversely impact some fisheries and fishermen more than others
– Create regulatory discards in the closed period

*End of Year Season Closure (option 3)*

(+ potential positive impact of action)
(- potential negative impact of action)

+ No additional resources required to implement
+ No additional reporting burden on fishermen or dealers
+ Reduces effort from current level
+ Could potentially end overfishing
– No buffer to increase probability of ending overfishing if stock or fishery conditions are variable
– Weather may prevent fishing during open periods
– Effort may increase during the open period reducing the effectiveness of the closure
– Reduction in fishing mortality may not be achieved
– Overfishing may still occur if recruitment is low
– May adversely impact some fisheries and fishermen more than others
– Create regulatory discards in the closed period

RECOMMENDATION

DMF Recommended Management Strategy:

The DMF recommends approval of the supplement to implement either option 1 or 2. To achieve a 20-33% reduction, any end of year season closure must begin no sooner than October 29 and no later than November 7 and continue through December 31. The Division supports a 20-33% reduction to exceed the threshold and either meet or approach the target. This reduction level increases the probability of, at a minimum, ending overfishing even if there is variability in fishing effort, market demand, striped mullet availability to the fishery, or recruitment fluctuations.

MFC Selected Management Strategy:

LITERATURE CITED

Bichy, J. 2000. Reproductive biology of Striped Mullet, *Mugil cephalus*, in North Carolina. Final Report to North Carolina Sea Grant. Fishery Resource Grant Project No. 97-FEG-09. 90 pp.

Collins, M.R., and B.W. Stender. 1989. Larval Striped Mullet (*Mugil cephalus*) and white mullet (*Mugil curema*) off the southeastern United States. Bulletin of Marine Science 45(3):580–589.

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Prepared by Daniel Zapf, Daniel.Zapf@ncdenr.gov, 252-948-3874, and
Jeffrey Dobbs, Jeffrey.Dobbs@ncdenr.gov, 252-808-8193
October 28, 2022

ROY COOPER
*Governor*

ELIZABETH S. BISER
*Secretary*

KATHY B. RAWLS
*Director*

Nov. 17, 2022

**MEMORANDUM**

**TO:** North Carolina Marine Fisheries Commission

**FROM:** Daniel Zapf and Jeff Dobbs
Striped Mullet Fishery Management Plan Co-Leads

**SUBJECT:** Striped Mullet Fishery Management Plan Amendment 2

**Issue**
Review the Striped Mullet Fishery Management Plan (FMP) Amendment 2 draft goal and objectives and discuss potential management strategies.

**Action Needed**
Vote on approval of Striped Mullet FMP Amendment 2 goal and objectives

**Background**
Results of the 2022 Striped Mullet Benchmark Stock Assessment were presented to the Marine Fisheries Commission (MFC) at its May business meeting. The peer reviewed stock assessment was approved for management use and indicates the North Carolina striped mullet stock is overfished and overfishing is occurring in the terminal year of the assessment (2019). Management actions in Amendment 2 will focus on ending overfishing and rebuilding the spawning stock biomass to provide sustainable harvest.

**Goal and Objectives**
The division has completed the scoping period for Amendment 2. The next step in the FMP process is for the MFC to consider approval of the Amendment 2 goal and objectives. The division will develop draft Amendment 2 to achieve the goal and objectives in collaboration with the Striped Mullet FMP Advisory.

The draft goal and objectives are:

**Goal:**
Manage the striped mullet fishery to achieve a self-sustaining population that provides sustainable harvest using science-based decision-making processes.

State of North Carolina | Division of Marine Fisheries
3441 Arendell Street | P.O. Box 769 | Morehead City, North Carolina 28557
252-726-7021

**Objectives:**

- Implement management strategies within North Carolina that sustain and/or restore the striped mullet spawning stock with adequate age structure abundance to maintain recruitment potential and prevent overfishing.
- Promote the restoration, enhancement, and protection of critical habitat and environmental quality in a manner consistent with the Coastal Habitat Protection Plan, to maintain or increase growth, survival, and reproduction of the striped mullet stock.
- Use biological, social, economic, fishery, habitat, and environmental data to effectively monitor and manage the fishery and its ecosystem impacts.
- Advance stewardship of the North Carolina striped mullet stock by promoting practices that minimize bycatch and discard mortality.

**Scoping Period**

The division developed a scoping document identifying potential management strategies and held a public scoping period for Amendment 2, Sept. 26-Oct. 7, 2022. In addition to accepting comments through an online questionnaire and U.S. Mail, the division held three in-person meetings in Manteo, Morehead City, and Wilmington. Over 200 stakeholders participated by attending in-person meetings or submitting comments online. The division received input from meeting attendees and 153 online comments. Comments centered on concerns over the stock assessment results, changes in market demand, regional management, gear specific management, year-round fishing needs, recreational fisheries, support for adaptive management, and concerns about the amount of finger mullet harvest.

**Potential Management Strategies**

Potential management strategies include sustainable harvest, recreational fishery management, small mesh gill net fishery management, stop net fishery management, and migration corridors. The MFC will have the opportunity to inform potential management strategies to be considered during development of Amendment 2.

## Potential Striped Mullet FMP Amendment 2 Management Strategies

**Sustainable Harvest**

- Quota management
- Fishing Seasons/days
- Trip Limits
- Size Limits (min/max/slot)
- Adaptive management
- Gear modifications

**Recreational Fishery**

- Characterize recreational fishery
- Support sustainable harvest
- Non-quantifiable measures
- Mutilated finfish rule

**Small Mesh Gill Nets**

- As tasked by MFC
- Support sustainable harvest
- Regulatory complexity
- Bycatch reduction
- Conflict

**Stop Net Fishery**

- Effectiveness of current management
- Support sustainable harvest

**Migration Corridors**

- Migration corridors to support sustainable harvest

Picture by Nolen Vinay

# Scoping Document

## Striped Mullet Fishery Management Plan

## What is Scoping?

Scoping is the first stage of the Division of Marine Fisheries (DMF) Fishery Management Plan (FMP) process. Scoping serves to:

(1) Provide notice to the public that a formal review of the FMP is underway.

(2) Inform the public of the stock status, when available.

(3) Solicit stakeholder input on relevant management strategies and issues that may need addressed.

(4) Recruit potential FMP advisory committee (AC) members to assist the DMF in drafting the plan.

Scoping is the best opportunity to provide input for consideration during FMP development.

This document provides an overview of the initial management strategies and issues identified by the DMF, as well as background information on the fisheries and stock. Management strategies developed in Amendment 2 will be dependent on statutory requirements, available data, research needs, and the consequences of management.

## Fishery Management


Management **PLANS** set specific management goals for a fishery. Management **STRATEGIES** are techniques to achieve the set management goals. Management **MEASURES** are the actions to achieve the management strategies.

**The N.C. Division of Marine Fisheries seeks your input on management strategies for the Striped Mullet Fishery Management Plan**

**September 2022**

# Striped Mullet Scoping Period September 26 - October 7, 2022

## Meetings

DMF staff will provide information about the N.C. Striped Mullet FMP Amendment 2. Following the presentation, the public will have an opportunity to give comment and speak directly with DMF staff.

Three in-person meetings will be held across the state with one meeting being available virtually. Links to scoping information, including webinar information and reference documents, can be found through the Striped Mullet Amendment 2 Information Page.

**Tuesday, September 27**

**6 p.m. to 8 p.m.**

Dare County Administration Building
Commissioners Meeting Room
954 Marshall C. Collins Drive
Manteo

**Tuesday, October 4**

**6 p.m. to 8 p.m.**

DMF Central District Office
5285 Highway 70 West
Morehead City

OR

Virtually through WebEx
Event number 2436 717 6123
Event password 1234

**Thursday, October 6**

**6 p.m. to 8 p.m.**

Department of Environmental Quality
Wilmington Regional Office
127 Cardinal Drive
Wilmington

## Can't attend but want to submit comments?

Written comments can be submitted by online form or U.S. mail. Comments must be received by October 7, 2022.

**To comment by online form:**

**To comment by U.S. mail, mail to:**

N.C. Division of Marine Fisheries
N.C. Striped Mullet Scoping
P.O. Box 769
Morehead City, NC 28557

***FMP Process Questions?***
***Contact the FMP Coordinator***
Corrin Flora
Corrin.Flora@ncdenr.gov
252-808-8014

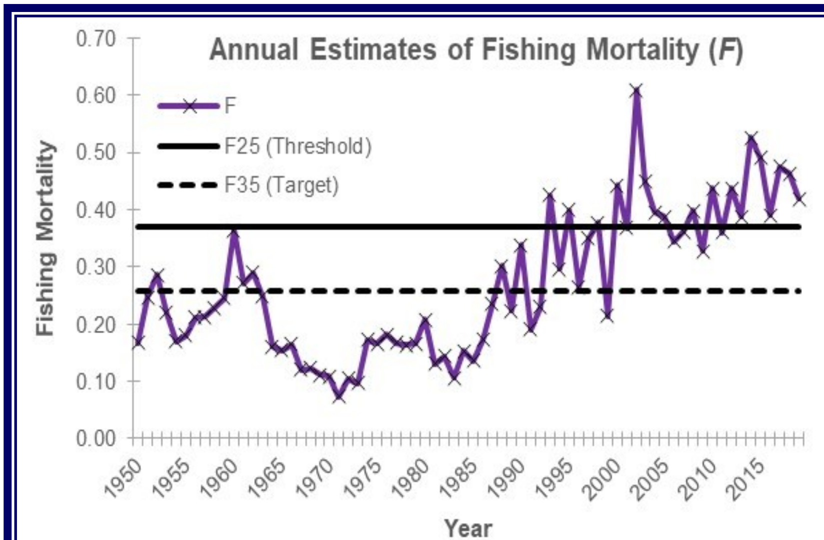
# 2022 STOCK ASSESSMENT

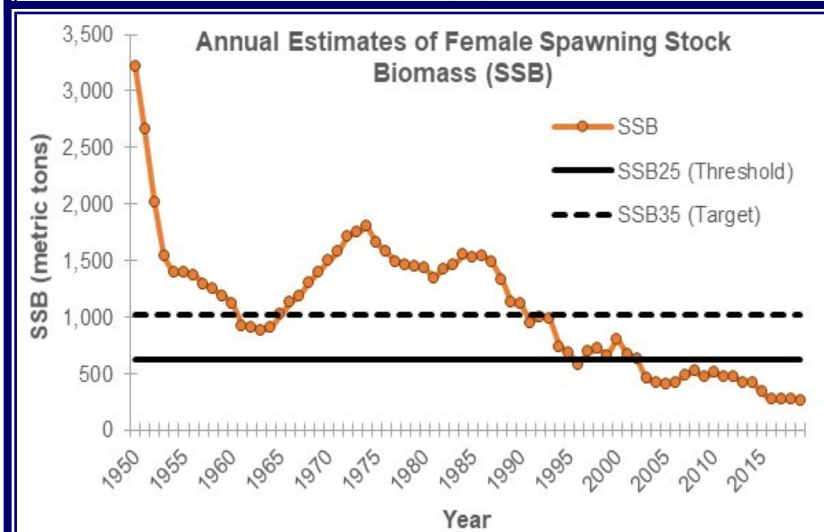
## Status of the Stock

The 2022 stock assessment indicates overfishing is occurring in the striped mullet fisheries and the North Carolina striped mullet stock is overfished.

Stock status is based on the 2019 fishing mortality (*F*) and spawning stock biomass (SSB). Both exceeded the reference points established in the Striped Mullet FMP Amendment 1.

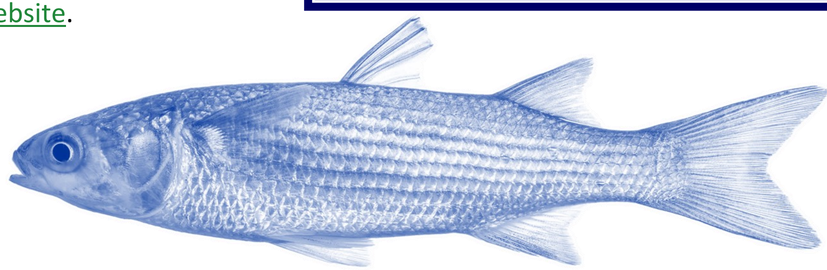
The North Carolina Fishery Reform Act of 1997 requires management end overfishing and achieve a sustainable harvest. To reach these goals within the 10-year time period, conservative management measures require a 20—33% reduction in total removals from 2019 landings.




## Stock Assessment Report and Fishery Management Plan

The complete 2022 Stock Assessment of Striped Mullet is available on the [DMF website](#).



***Striped Mullet Questions?***
***Contact lead biologists***


Daniel Zapf
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252-948-6481

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252-808-8193

# AMENDMENT 2

## Statutorily Required Management Strategy: Sustainable Harvest

### Background

The Fisheries Reform Act requires implementing management to end overfishing in two years and rebuild the spawning stock biomass to a level of sustainable harvest in 10 years upon adoption of the plan. Projections based on the stock assessment indicate a conservative 20-33% reduction in total removals is needed to end overfishing and rebuild the spawning stock of striped mullet to a sustainable level. If reductions only come from the commercial sector a 35.4% reduction is needed. The division asks for public input about how the striped mullet resource is used by stakeholders and considerations to account for in the fishery when making management decisions. Possible management measures to achieve sustainable harvest include:

- Quota management
- Fishing seasons
- Trip limits
- Size limits (minimum, maximum, or slot limits)
- Specific fishing days (weekday vs. weekend)
- Gear modifications
- Area closures

Picture by Nolen Vinay

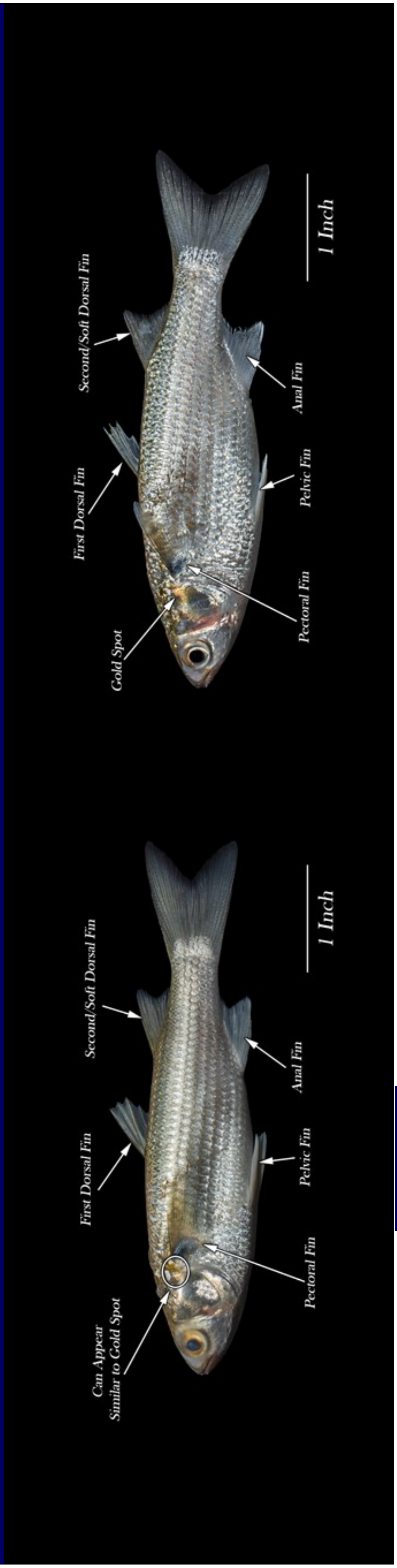
## STAKEHOLDER INPUT

Answers to these questions are an important part of plan development and a valuable part of our process.


- Why do you fish for striped mullet (roe, bait, meat, or other)?
- What size striped mullet do you target?
- How often do you fish for striped mullet?
- What time of year is most important to have access to striped mullet?
- What area do you fish for striped mullet?
- What ideas do you have to end overfishing and rebuild the striped mullet stock?
- Should management measures be considered statewide or regionally?
- Should management be considered to protect migrating striped mullet?
- Should roe, bait, and food fish be managed separately?

White Mullet

Striped Mullet




# Additional Management Strategies: Recreational Fishery

## Background

Under Amendment 1, recreational harvest of striped mullet is limited to 200 mullet (white and striped combined) per person per day. Since July 2006, striped mullet has been exempt from the mutilated finfish rule, allowing it to be used as cut bait.

Striped mullet recreational harvest estimates in North Carolina are highly uncertain with proportional standard error (PSE) exceeding 50% in most years. This means the fishers sampled may or may not represent the fishery and harvest may be much more or less than estimated. Uncertainty may be due to limited bait samples since most recreational harvest of striped mullet is for live or cut bait in other fisheries. Recent limitations on fishing seasons of target species, like southern flounder, have likely decreased demand for striped mullet as live bait. However, there are many other fisheries which use striped mullet as bait.

Further characterization of the recreational mullet fishery is needed to understand stakeholder use.

Even though recreational estimates are uncertain, non-quantifiable management measures restricting recreational harvest of striped mullet may be necessary. The division is interested in public input about how the striped mullet resource is used by recreational stakeholders and what the most important aspects of the fishery are when making management decisions.

## STAKEHOLDER INPUT

Answers to these questions are an important part of plan development and a valuable part of our process.

- What gear do you use to catch mullet?
- How many mullet do you typically catch and keep in a trip?
- What size mullet do you prefer?
- Do you purchase mullet for bait?
- Could other species be used for bait instead of mullet?
- What species do you target when using mullet as bait?
- What seasons do you use mullet as bait?

# Additional Management Strategies: Small Mesh Gill Net

## Background

Gill nets are one of the most controversial fishing gears used in North Carolina waters. Although gill net fishing effort has decreased significantly over the last two decades, this gear continues to be the subject of debate and opinion concerning the impact on our fisheries. At the direction of the MFC, in 2021 the DMF drafted an **issue paper** reviewing rules and available data for the small mesh gill net fishery and developed potential options for rulemaking. The issue paper characterized the estuarine small mesh gill net fisheries in North Carolina and included options aimed at simplifying small mesh gill net regulations, reducing bycatch, and reducing conflict between stakeholders.

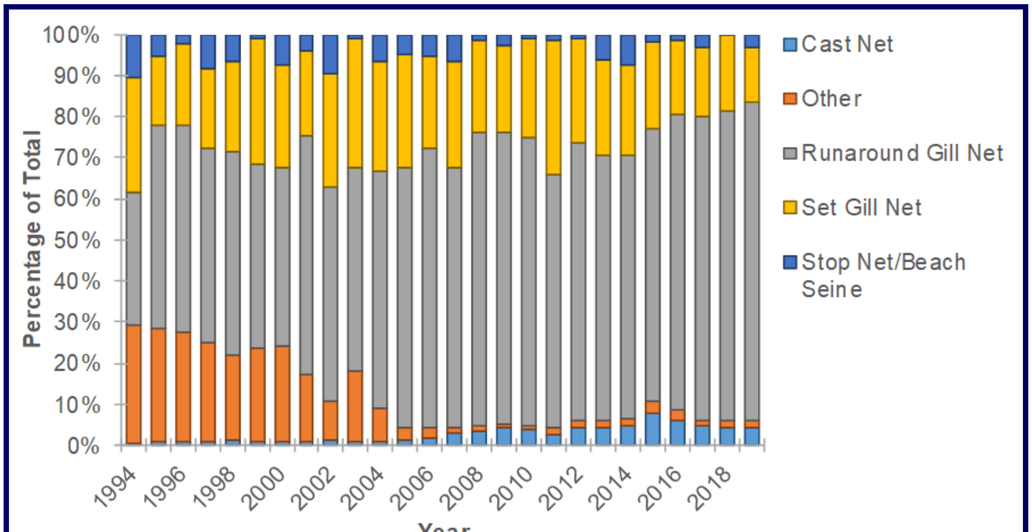
At its August 2021 business meeting, the MFC passed a motion to not initiate rulemaking on small mesh gill nets but refer the issue through the FMP process for each species, and any issues or rules coming out of the species-specific FMP to be addressed at that time.

Small mesh gill nets are the predominant gear used to harvest striped mullet in North Carolina. Most striped mullet are harvested commercially using runaround or other actively fished gill nets. Because there are no direct regulations limiting the commercial harvest of striped mullet, commercial discards are currently not an issue. Typically all striped mullet caught in commercial operations are landed and sold. However, if regulations are implemented to recover the stock, it may be necessary to address discards. The division is interested in public input about modifications that could be made to small mesh gill net regulations to address regulatory complexity, bycatch reduction, and reduction of conflict between stakeholders.

STAKEHOLDER INPUT

Answers to these questions are an important part of plan development and a valuable part of our process.

- What modifications would you make to your fishing operation to catch less striped mullet in your gill net?
- Do you actively fish your nets more frequently when attendance requirements are in place?
- Do you set nets when attendance is mandatory? How do attendance requirements affect your fishing operation?
- What are the major causes of conflict between small mesh gill netters and other stakeholders?
- How would a minimum mesh size affect you? Why do you use your preferred mesh size?
- How would a yardage limit effect you? Why do you use your preferred yardage?
- How does fishing area effect the choices in gill net mesh size and yardage?




Percentage of North Carolina's commercial striped mullet landings from major gear types,

# Additional Management Strategies: Stop Net Fishery

## Background

Stop nets and seines were the dominant gears in the early years of the fishery up to 1978, accounting for upwards of 70% of the commercial landings. Due to the schooling nature of striped mullet, the beach seine fishery has the potential to be and historically has been a high volume fishery, landing thousands of pounds in a single trip.

### STAKEHOLDER INPUT

Answers to these questions are an important part of plan development and a valuable part of our process.

- Has management reduced conflict between users of different gear types (e.g. gill net and stop net users)?

# Additional Management Strategies: Migration Corridor

## Background

Striped mullet undergo annual spawning migrations in the fall from estuarine waters to the ocean. Large schools of striped mullet form, making them easy to target and harvest in large quantities. Designation of seasonal or permanent migration corridors limiting harvest or fishing gears could be used to provide additional protection to the spawning stock.

### STAKEHOLDER INPUT

Answers to these questions are an important part of plan development and a valuable part of our process.

- Would designation of migration corridors alter the way you fish?
- Is it important to have access to striped mullet in all areas at all times of year?
- Are there areas or times when fishing for striped mullet should not be allowed?


### Other Management

Are there other relevant strategies that should be considered for Amendment 2? The division wants to hear from stakeholders on their ideas.

Management strategies considered in Amendment 2 are dependent on statutory requirements, available data, research needs, and the effectiveness of the solution.