North Carolina Marine Fisheries Commission

FISHERY MANAGEMENT PLANS

FMP Update Memo

N.C. FMP for Interjurisdictional Fisheries

Striped Mullet Stock Assessment Report

Amendment 2 to the Estuarine Striped Bass FMP

Amendment 3 to the Southern Flounder FMP

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April 29, 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

Issue

Update the N.C. Marine Fisheries Commission (MFC) on the status of North Carolina Fishery Management Plans (FMPs).

Action Needed

At its May 2022 business meeting, the MFC is scheduled to **vote on approval of the 2022 FMP for Interjurisdictional Fisheries Information Update**.

Overview

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

Spotted Seatrout FMP

A benchmark stock assessment for spotted seatrout is underway coinciding with the scheduled Spotted Seatrout FMP review. The prior stock assessment from 2014 indicated the stock is not overfished and is not experiencing overfishing. The benchmark stock assessment will be completed in 2022.

Striped Mullet FMP

A benchmark stock assessment for striped mullet has been completed as the initial step to the scheduled review of the Striped Mullet FMP. The stock assessment, through terminal year 2019, indicates the stock is undergoing overfishing and is overfished. An external, peer review panel concluded this stock assessment to be the best scientific information available and suitable for management advice. At the May 2022 business meeting, division staff will present the MFC with an overview of the 2022 Striped Mullet Stock Assessment. The division will hold a scoping period for Amendment 2 to the Striped Mullet FMP later this year, soliciting public input to inform the plan. Results of the scoping period, the draft Goal and Objectives of Amendment 2, and a request for additional management strategies to be considered will be brought before the MFC following the scoping period.

Estuarine Striped Bass FMP

At the February 2022 business meeting, the MFC voted to send draft Amendment 2 for review by the public and MFC Advisory Committees. The division held a public comment period from March 4 to April 1, including a public listening session and Northern, Southern, and Finfish Advisory Committee meetings. Input from the public and recommendations from the Division and Advisory Committees were added to the draft plan. At the May 2022 business meeting, staff will present an overview of public comment and recommendations and the MFC will select preferred management for the Estuarine Striped Bass FMP Amendment 2. Once MFC preferred management is selected, the plan will be sent to the DEQ Secretary and appropriate legislative committees for 30-day reviews.

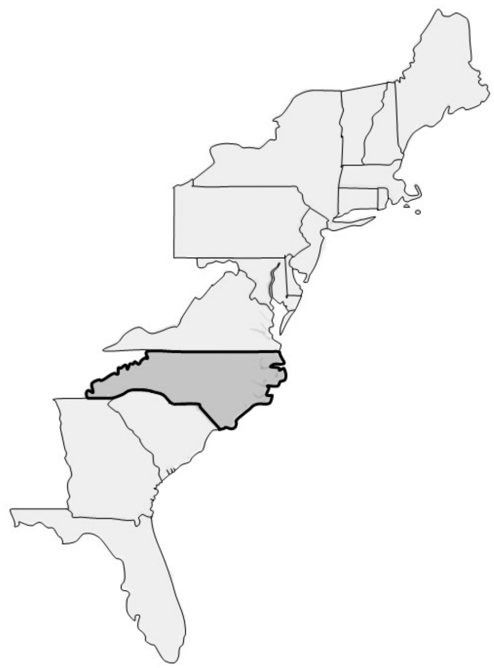
Southern Flounder FMP

At the February 2022 business meeting, the MFC selected preferred management for Amendment 3 to the Southern Flounder FMP. The plan was updated to include the preferred management and sent to the DEQ Secretary for disbursement to legislative bodies for review. At the May 2022 business meeting, the MFC will vote on final approval of the Southern Flounder FMP Amendment 3.

FMP for Interjurisdictional Fisheries

At the November 2021 business meeting, the MFC approved the Goal and Objectives of Amendment 2 of the NC FMP for Interjurisdictional Fisheries. This unique state FMP adopts, by reference, management measures appropriate for North Carolina contained in finfish FMPs approved by the federal Councils or the Atlantic States Marine Fisheries Commission (ASMFC) as minimum standard. Division staff developed draft Amendment 2, which included management options for plan retirement, and held a workshop in December 2021 with the Finfish Advisory Committee serving as the FMP Advisory Committee. Following these meeting and based on the feedback received, the Division determined that further consideration is warranted before plan retirement is considered. At the May 2022 business meeting, the MFC will vote on approval of the 2022 FMP for Interjurisdictional Fisheries Information Update to satisfy the periodic review of the plan.

NORTH CAROLINA
FISHERY MANAGEMENT PLAN
FOR INTERJURISDICTIONAL FISHERIES
2022 INFORMATION UPDATE



By

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

ACKNOWLEDGEMENTS

The N.C. Fishery Management Plan (FMP) for Interjurisdictional Fisheries 2022 Information Update was developed by the N.C. Department of Environmental Quality (DEQ) Division of Marine Fisheries (NCDMF) under the direction of the N.C. Marine Fisheries Commission (NCMFC) with advice from the FMP Advisory Committee (AC), which the Finfish AC was appointed), and the NCDMF Plan Development Team (PDT), all who contributed their time and knowledge to this document.

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The following division staff were also invaluable in assisting with the development of this document: Kathy Rawls and Catherine Blum. Also, we are grateful for the administrative support from Dana Gillikin, Deborah Manley, Jennifer Lewis, Jesse Bissette, and Patricia Smith.

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EXECUTIVE SUMMARY

The original N.C. Fisheries Management Plan (FMP or Plan) for Interjurisdictional Fisheries was approved in September 2002, amended in 2008, and updated in 2015. The Plan adopts management measures consistent with N.C. law, within approved FMPs by the Atlantic States Marine Fisheries Commission (ASMFC) and the South Atlantic and Mid-Atlantic fishery management councils (SAFMC and MAFMC, respectively) by reference as the minimum standard. The goal of these plans, established under the Magnuson-Stevens Fishery Conservation and Management Act (MSA; federal Councils FMPs) and the Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA; ASMFC FMPs), are similar to the goals of North Carolina's Fisheries Reform Act of 1997 (FRA) to "ensure long-term viability" of these fisheries.

Amendment 1 to the N.C. FMP for Interjurisdictional Fisheries was adopted by the North Carolina Marine Fisheries Commission (NCMFC) in June 2008. The amendment did not change the goal and objectives of the plan; however, it included a management strategy, with associated rule changes, to streamline and consolidate the use of proclamation authority by the North Carolina Division of Marine Fisheries (NCDMF) Director to implement management measures to comply with or complement ASMFC and Council FMPs. The amendment also included appendices containing information on applicable federal statutes, species management summaries, and management measures implemented for consistency with ASMFC and Council FMPs.

This document is an information update to the N.C. FMP for Interjurisdictional Fisheries. This update modifies the objectives of the plan by combining several previous objectives to make them more focused and concise; with approval by the NCMFC. This update does not provide new management strategies. An information update is a statutorily required review of an FMP at least once every five years that determines the management measures contained in an FMP comply with the requirements of N.C. General Statute (N.C.G.S.) §113-182.1 for ensuring the long-term viability of the state's commercially and recreationally significant species or fisheries. An information update incorporates changes in factual and background data since the last review of the plan and does not alter management strategies or management measures or introduce and address new management issues not previously included in the FMP. An information update refreshes the FMP with the most current statistics, trends, research, etc. available at the time the information update is developed.

This FMP is the policy instrument that allows management measures contained in approved FMPs developed through the ASMFC and Council processes to be implemented in the state waters of North Carolina. The purpose of the Plan is for the State to maintain compliance or compatibility with approved ASMFC and Council FMPs; to reduce duplication of effort between State, ASMFC, and Council FMPs; define the roles and powers of the NCMFC and NCDMF in those processes; and foster improved communication between the NCMFC, its advisory committees, and the ASMFC and Councils.

BACKGROUND

The original N.C. Fisheries Management Plan (FMP or Plan) for Interjurisdictional Fisheries was approved in September 2002, amended in 2008, and updated in 2015. The Plan adopts management measures consistent with N.C. law, within approved FMPs by the Atlantic States Marine Fisheries Commission (ASMFC) and the South Atlantic and Mid-Atlantic fishery management councils (SAFMC and MAFMC, respectively) by reference as the minimum standard. The purpose of the Plan is for the State to maintain compliance or compatibility with approved ASMFC and Council FMPs; to reduce duplication of effort between State, ASMFC, and Council FMPs; define the roles and powers of the North Carolina Marine Fisheries Commission (NCMFC) and North Carolina Division of Marine Fisheries (NCDMF) in those processes; and foster improved communication between the NCMFC, its advisory committees, and the ASMFC and Councils.

The N.C. Fisheries Reform Act of 1997 (FRA), and subsequent revisions, requires the Department of Environmental Quality (DEQ) to prepare FMPs for adoption by the NCMFC for all commercially or recreationally significant species or fisheries that make up North Carolina's marine or estuarine resources. State FMPs are developed and drafted by the NCDMF on behalf of the DEQ. For many interjurisdictional (migratory) species of commercial or recreational significance to North Carolina, FMPs have been developed and implemented by the compact of states under the ASMFC or under FMPs developed by the federal Councils. The goal of these plans, established under the Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA; ASMFC FMPs) and the Magnuson-Stevens Fishery Conservation and Management Act (MSA; federal Councils FMPs), are similar to the goals of the FRA to "ensure long-term viability" of these fisheries. For the purposes of this plan, managing for sustainable harvest as defined in the FRA is synonymous to targets defined in each of the ASMFC and Council FMPs.

N.C. General Statutes (N.C.G.S.) acknowledge overlapping authority and define the hierarchy of authority between the State, ASMFC, SAFMC, and MAFMC. Management measures established by the NCMFC must be consistent for fisheries where the ASMFC and Councils have primary jurisdiction. N.C.G.S. §113-182 clarifies that regulation of fish and fisheries in the Atlantic Ocean out to the limit of the federal Exclusive Economic Zone (EEZ) should be consistent with the MSA. Additionally, Article 19 of Chapter 113 of the N.C. General Statutes (N.C.G.S. §113-251 through 113-258) fully incorporates the ASMFC compact. ASMFC and Council FMPs adopted by the NCMFC through the N.C. FMP for Interjurisdictional Fisheries are held to all standards established in N.C.G.S. §113-182.1 and associated policies.

This FMP is the policy instrument that allows management measures contained in approved FMPs developed through the ASMFC and Council processes to be implemented in the state waters of North Carolina. All FMPs and amendments are maintained electronically on the NCDMF, ASMFC, SAFMC, or MAFMC websites.

MANAGEMENT AUTHORITY

Fisheries management along the United States East Coast has overlapping authorities (Figure 1). The ASMFC consists of 15 states from Maine through the east coast of Florida and is governed by the ACFCMA. The ASMFC adopts plans for interjurisdictional species with fisheries that occur primarily in state waters, 0-3 nautical miles offshore. However, there are species and species groups jointly managed between the ASMFC and the Councils. Under the MSA, the Councils manage fisheries that occur primarily in federal waters from 3-200 nautical miles offshore; the SAFMC manages from North Carolina through the east coast of Florida and the MAFMC manages from New York through Virginia. Although the SAFMC has primary management authority over federal waters off the coast of North Carolina, North Carolina is an active, voting member on the ASMFC, SAFMC, and MAFMC. In addition, the management unit for a Council-managed FMP can extend beyond the Council's range based on stock distribution. The NCMFC authority for management includes the state internal estuarine and ocean waters offshore to 3 nautical miles.

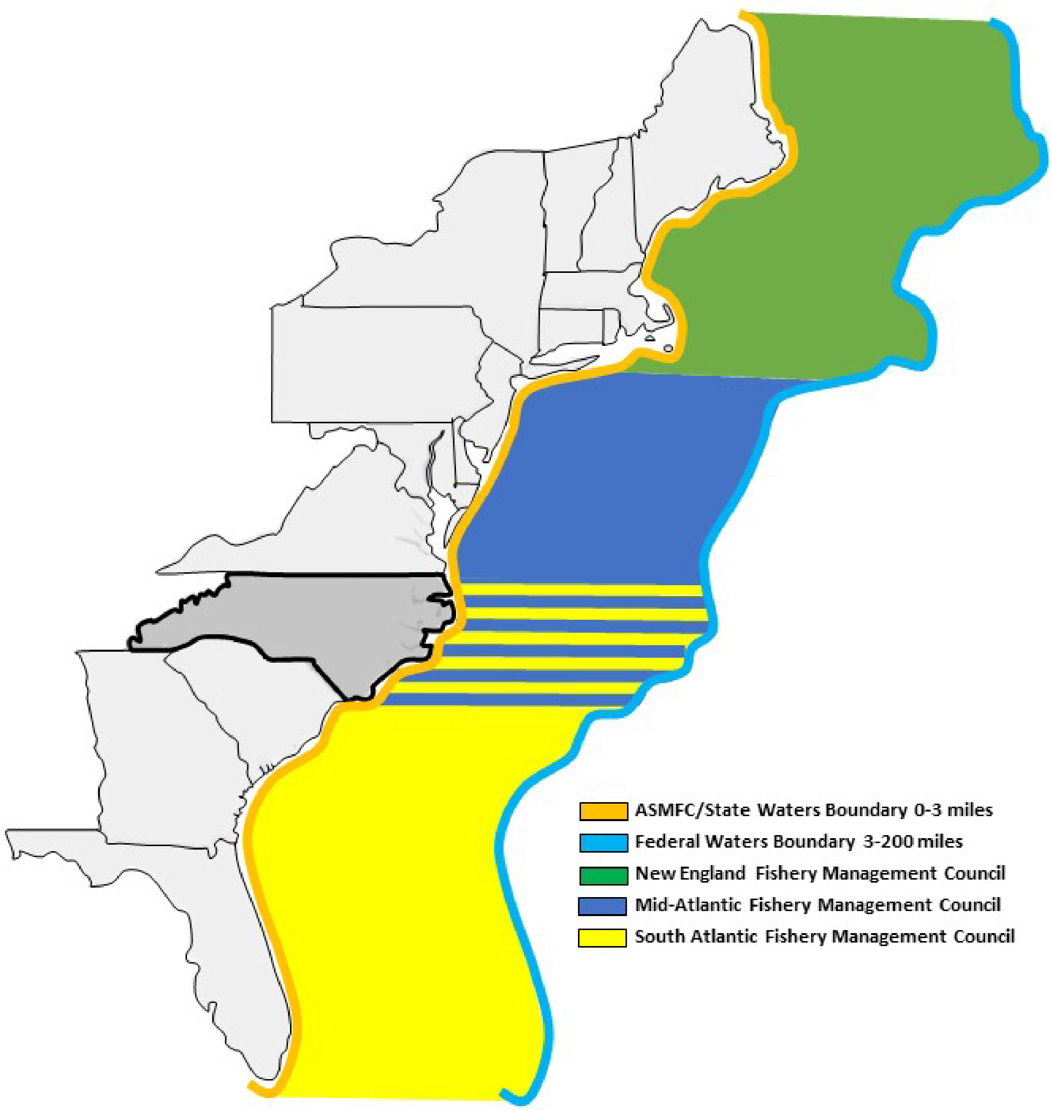

Figure 1. Management authorities of state (0-3 nautical miles) and federal (3-200 nautical miles) waters of the United States East Coast

The ACFCMA and the MSA grant the authority for management of coastal, interjurisdictional fisheries to the ASMFC and the Councils. These acts provide standards for the preparation and implementation of FMPs that will achieve and maintain sustainable harvest in coastal fisheries. These acts also serve to protect the interest of each participating state in the various stocks that are managed.

Participation by the State is critical to ensure N.C. fisheries resources are represented, considered, and adequately protected. Through NCDMF staff, state ASMFC and Council members, and citizen advisors, North Carolina participates fully in the development of interjurisdictional FMPs that impact N.C. commercial and recreational fisheries. This includes North Carolina citizens representing State interests by voting on fishery management plans, strategies, and measures. All committee and advisory panel meetings and most board meetings are public, and anyone can attend. Many include a public comment period where those in attendance can comment directly on the meeting agenda items. Additionally, the ASMFC, SAFMC, and MAFMC all have websites dedicated to public input.

Several N.C. General Statutes deal with the adoption of federal regulations developed under the authority of the ASMFC or adopted through federal Councils by the Secretary of Commerce. N.C.G.S. §150B-21.6 states "an agency may incorporate the following material by reference in a rule without repeating the text of the referenced material: . . . (2) All or part of a code, standard, or regulation adopted by another agency, the federal government, or a generally recognized organization or association." N.C.G.S. §113-228 states that the NCMFC "in its discretion may by reference in its rules adopt relevant provisions of federal laws and regulations as State rules." Additionally, this statute provides for the NCMFC to be "exempt from any conflicting limitations in G.S. 150B-21.6 so that it may provide for automatic incorporation by reference into its rules of future changes within any particular set of federal laws or regulations relating to some subject clearly within the jurisdiction of the Department."

N.C.G.S. §143B-289.51 and N.C.G.S. §143B-289.52 provide authority for the NCMFC to advise the State regarding ocean and marine fisheries within the jurisdiction of the ASMFC and federal Councils, to manage or regulate fishing in the Atlantic Ocean, and to adopt relevant State rules for compliance or compatibility with or implementation of ASMFC or Council FMPs. Consequently, the NCDMF and NCMFC have the authority to develop an FMP that adopts ASMFC and federal Council plans by reference.

MANAGEMENT UNIT: FINFISH STOCKS MANAGED BY THE COUNCILS AND COMMISSION

The management unit for this plan comprises all finfish species managed by ASMFC and Council FMPs that are commercially or recreationally significant finfish species for North Carolina, as described in N.C.G.S. §113-182.1, or where there are overriding finfish species compliance requirements the State must adhere to in state waters, such as threatened or endangered species. Table 1 summarizes the finfish species or species groups managed under the N.C. FMP for Interjurisdictional Fisheries as of this update.

Table 1. Management Unit. Finfish species or species groups managed under the jurisdiction of the ASMFC, South and/or Mid-Atlantic fishery management councils and the NCMFC that are included in this Plan. Click on the "X" to go to the species management website.

Species or species group	Atlantic States Marine Fisheries Commission	South Atlantic Fishery Management Council	Mid-Atlantic Fishery Management Council	North Carolina Marine Fisheries Commission
American Eel	X			
Atlantic Croaker	X			
Atlantic Menhaden	X			
Atlantic Striped Bass	X			X
Atlantic Sturgeon[1]	X			
Black Drum	X			
Black Sea Bass – North of Cape Hatteras	X		X	
Bluefish	X		X	
Cobia	X			
Red Drum	X			X
River Herring	X			X
Scup – North of Cape Hatteras	X		X	
Shad	X			
Sharks	X			
Spanish Mackerel	X	X		
Spiny Dogfish	X		X	
Spot	X			
Spotted Seatrout	X			X
Summer Flounder	X		X	
Tautog	X			
Weakfish	X			
Dolphin/Wahoo		X		
King Mackerel		X		
Snapper Grouper Complex (includes Black Sea Bass – South of Cape Hatteras)[2]		X		
Monkfish			X	

[1] Listed as endangered under the ESA.
[2] Includes 55 species
Bold Species or species groups require federal permits for commercial and/or for-hire fishermen fishing in federal waters.

Finfish species may be added to or removed from ASMFC or Council FMPs between comprehensive reviews of the N.C. FMP for Interjurisdictional Fisheries. If a finfish species of importance to the State is added to an ASMFC or Council FMP, that change is automatically incorporated into the N.C. FMP for Interjurisdictional Fisheries by reference. Rule 15A NCAC 03M .0512 grants proclamation authority to comply with ASMFC or Council FMPs. If a finfish species is removed from an ASMFC or Council FMP, the authority is no longer in place to manage the species via NCMFC Rule 15A NCAC 03M .0512. Management measures must then be implemented by an existing species-specific rule, or a new rule must be adopted to manage the finfish species in State waters. Updates will be made to Table 1 as needed in the annual NCDMF FMP Review document and during future comprehensive reviews of this plan to document finfish species added or removed from the management unit covered by this FMP.

GOAL AND OBJECTIVES

The goal of the N.C. FMP for Interjurisdictional Fisheries is to adopt FMPs, consistent with N.C. law, approved by the ASMFC or Councils by reference and implement corresponding fishery regulations in North Carolina to provide compliance or compatibility with approved FMPs and amendments, now and in the future. To achieve this goal, the following objectives shall be met:

1. Participate fully, consistent with N.C. law, in all levels (advisory panels, technical committees, stock assessment subcommittees, plan development and review teams, management boards, monitoring committees, and other committees) of the ASMFC and Council processes for developing FMPs and amendments through appropriately informed NCDMF staff, NCMFC members, citizen advisors, and the public at large.
2. Adopt management measures appropriate for N.C. coastal waters to implement measures approved by the ASMFC or promulgated by the Secretary of Commerce necessary to implement FMPs and achieve the sustainable harvest for ASMFC- and Council-managed species.
3. Promote education and public information to help identify the causes and nature of problems in the fish stocks managed by the ASMFC or Councils, their habitat and fisheries, and the rationale for management efforts to solve these problems.
4. Develop and implement a management and regulatory process that provides adequate resource protection and considers the needs of all user groups.

INTERJURISDICTIONAL MANAGEMENT

Ideally, all measures to conserve the marine and estuarine resources of North Carolina would be developed and implemented solely under the State FRA FMP process. However, state and federal authorities and initiatives overlap due to the interjurisdictional nature of many species. In these cases, interstate and federal plans serve to protect not only species sustainability, but also serve to balance access to the resource amongst competing states. This FMP describes the overlap and hierarchy of authority defined in N.C.G.S. to implement management of interjurisdictional species among federal, interstate, and state management authorities.

ATLANTIC STATES MARINE FISHERIES COMMISSION AND THE ATLANTIC COASTAL FISHERIES COOPERATIVE MANAGEMENT ACT

The ASMFC is an interstate compact ratified in 1942 to manage shared migratory fisheries resources from Maine to Florida. The ASMFC mission is “to promote the better utilization of the fisheries, marine, shell and diadromous, of the Atlantic seaboard through the development of cohesive fishery management plans along the Atlantic coast, rather than disparate state-specific plans for the same species." The Commission's Interstate Fisheries Management Program (ISFMP) began in 1981. The goal of the program is to promote cooperative management through interstate FMPs.

The ISFMP operates under the direction of the ISFMP Policy Board and the species management boards. The ISFMP Policy Board is composed of one representative from each member state, the District of Columbia, the Potomac River Fisheries Commission, National Oceanic and Atmospheric Administration (NOAA) Fisheries, and United States Fish and Wildlife Service (USFWS). The Policy Board provides overall guidance and ensures consistency with the ISFMP Charter and between FMPs. The species management boards consider and approve the development and implementation of FMPs, including the integration of scientific information and proposed management measures. In this process, the species management boards primarily rely on input from five main sources – species technical committees, plan development teams, plan review teams, the Law Enforcement Committee, and species advisory panels. North Carolina and the NCDMF have staff and citizens who serve as members of ASMFC management boards, various committees and teams, and advisory panels. The NCDMF Director, along with legislative and gubernatorial appointees, are the voting members on the ASMFC, with NCDMF staff and citizen advisors representing the scientific, environmental, commercial, and recreational interests of North Carolina. Table 2 outlines the number of positions which North Carolina participates.

Table 2. Number of North Carolina participants per ASMFC, SAFMC, and MAFMC.

	Boards/ Councils	Liaisons	Technical Committees	Committees/ Workgroups	Advisory Panels
ASMFC	3		20	13	14
SAFMC	3	4		40	68
MAFMC	3	1		23	19

In 1993, Congress enacted the ACFCMA which mandates all Atlantic states implement coastal FMPs (for fisheries within three nautical miles from shore) adopted by the ASMFC to safeguard the future of Atlantic coastal fisheries in the best interest of both the fishermen and the nation. The ACFCMA expanded and altered the powers and purposes of the ASMFC. The ASMFC was required by Congress to establish and implement fisheries management for migratory fish stocks along the Atlantic coast that had historically been state controlled. In so doing, the ASMFC exercises the sovereignty of the United States, rather than the collective power of the compact states. The ACFCMA also expanded the ASMFC jurisdiction to include conservation of the marine environment to assure the availability of coastal fisheries resources on a long-term basis.

FEDERAL REGIONAL FISHERY MANAGEMENT COUNCILS AND THE MAGNUSON-STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT

The 2006 reauthorization of the MSA maintains the establishment of the federal Councils to "exercise sound judgment in the stewardship of fishery resources through the preparation, monitoring, and revision of Fishery Management Plans which enables the States, the fishing industry, consumer and environmental organizations, and other interested persons to participate in, and advise on, the establishment and administration of such plans and which take into account the social and economic needs of the States." Jurisdiction of the Councils is for all fish within the

EEZ and fishery management authority beyond the EEZ over anadromous species and Continental Shelf fishery resources. The MSA calls for FMPs to set catch levels to prevent overfishing, based on scientific advice, by 2010 for stocks subject to overfishing. The Councils shall "establish a mechanism for specifying annual catch limits in the plan (including a multiyear plan), implementing regulations, or annual specifications, at a level such that overfishing does not occur in the fishery, including measures to ensure accountability". Management measures must be prepared and implemented to end overfishing immediately within two years of notification. In 2013, Congress began the process of reauthorization of the existing MSA, which continues at the time of this writing.

The Councils are comprised of the state Division Director, or their designee, and obligatory and at-large positions appointed by the U.S. Secretary of Commerce. Like the ASMFC, the Councils appoint citizen advisors from states that have an interest in the specific fishery, to serve on advisory panels to assist in the development of FMPs. Due to its geographic position as a transition zone between northern and southern fish populations, North Carolina is a member of both the Mid-Atlantic and South Atlantic fishery management councils.

PROTECTED RESOURCES LAWS

N.C.G.S. §113-189 ensures the protection of migratory birds, marine mammals, sea turtles, and finfish by referencing the Migratory Bird Treaty Act of 1918 (MBTA), the Marine Mammal Protection Act of 1972 (MMPA), and the Endangered Species Act of 1973 (ESA). The N.C. FMP for Interjurisdictional Fisheries references ASMFC and Council FMPs to comply with these federal requirements. The MBTA, MMPA, and ESA take precedence when considering FMP management.

The MBTA was established by Congress in 1918. This Act implements four international conservation treaties which the United States entered with Canada in 1916, Mexico in 1936, Japan in 1972, and Russia in 1976. The intent is to ensure sustainability of all protected migratory bird species. The MBTA prohibits the take of protected migratory bird species without authorization by the Department of the Interior USFWS. In 2004, the MBTA was amended to clarify that it only applies to migratory species native to the United States or its territories. The Service publishes a list of all nonnative, human-introduced bird species to which the MBTA does not apply.

The MMPA was established by Congress in December 1972. NOAA Fisheries is responsible for protecting whales, dolphins, porpoises, seals, and sea lions. The USFWS protects walrus, manatees, sea otters, and polar bears. The primary objectives of the MMPA are to conserve and recover marine mammal species. The MMPA prohibits marine mammals from being harassed, fed, hunted, captured, or killed, or the attempt to do so. The Marine Mammal Commission provides the science-based oversight of United States and foreign policies and federal agency actions addressing human impacts on marine mammals and their ecosystems. NOAA Fisheries, under a Memoranda of Agreement with other agencies, issues regulations, national policies, and guidance to promote efficiency and consistency in implementing the MMPA. All marine mammals are protected under the MMPA, but some are also protected under the ESA.

The ESA was enacted by Congress in 1973 "to provide a means whereby the ecosystems upon which endangered and threatened species depend may be conserved, (and) to provide a program for the conservation of such endangered species and threatened species." The ESA is a comprehensive act that covers many aspects of endangered species protection and management. The USFWS and the NOAA Fisheries Office of Protected Resources (OPR) share responsibility for implementing the provisions of the ESA. A species is considered "endangered" if it is in danger of extinction throughout all or a significant part of its range, and "threatened" if it is likely to become an endangered species within the foreseeable future.

The ESA prohibits the "take" of any listed species, which is defined as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct." Exceptions are provided for in Sections 6, 7, and 10 of the ESA through permits specific to certain activities. Section 6 allows for cooperative agreements with States actively engaged in research and monitoring that directly benefits the conservation of listed species, Section 7 relates to interagency cooperation amongst federal agencies, while Section 10 allows for takes that are incidental to otherwise lawful activities, such as fishing.

There are two primary provisions to Section 7: 1) federal agencies shall further the goals of the ESA; and 2) federal agencies must consult with NOAA Fisheries or USFWS to ensure actions funded, authorized, or carried out will not jeopardize listed species or result in critical habitat alterations. Although this section relates to federal agencies, state projects can be impacted. Projects with federal authorization or funding are subject to Section 7 consultation. NCDMF has received biological opinions regarding Section 7 consultations on several grants which data is used for state, ASMFC, and federal FMPs.

Section 10 permits are an important tool, as they allow for a fishery to continue (under constraints and conditions) that would otherwise have to shut down. NCDMF has worked with NOAA Fisheries OPR in the development of Section 10 permits for inshore gill net and shrimp trawl fisheries. The permits have allowed for alternate management measures for the fisheries under an approved conservation plan designed to minimize impacts to endangered and threatened species.

The N.C. FMP for Interjurisdictional Fisheries must ensure that no inconsistencies in management strategies exist regarding the MBTA, MMPA, and ESA requirements for species managed under this FMP or species-specific N.C. FMPs. FMPs need to minimize activities that jeopardize the continued existence of an endangered or threatened species or result in the destruction or adverse modification of critical habitat. Protected resources requirements take precedence over any FMP management considerations.

ASMFC AND COUNCILS FMP DEVELOPMENT

The process for developing FMPs is similar at the ASMFC and Council levels, and in North Carolina as set by the FRA. The development of an FMP or amendment begins with a scoping process. This is the stage when issues are identified by the ASMFC or Councils with input from the public through public hearings. A public hearing document is produced by the plan development teams of the ASMFC or Councils. It contains management options aimed at rebuilding an overfished fishery or maintaining a sustainable fishery. After the scoping process, issues are discussed and included for additional analysis or rejected from further consideration. Proposed actions are reviewed by technical scientific committees to determine which alternatives achieve the conservation goals of the FMP.

A draft FMP or amendment is then developed by a species management board or Council committee and plan development team. Draft plans are taken out for public hearings (FMP development). Citizen advisory panels provide input during the scoping phase as well as prior to final action being taken. For ASMFC FMPs, public hearings may be held in the states that declare an interest in the fishery as well as online. For Council FMPs, public hearings are usually held in each representative state and/or online. At this point in the process, formal public comment is taken from individuals and organizations with an interest in the FMP. The ASMFC or Council reviews public comments and selects preferred alternatives. For FMPs developed by the ASMFC, final species management board approval is followed by final approval by the full Commission and enacted with no further comments accepted. Management measures contained in FMPs approved by the full ASMFC go to the individual states for implementation through each State's administrative process. Council-approved FMPs must be subsequently reviewed by NOAA Fisheries to ensure all MSA standards and other Federal acts are satisfied, published in the Federal Register for a public comment period as required under the National Environmental Policy Act (NEPA) and approved by the Secretary of Commerce. For FMPs developed by the Councils, comments are accepted again after the proposed rule to implement management changes is published by the Secretary of Commerce, and the agency is required to respond to all comments received before the rule is effective.

An abbreviated process for implementing a defined set of management changes that does not require scoping is available for both the ASMFC and Councils. For ASMFC FMPs, a defined set of management changes and abbreviated process are outlined in each FMP's "adaptive management" section, and the public instrument used to describe the changes under consideration is called an "addendum." Similarly, for Council FMPs, both the management changes and abbreviated process are outlined in each FMP's "framework procedure," and the public instrument used to describe the changes under consideration is called a "framework amendment" or "regulatory amendment." For both ASMFC and Council FMPs, the suite of management changes allowed under this abbreviated process usually includes such items as size limits, recreational bag limits, commercial trip limits, closed seasons and quotas. For ASMFC FMPs, an addendum is noticed for a 30-day public comment period, and states may request a public hearing be conducted in their jurisdictions or online during that timeframe. For Council FMPs, a 30-day comment period on the proposed rule to implement management changes is noticed; unlike the full amendment process, there is no accompanying comment period on the amendment document itself. However, Councils will accept public comment on a regulatory amendment as part of their normal public comment process during and between Council meetings.

Finally, as part of the ISFMP under the ASMFC process, states and jurisdictions are allowed to implement management measures more restrictive than those required for compliance with an interstate FMP but may not be less restrictive than the minimum standards.

COORDINATION OF FMP DEVELOPMENT WITH THE N.C. MARINE FISHERIES COMMISSION

Numerous individuals from member states are involved in the development of interjurisdictional FMPs; however, there is a need for specific roles to be identified for the NCDMF and the NCMFC to ensure that both are well-informed on the issues surrounding the development and approval of these ASMFC and federal plans.

In order to facilitate information exchange, the NCMFC is informed at their quarterly business meetings of ASMFC and federal Councils' activities. Copies of scoping documents, ASMFC or Council meeting summary memoranda, annual compliance reports, implementation plans, Public Information Brochures (PIBs), and all other pertinent documents are made available. The NCDMF NCMFC Liaison office staff is responsible for circulating documents to the NCMFC.

The NCMFC may refer any of these materials to its advisory committees for review. The NCMFC may also recommend additional alternatives appropriate for committee review and feedback. The NCDMF submits comments from the NCMFC to the appropriate management agency as part of the public input process. The NCDMF NCMFC Liaison office staff provides resulting documents, notices of hearings, notices of final actions, and proposed rules to the NCMFC for review. Also, the NCDMF Public Information Officer forwards announcements regarding relevant ASMFC and Council issues to stakeholders via email distribution lists.

IMPLEMENTATION OF COMMISSION AND COUNCIL FMPS

Federal law requires the conservation management actions approved through an ASMFC or Council FMP be implemented by the State of North Carolina. Both the ACFCMA and the MSA contain measures that may be taken by the federal government should actions be taken, or fail to be taken, that will substantially and adversely affect the carrying out of such FMPs. Through the N.C. FMP for Interjurisdictional Fisheries, the NCMFC adopts management measures appropriate for North Carolina as the minimum standards for the management unit, species, or species group. This includes compliance requirements of ASMFC plans. As an example, the ASMFC Black Drum FMP required all states with a declared interest in the species to establish a maximum possession limit and minimum size limit of at least 12 inches by January 1, 2014, and to increase the minimum size limit to no less than 14 inches by January 1, 2016.

If necessary, prior to NCMFC action, the NCDMF Director may implement any approved management measure by proclamation as authorized by NCMFC Rule 15A NCAC 03M .0512. Per N.C.G.S. §113-221.1, there are three required elements that establish proclamation authority. The NCMFC must authorize the NCDMF Director the ability to issue a proclamation, there must be a particular rule in place, and the rule must be affected by a variable condition. If ASMFC- or Council-managed species continue to be subject to variable conditions, it will continue to be managed via proclamation authority to keep pace with the changes; this has been in practice with the N.C. FMP for Interjurisdictional Fisheries since the 2008 Amendment. Should conditions become stable, the NCMFC may consider rulemaking.

The N.C. FMP for Interjurisdictional Fisheries does not restrict the State of North Carolina or the NCMFC from implementing additional measures deemed appropriate by the best available information and in the best interest of the fisheries resources of North Carolina. The four species in Table 1 that also have N.C.-specific FMPs illustrate this point. The State FMP process provides N.C. citizens consideration of the stock condition, enhanced public involvement, and direct authority of the NCMFC to implement management strategies. Also, N.C.G.S. §150B-19.1 sets forth the principles of rulemaking to require that FMP rules, when appropriate, "shall be based on sound, reasonably available scientific, technical, economic, and other relevant information" and does not place an undue burden upon those persons or entities who must comply with the management action. The following brief overview of the four species with dual N.C. FMPs describes the specific conditions that prompted development of each individual N.C. FMP.

STRIPED BASS

Atlantic striped bass abundance from North Carolina to Maine declined dramatically in the late 1970s. Because of the historical importance of striped bass to both the commercial and recreational sectors throughout the entire region, as well as the interjurisdictional migratory behavior of striped bass, the U.S. Congress passed the Atlantic Striped Bass Conservation Act – P.L. 98-613 on October 31, 1984. The historical act established a unique state-based, federally backed management scheme; however, it only applied to Atlantic Ocean migratory stocks, not the N.C. riverine native stocks.

The NCMFC and the N.C. Wildlife Resources Commission (NCWRC) in cooperation with USFWS implemented a Memorandum of Agreement in 1990 to address management of striped bass in the Albemarle Sound and Roanoke River (covered by the Atlantic Striped Bass Conservation Act). The original Estuarine Striped Bass FMP was approved by the NCMFC in 1994 and aimed to continue recovery of the Albemarle/Roanoke stock, which at the time was at historically low levels of abundance and was experiencing chronic spawning failures. For the first time, this comprehensive plan addressed the management of all estuarine stocks of striped bass in the State. The plan also satisfied the recommendation contained in the 1992 U.S. Fish and Wildlife Service Report to Congress for the North Carolina Striped Bass Study that such a plan be prepared. The N.C. Estuarine Striped Bass FMP conformed to the requirements in the FRA of 1997 to fully address management for all N.C. estuarine stocks and was approved in 2004.

Atlantic Ocean migratory striped bass are managed under the ASMFC Amendment 6 to the Interstate FMP for Atlantic Striped Bass and its addenda. Under Amendment 6, the Albemarle Sound-Roanoke River (AR) stock was exempt from the size and possession limits applied to the coastal migratory stock because a more conservative fishing mortality (*F*) target is used by the state. This allowed the state to implement its own seasons, harvest caps, and size and bag limits so long as the stock remained under the *F* target. Addendum IV to Amendment 6 formally deferred management of the AR stock to the state, under the guidance of the ASMFC, since the stock was deemed to contribute minimally to the coastal migratory population. NCDMF stock assessments for the AR stock must be approved by the ASMFC's Striped Bass Management Board. Striped bass stocks in the Central Southern Management Area (CSMA) do not fall under ASMFC jurisdiction as they do not migrate to the ocean. Estuarine striped bass (AR and CSMA stocks) in

North Carolina are collectively managed under Amendment 1 to the N.C. Estuarine Striped Bass FMP, its revisions, and Supplement A. It is a joint FMP between the NCMFC and the WRC.

RIVER HERRING

The ASMFC Interstate FMP for Shad and River Herring was initially approved in 1985. The FMP included expanded biological monitoring and reporting requirements for river herring and recommended that existing management regimes be maintained or strengthened. State concern over long term reductions in landings and juvenile abundance led to seasonal closures and harvest quotas in the early 1990s and adoption of the state N.C. River Herring FMP in 2000. The State FMP was developed to comprehensively manage the fishery in state waters jointly between the NCMFC and the NCWRC. Amendment 1 to the North Carolina River Herring FMP implemented a no-harvest provision for commercial and recreational fisheries of river herring in coastal waters of the state, effective in 2007 due to continued decline of the stocks (NCDMF 2007).

Since 2009, North Carolina river herring have been managed through Amendment 2 to the Interstate FMP for Shad and River Herring. Amendment 2 requires sustainable fishery management plans (SFMPs) to harvest river herring. Since North Carolina does not allow the harvest of river herring, an SFMP is not required at this time. If a fishery for river herring is to reopen in North Carolina it would have to occur through the ASMFC plan.

RED DRUM

The red drum stocks in North Carolina were classified as stressed-declining in the 1997 NCDMF Stock Status Report and based on initial NCMFC FMP Guidelines, red drum were given high priority for immediate FMP development. The guidelines also provided for a provisional plan required within 90 days of a listing of stressed-declining in the NCDMF Stock Status Report. Interim measures were implemented as part of the interim measures in October 1998 to prevent further decline in the status of the red drum stocks while the full FMP was developed. The NCMFC initiated N.C. Red Drum FMP was completed in March 2001. At that time, the most recent stock assessment indicated that overfishing was continuing to occur on red drum and the action was taken to move toward reaching the ASMFC Amendment 1 goal of 40% spawning potential ratio (SPR) and an overfishing definition of 30% SPR.

Prior to implementation of interim measures in 1998, red drum along the Atlantic coast were already managed jointly by the ASMFC and the SAFMC. The ASMFC originally adopted their red drum FMP in 1984. The SAFMC Red Drum FMP was developed and passed in 1990 and measure in the SAFMC plan were adopted subsequently as Amendment 1 to the ASMFC Red Drum FMP. This joint FMP stated that intense fishing mortality on juvenile red drum in state waters was resulting in reduced recruitment to the adult spawning stock. Management measures in place prior to October 1998 were the result of Amendment 1 to the ASMFC plan. This FMP took interim steps to increase SPR to 10% through size and harvest restrictions and was adopted by North Carolina in 1992. The N.C. Red Drum FMP proceeded because measures taken as part of the ASMFC/SAFMC plan were inadequate to prevent overfishing on the stock and no interjurisdictional plan at the time had taken the necessary action to end overfishing The N.C. Red

Drum FMP adopted the 30% overfishing and 40% target consistent with those in Amendment 1 to the ASMFC Red Drum FMP.

In 1999, the SAFMC recommended management authority for red drum be transferred fully to the states and managed by the ASMFC. This recommendation was in part due to the inability to determine the overfished status, which prevented establishing stock rebuilding targets and schedules, as required under the revised Sustainable Fisheries Act of 1996. The transfer resulted in the development of an amendment to the interstate ASMFC FMP to include the provisions of the ACFCMA and to address the overfishing status of red drum.

ASFMC adopted Amendment 2 to the Red Drum FMP in June 2002, which serves as the current management plan for this species along with N.C. Amendment 1. Amendment 2 to the ASMFC FMP maintains the 30% overfishing and 40% target for SPR. Amendment 2 sets a maximum size limit in all fisheries at 27 inches total length. Individual states are allowed to select recreational creel and size limits provided those limits, along with existing or more restrictive commercial regulations, achieve the *F* (fishing mortality rate) target. Management measures in place through the state plan at the time of the adoption of ASMFC Amendment 2 to the Red Drum FMP were sufficient to prevent overfishing and meet all ASMFC compliance measures.

SPOTTED SEATROUT

Spotted seatrout are managed with guidance provided by the ASMFC Omnibus Amendment to the Interstate ASMFC FMPs for Spanish Mackerel, Spot, and Spotted Seatrout. North Carolina complies with the ASMFC spotted seatrout minimum size limit for both recreational and commercial sectors and has adopted the recommended 20% SPR threshold. Due to the mostly non-migratory nature of spotted seatrout, states are primarily responsible for assessing and managing their spotted seatrout stocks. The N.C. Spotted Seatrout FMP and its supplement were developed to fully address the status of the stock through the State stock assessment process and to ensure long-term sustainability for the spotted seatrout stock in North Carolina.

These four FMPs have varying levels of ASMFC oversight and management requirements in North Carolina. On one end of the spectrum, river herring and red drum in North Carolina are more directly managed by ASMFC whereas management of AR striped bass and spotted seatrout is largely left to the State. Measures implemented for compliance with ASMFC or Council FMPs are documented through a revision to the species-specific N.C. FMP. Changes in management strategies are documented in an information paper that is part of the FMP. The information paper provides the rationale agreed to by the NCDMF and the NCMFC for the change in management under the existing adaptive management authority. Adaptive management measures implemented by the revision shall be considered in the next review of the specific N.C. FMP.

Should management actions be approved by the ASMFC or Councils that fail to meet legislative requirements or are deemed contrary to the best interest of the resources or fishermen of the State of North Carolina, the NCMFC may challenge those restrictions, realizing the implications of non-compliance could substantially and adversely impact the fishery. A majority vote of the NCMFC would be required to go out of compliance with an ASMFC FMP or to not complement the management measures contained in a Council FMP in state waters. For ASMFC FMPs, a determination of non-compliance for North Carolina would be forwarded to the Secretary of Commerce. If the Secretary determines the measures the state failed to implement and enforce are necessary for conservation, a moratorium for the fishery in question is imposed within the waters of the non-complying state. Enforcement of the moratorium is by federal agents and the United States Coast Guard. For the Council FMPs, the Secretary of Commerce may regulate the applicable fishery within the state boundaries if a state takes an action or fails to take any action that substantially and adversely affects the carrying out of a Council FMP.

An alternative to an NCMFC decision to go out of compliance or not complement measures is an appointment of a Compliance Advisory Panel (CAP) by the NCMFC chair. The CAP reviews whether consistency with an ASMFC or Council FMP should be challenged. Additionally, in cases where an FMP allows states to develop alternative management options, a CAP may be formed and recommend management actions most appropriate for the State to meet the requirements of an FMP. Many of the FMPs and amendments developed by ASMFC require an implementation plan to outline how a state will comply with required management measures.

Recommendations developed by the CAP are required to be reviewed by the NCMFC's Finfish Advisory Committee, regional advisory committees, and full NCMFC. The NCMFC reviews and provides recommendations to NCDMF for presentation to the Councils/ASMFC. Once the implementation plan is approved by the Council/ASMFC, the NCMFC is required to adopt any rules necessary to comply with the ASMFC plan and/or necessary to complement actions in the federal Council plan. Some FMPs, however, impose mandatory fishery management measures, including quotas, bag limits, size limits, trip limits, etc., for which there are no options or exceptions. Mandatory management measures are required to be adopted by each state affected as the minimum standard except as noted in the challenge process previously described and presented in a state implementation plan.

Finally, North Carolina has considered withdrawing from the ASMFC compact on two occasions. The implications of withdrawal from the compact have been reviewed by the N.C. Attorney General's Office and addressed in the 1995 legislative session with the creation of the Atlantic States Marine Fisheries Compact Withdrawal Committee in 1996. In both instances, the rationale against withdrawal was based on the finding that a state is still subject to the ASMFC actions, regardless of its membership in the compact (See Interjurisdictional FMP 2008 for advisory memorandum from office of N.C. Attorney General). In other words, if a state chooses to leave the ASMFC compact, the state remains subject to the ASMFC requirements but loses voting rights during management determinations. The ASMFC does have an appeal process a state may employ to have a decision made by a species management board reconsidered by the ISFMP Policy Board. The ISFMP charter also allows an appeal to the ISFMP Policy Board to challenge ASMFC out-of-compliance determinations.

In conclusion, a variety of tools exist within the framework of the N.C. FMP for Interjurisdictional Fisheries to ensure the needs of North Carolina's fisheries are considered during both the development and implementation of ASMFC and Council FMPs. The tools outlined in this plan are intended to assist in achieving the goal of minimizing duplication of management effort while meeting all relevant state and federal regulations.

ROY COOPER
Governor
ELIZABETH S. BISER
Secretary
KATHY B. RAWLS
Director

April 29, 2022

MEMORANDUM

TO: N.C. Marine Fisheries Commission

FROM: Laura Lee, Lead Stock Assessment Scientist
Morgan Paris, Jeffrey Dobbs, Daniel Zapf, Striped Mullet FMP Co-Leads
Fisheries Management Section

SUBJECT: Updates on 2022 Stock Assessment of Striped Mullet in North Carolina Waters

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Issue

The 2022 Stock Assessment of Striped Mullet was completed as the initial step to the scheduled review of the Striped Mullet FMP. This memo provides a summary of results of the 2022 striped mullet stock assessment.

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

Findings

- The stock was modeled using Stock Synthesis (SS3), an integrated statistical catch-at-age, forward-projecting, length-based, age-structured model using data from 1950 to 2019.
- The terminal year (2019) fishing mortality (*F*) estimate indicates overfishing is occurring (See Fig. 4.1).
- The terminal year (2019) spawning stock biomass (SSB) estimate indicates the stock is overfished (See Fig. 4.2).
- The data and the model predictions suggest a decreased presence of larger, older striped mullet in the population.
- An external peer review panel concluded the stock assessment is suitable for management.

Overview

Stock assessments involve a full analysis and review of the stock, including consideration of data inputs, new or improved assessment models, and refining the Biological Reference Points (BRPs). The BRPs were maintained from the prior assessment since the fishery continues to target mature female fish during the spawning season and the forage importance of the striped mullet to the ecosystem. The BRPs for this assessment are listed below in Table 1, along with the estimates of fishing mortality (*F*) and spawning stock biomass (SSB) from the terminal year of the assessment. The estimate of *F* in the terminal year of the assessment (2019) was 0.42, which is above the *F* threshold of 0.37, indicating the stock is undergoing overfishing. The estimate of SSB in the terminal year of the assessment was 263 metric tons (mt), which is below the SSB threshold of 619 mt, indicating the stock is overfished.

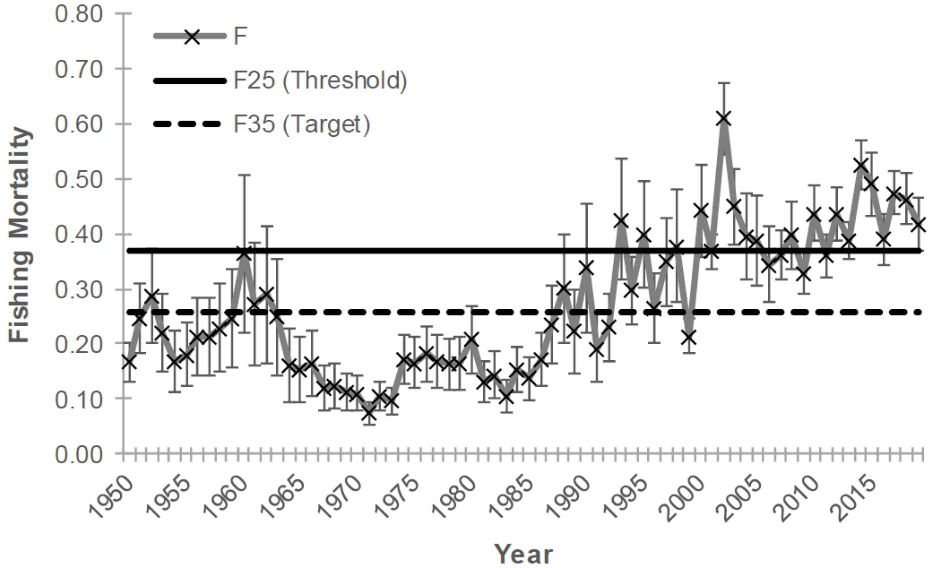

Figure 4.1. Comparison of annual estimates of fishing mortality (numbers weighted, ages 1-5) from the base run to estimates of the fishing mortality target ($F_{35\%}$) and threshold ($F_{25\%}$). Error bars represent 2 ± standard deviations.

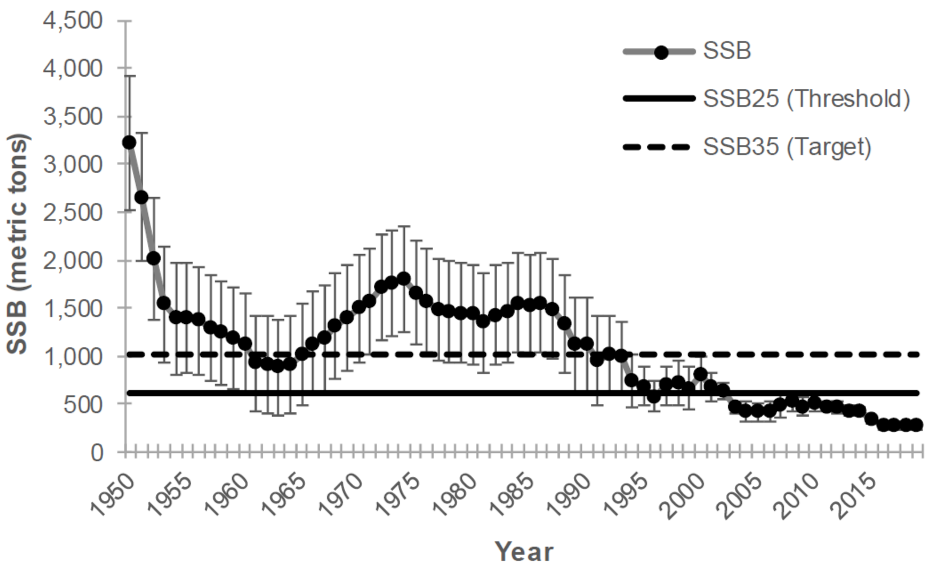

Figure 4.2. Comparison of annual estimates of female spawning stock biomass (SSB) from the base run to estimates of the SSB target ($SSB_{35\%}$) and threshold ($SSB_{25\%}$). Error bars represent 2 ± standard deviations.

An external peer review was held in April 2022. The panel concluded the assessment model and results are suitable for providing management advice. The panel noted results from this assessment are very different from the previous (2018) assessment. Conflicting results were attributed to differences in the 2022 and 2018 model configurations. The panel considers the current model a substantial improvement, representing the best scientific information available.

Stock Assessment of Striped Mullet (*Mugil cephalus*) in North Carolina Waters

2022

Prepared by

North Carolina Division of Marine Fisheries
Striped Mullet Plan Development Team

April 2022

NCDMF SAP-SAR-2022-01

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This report was prepared by the North Carolina Division of Marine Fisheries (NCDMF) Striped Mullet Plan Development Team. The members are Daniel Zapf (co-lead), Morgan Paris (co-lead), Jeff Dobbs (co-lead), Alan Bianchi, David Dietz, Marc Hamric, Kim Harding, Casey Knight, Laura Lee (lead analyst), Lee Paramore, Jason Parker, Jason Rock, Mclean Seward, Thom Teears (lead analyst), Vicky Thayer, Amanda Tong, and Amos Williams.

We would also like to thank Steve Poland, Corrin Flora, Tina Moore, and Katy West for their contributions to the stock assessment. We thank Dr. Carolina Minte-Vera for advice and assistance with model diagnostics.

We are especially grateful to the external peer reviewers for offering their time and effort to review this striped mullet stock assessment: Chris McDonough (peer review panel chair) at the South Carolina Department of Natural Resources' Office of Fisheries Management, Dr. Nikolai Klibansky at NOAA Fisheries, and Dr. Dustin Addis at the Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute.

EXECUTIVE SUMMARY

The North Carolina Fisheries Reform Act requires that fishery management plans be developed for the state's commercially and recreationally important species to achieve sustainable levels of 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 the long-term viability of stocks.

A forward-projecting, length-based, age-structured model was applied to data characterizing commercial landings, recreational harvest, fisheries-independent survey indices, and biological data collected from 1950 through 2019. 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.

Amendment 1 to the NCDMF FMP for striped mullet adopted a fishing mortality threshold of $F_{25\%}$ and a fishing mortality target of $F_{35\%}$. The working group recommended complementary reference points for stock size 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. Predicted F in 2019 is 0.42, which is larger than the $F_{25\%}$ threshold and so suggests that overfishing is occurring. The model estimated a value of 619 mt for the $SSB_{25\%}$ threshold and a value of 1,015 mt for the $SSB_{35\%}$ target. Female SSB in 2019 was estimated at 263 mt, which is smaller than the $SSB_{25\%}$ threshold and so suggests the stock is overfished.

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

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1 INTRODUCTION

1.1 The Resource

Striped mullet (*Mugil cephalus*) occur in fresh, brackish, and marine waters in tropical and subtropical latitudes worldwide. Their widespread distribution results in them being known by many names: jumping mullet, black mullet, grey mullet, popeye mullet, whirligig mullet, common mullet, molly, callifavor, menille, liza, and lisa (Ibáñez-Aguirre et al. 1995; Leard et al. 1995). The striped mullet resource is an important food source, supporting commercial and recreational fisheries worldwide. In North Carolina, striped mullet are harvested recreationally and commercially and are typically targeted for bait and roe.

Three Mugilid species exist in North Carolina: the striped mullet, white mullet (*Mugil curema*), and mountain mullet (*Agonostomus monticola*). Striped mullet and white mullet sometimes overlap spatially but can be distinguished by the presence of longitudinal stripes in striped mullet, anal fin ray counts, or pectoral fin measurements (Collins 1985a, 1985b).

1.2 Life History

1.2.1 Stock Definitions

The unit stock is defined as all striped mullet inhabiting North Carolina coastal and inland waters. Tagging studies in North Carolina indicate a residential adult stock (Wong 2001; Bacheler et al. 2005) since most (98.2%) striped mullet dart-tagged in North Carolina (n = 14,987) between 1997 and 2001 were recovered in state waters (Wong 2001). Striped mullet tagging studies, in general, reveal a small mark-recapture distance and a typical southward spawning migration along the South Atlantic Bight (SAB; Mahmoudi et al. 2001; McDonough 2001; Wong 2001). An observed northward movement pattern during and after its spawning period suggests that adults continue to colonize North Carolina estuarine habitats after its southward spawning migration (Bacheler et al. 2005). In conjunction with the southward (and offshore) spawning migration by adults, the northward advection of eggs and larvae via the Gulf Stream likely provides some measure of self-replenishment of the North Carolina stock. However, the influx of eggs and larvae into North Carolina from stocks residing in South Carolina to Florida is uncertain, as is the northward loss of North Carolina-born eggs and larvae into the mid-Atlantic Bight. Although these larval recruitment processes that occur on a coast-wide scale would suggest a genetically homogenous striped mullet population in the SAB, the assumption of a distinct North Carolina stock was necessary for this assessment. As a reference, the Gulf States Marine Fisheries Commission considers all striped mullet occurring in the United States Gulf of Mexico as one population because of widespread larval mixing but also recognizes that state-specific or regional management programs (including assessments) are appropriate because of the limited movement patterns observed by juveniles and adults (Leard et al. 1995).

1.2.2 Movements & Migration

Striped mullet larvae are found during winter and spring months over a range of offshore depths (9 to 914 m) in the SAB (Collins and Stender 1989). The greatest abundance of larvae occurs at <25°C (mean = 23°C) and >34 ppt in the Gulf of Mexico (Ditty and Shaw 1996) and along the 180-m contour off the SAB (Powles 1981). Larval size is negatively related to distance from shore, indicating an inshore migration with growth (Powles 1981; Collins and Stender 1989). Larvae exhibit a strong association with surface waters and show no indication of diel vertical migration

(Powles 1981; Collins and Stender 1989). The shoreward migration in the SAB is likely facilitated by onshore, wind-driven drift, characteristic of southeast U.S. winter wind patterns (Powles 1981).

Larval and young-of-year (YOY) striped mullet are absent in offshore waters by April in the Gulf of Mexico and by early March in the SAB (Anderson 1958; Ditty and Shaw 1996). Pre-juvenile striped mullet are 20 to 25 mm when they appear on outer beaches and are reported as early as November in Georgia (Gunter 1945; Anderson 1958; Ditty and Shaw 1996). Pre-juveniles enter estuarine areas from December through March in North Carolina, at approximately 22 mm (Higgins 1927; NOAA, unpublished data). YOY overwinter in estuarine marsh areas and apparently scatter among a range of habitat types during summer and fall months (Anderson 1958). Collins (1985a) noted YOY and juveniles move into deeper waters with the adult migration in the fall.

Adults occupy shallow waters during a 'trophic' (feeding) phase from spring to summer/early fall between migration (spawning) periods (Martin and Drewry 1978) and generally do not move extensively during this period (Leard et al. 1995). Most adult movement occurs during a pronounced spawning migration that occurs in fall and winter months in the southeast U.S. and Gulf of Mexico (Leard et al. 1995; Collins 1985a; Bichy 2000). Onset of migration is marked by increased schooling aggregations and downstream movement towards marine waters (Jacot 1920; Martin and Drewry 1978). Increased migratory movements have been associated with north/northwest winds and cold fronts (Jacot 1920; Apekin and Vilenskaya 1979; Mahmoudi et al. 1990; NCDMF, unpublished data). Hurricanes and unseasonably warm fall water temperatures may delay or disrupt spawning migrations (Thompson et al. 1991). Patterns of movement unrelated to spawning are otherwise difficult to generalize, as all age groups can be found from freshwater to lower estuarine waters at all times of the year (Thomson 1955). Partial migration, where only a proportion of a population migrates during a season, has been observed to occur in striped mullet populations on the east coast of Florida (Myers et al. 2020) and the eastern coast of Australia (Fowler et al. 2016) and is suggested to occur in relation to skipped spawning.

Most tagging studies show limited distances between tagging and recapture locations for adults (Idyll and Sutton 1951; Broadhead and Mefford 1956; Collins 1985a; Mahmoudi et al. 2001; McDonough 2001; Wong 2001). Ninety percent of recaptures occurred within 32 km of the tagging location in Florida (Idyll and Sutton 1951; Broadhead and Mefford 1956), while 91% of recaptures were found within 83 km of the release site in North Carolina (Wong 2001). Most of the movements observed in tagging studies are associated with the spawning migration. The spawning migration along the southeast U.S. coast occurs in a general southward direction (Jacot 1920; Broadhead and Mefford 1956; Martin and Drewry 1978; Wong 2001). The majority of tagged fish recaptured during spring months (presumably after spawning) in North Carolina were found south of the original tagging location (Wong 2001). Northern movement has been reported in the fall, lagging behind the southward migration by about 2 months but on a smaller scale (Bacheler et al. 2005); however, egg and larval transport occurs in a northward direction with the Florida current (Gulf Stream) along the southeastern U.S. (Able and Fahay 1998). The overall direction of recapture in tagging studies in North Carolina and South Carolina was to the south (McDonough 2001; Wong 2001). Almost every out-of-state recapture was found in more southern states. Low percentages of out-of-state recaptures in North Carolina and South Carolina (1.8% and 9%) suggest striped mullet stocks are residential to native states. Mahmoudi et al. (2001) noted the majority of adults in Florida were recaptured in the same system in which they were tagged.

1.2.3 Age & Size

Otoliths and scales have been validated as ageing structures for striped mullet (Hsu and Tzeng 2009). Striped mullet are approximately 11 mm at the end of the larval stage (24 to 28 days; Martin and Drewry 1978). Martin and Drewry (1978) recognize a pre-juvenile stage from 11 to 52 mm total length (TL), with an approximate age of 30 to 90 days at its conclusion (Thomson 1966).

The juvenile stage encompasses a size range from 52 to 248 mm TL (Martin and Drewry 1978). Striped mullet reach 50 mm TL by 5 months (by their first March–May; Futch 1966). Males and females are at similar lengths at early ages (<age 2), after which, females grow larger and live longer (Mahmoudi et al. 1990; NCDMF, unpublished data). Large variability in size at early ages is seen in North Carolina, South Carolina, and Georgia stocks (Foster 2001; McDonough 2001; Carmichael and Gregory 2001). North Carolina striped mullet appear to achieve larger mean lengths at earlier ages than more southern U.S. states (Bichy 2000; Carmichael and Gregory 2001). For example, mean length for age-1 striped mullet (both sexes) in South Carolina was 257 mm TL, substantially smaller than that observed for males (325 mm TL) and females (350 mm TL) in North Carolina (McDonough 2001; NCDMF, unpublished data). On average, age-2 males and females in South Carolina were 310 mm compared to 348 mm TL and 390 mm TL in North Carolina, respectively (McDonough 2001; NCDMF, unpublished data). Since birth date is standardized as January 1 for ageing convention along the U.S. east coast, earlier spawning times and true birth dates in North Carolina may contribute to slightly larger mean lengths at young ages. The maximum age for striped mullet has been reported as 13 years (Thomson 1963); however, male and female maximum ages of 14 and 13 years were recorded in North Carolina research (NCDMF, unpublished data). A 15-year-old striped mullet of unknown sex was observed in 2017 by the North Carolina Division of Marine Fisheries (NCDMF). Maximum reported sizes ranged from 698 mm TL in North Carolina to a 914 mm TL specimen from India (Gopalakrishnan 1971; NCDMF, unpublished data).

1.2.4 Growth

1.2.4.1 Larvae

Beginning at an average size of 2.65 mm, larvae grow quickly at first (Pattillo et al. 1999; Martin and Drewry 1978) before growth slows during the time they deplete their yolk sac (4–5 days; Kuo et al. 1973; Martin and Drewry 1978). Once feeding begins, between 5 and 8 days after hatching, the larvae grow more quickly. Striped mullet are approximately 11 mm at the end of the larval stage (24 to 28 days; Martin and Drewry 1978).

1.2.4.2 Juveniles

The juvenile stage occurs when striped mullet are between 52 and 248 mm TL, the intervening size (11–52 mm TL) is considered the pre-juvenile stage (Martin and Drewry 1978). Striped mullet have been observed arriving to North Carolina waters during this stage by mid-January (Higgins 1927). Growth at this stage is slow or nonexistent until water temperature reaches around 20°C in April. Striped mullet grow approximately 20 mm per month from May to October. Anderson (1958) estimated 5 mm growth per month for Georgia YOY (~18 to 19 mm standard length) from November until January, followed by no growth during the coldest winter months. About 10 mm growth occurred between February and March during rising water temperatures, followed by a growth rate of 17 mm per month through October. Anderson (1958) suggested that the longer period of delayed YOY growth observed by Higgins in North Carolina was due to the extended time with temperatures <20 °C.

1.2.4.3 Adults

Adults grow at a rate of 38 mm to 64 mm per year (Broadhead 1953; Wong 2001). Spring and summer growth is twice as fast as fall and winter growth (Broadhead 1953; Rivas 1980). Adults grew 7 mm in each of the first and fourth quarters of the year and averaged 16 and 19 mm growth in the second and third quarters of the year in a Florida tagging study (Broadhead 1958). Thompson et al. (1991) indicated that energy required for somatic growth was reallocated for reproduction and post-spawning recovery (during the fall and winter, November–March). Summer growth depression in striped mullet (age 1+) was observed in Texas, associated with prolonged elevation of water temperatures and potential shifts in food types (Moore 1973; Cech and Wohlschlag 1975). A similar cessation in otolith marginal incremental growth was observed for older striped mullet in August and September in North Carolina (Carmichael and Gregory 2001).

1.2.4.4 Models

Biological samples were obtained from various fisheries-independent and fisheries-dependent sources and collected by the NCDMF.

Age-Length

Available otolith-based age data were fit with a von Bertalanffy age-length model to estimate growth parameters for both female and male striped mullet. Length at age was modeled using the von Bertalanffy (1938) growth model as:

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

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

where j indexes the sex, L_i and t_i are the fork length (cm) and age (fractional age in years) of individual i, respectively, and the parameters to be estimated were the asymptotic length L_∞, 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 growth parameters priors. 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 σ_{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 σ_{L_∞} and σ_K are standard deviations of lnL_∞ and lnK across sexes and represent variability in growth between sexes; φ is the covariance of lnL_∞ and lnK across sexes. High negative correlation of L_∞ 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_∞ 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 10^{th} of the remaining samples from each chain were saved for analysis. The JAGS (version 4.3.0) was used to run the Bayesian analysis.

The predicted growth curves appeared to fit the observations well for females (Figure 1.1) and males (Figure 1.2). The estimated parameters from this and previous studies are presented in Table 1.1.

Length-Weight

Parameters of the length-weight relationship were also estimated in this study. The relation of fork length in centimeters to weight in kilograms was modeled for males and females separately using non-linear least squares. Weight (W) at length (L) was modeled as:

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

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 1.3 (females) and 1.4 (males).

1.2.5 Reproduction

Striped mullet are gonochoristic and their sex is genetically determined (McDonough et al. 2005). Due to the plasticity of their gonad development, striped mullet retain some characteristics of the opposite sex during the initial stages of differentiation. Undifferentiated gonads appear to have male morphological characteristics. Previous studies have suggested the possibility of hermaphrodism in striped mullet (Stenger 1959; Moe 1966). Yet, there is only one documented example of a simultaneous hermaphroditic striped mullet (Franks et al. 1998). It has been shown that most immature mullet were sexually differentiated by the time of their first annular increment deposition (15–19 months; McDonough et al. 2005) or at 175 mm to 225 mm (Stenger 1959; Bichy 2000).

The majority of striped mullet reach sexual maturity at 300 mm (male range = 250 mm to 325 mm, female range = 290 mm to 430 mm) and at age 2 (McDonough et al. 2005). However, striped mullet in North Carolina appear to mature at a younger age and larger size than other striped mullet populations, with an estimated age of maturity of age 1 for both males and females and at 285 mm and 335 mm for males and females, respectively (Bichy 2000). Striped mullet can mature in a range of salinities; however, the best production is reached when their gonads develop in salinities of 13 to 35 ppt (McDonough et al. 2005). Reported estimates of fecundity in North Carolina ranged from 4.8×10^5 to 4.2×10^6 eggs per female (Bichy 2000).

Immature and inactive males and females have been collected during every month of the year. The presence of ripe males from October through February and developing females from August through March support the idea of an extended spawning season from October through March. In striped mullet, it is unknown what initiates gametogenesis, but it is generally accepted that changes in temperature and photoperiod help regulate the seasonal reproductive cycle (McDonough et al. 2005). Bichy (2000) found the proportion of males to females varied by fish length with fish over 300 mm being predominately female. Below 300 mm, males dominated, but the sex ratio was closer to 1:1. Skipped spawning has also 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), though factors influencing skipped spawning are unknown (Myers et al. 2020).

In North Carolina, peak spawning occurs from October through early December when estuarine water temperatures are often below 15°C, suggesting striped mullet spawn when estuarine water temperatures are between 13°C and 22°C (Bichy 2000). Striped mullet are considered isochronal spawning fishes (Greeley et al. 1987; Render et al. 1995). The spawning location of striped mullet is largely based in theory and indirect evidence of larval size, but it has been suggested that striped mullet spawn offshore in and around the edge of the continental shelf, often referred to as the SAB (Collins and Stender 1989).

Previous NCDMF stock assessments of striped mullet (Wong 2006; NCDMF 2103, 2018) 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, histological) to estimate the maturity ogive for striped mullet 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 striped mullet 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 31.9 cm and the estimated slope was -0.375 (Figure 1.5).

1.2.6 Natural Mortality

Natural mortality (M) is one of the most important, and often most uncertain, parameters used in stock assessments. Few studies exist directed at the natural mortality of striped mullet. Stomach content analyses of bottlenose dolphin (*Tursiops truncatus*) in Florida found 16.7% frequency occurrence of mullet (*Mugil* spp.; Barros and Odell 1990). Another study of bottlenose dolphin stomach contents in Florida found <1% frequency of occurrence of striped mullet (Pate and McFee 2012). Finally, a North Carolina study found a 3% frequency of occurrence of striped mullet in the stomach contents of bottlenose dolphins (Gannon and Waples 2004).

Several approaches have been developed to provide indirect estimates of M at age (Peterson and Wroblewski 1984; Boudreau and Dickie 1989; Lorenzen 1996, 2005). Here, the Lorenzen (1996) approach was used to produce estimates of M at age. This approach is based on the relationship of body weight to natural mortality and requires estimates of parameters from the von Bertalanffy age-length growth function, estimates of parameters from the length-weight relationship, and the range of ages over which M will be estimated. Based on empirical age data collected by the NCDMF, a maximum age of 13 was used for females and a maximum age of 14 was used for males (section 1.2.3). As expected, estimates of M decrease with increasing age (Table 1.3).

1.2.7 Food & Feeding Habits

Striped mullet are recognized as an important ecological bridge among a wide range of trophic levels. They connect base food chain items such as detritus and diatomaceous microalgae, phytoplankton and zooplankton, and marine snow (Odum 1968; Moore 1974; Collins 1985a; Larson and Shanks 1996; Torras et al. 2000) with top-level predators, such as birds, fishes, sharks, and bottlenose dolphins (Breuer 1957; Thomson 1963; Collins 1985a; Barros and Odell 1995; Fertl and Wilson 1997; Binion-Rock 2018); however, striped mullet likely contribute minimally to the diets of juvenile and adult red drum (Facendola and Scharf 2012; Peacock 2014), striped bass (Rudershausen et al. 2005) and other finfish species (Binion-Rock 2018) in North Carolina estuaries. Carnivorous feeding (on copepods, mosquito larvae, and microcrustaceans) is common in striped mullet larvae and small juveniles (Harrington and Harrington 1961; De Silva 1980), followed by a stronger dependence on benthic (bottom) detritus and sediment with increasing body size (De Silva and Wijeyaratne 1977).

Adult striped mullet are well-documented herbivorous detritivores (Odum 1970; Collins 1985a). Adults are commonly described as 'interface feeders' (feed on water surface, water bottom, or surface of objects). Adults consume epiphytic (attached to the surface of a plant) and benthic microalgae (*viz*. unicellular green algae, filamentous blue-green algae, diatoms), bacteria, Protozoa, and other microorganisms associated with the top layers of fine sediments, detritus, and submerged surfaces such as rocks, eelgrass (*Zostera marina*), and turtle grass (*Thalassia* spp.) blades (Odum 1970; Moore 1974). Adults also feed on surface water 'scum' composed of accumulations of microalgae (Odum 1970). Ingested sediment particles are known to function as a grinding substrate in the degradation of plant cell walls in a gizzard-like pyloric stomach of the striped mullet (Thomson 1966). Anecdotal reports of feeding behaviors on mid-water polychaetes, *Nereis succinea*, and live bait of anglers also indicate opportunistic, carnivorous feeding by adults in non-interface areas (Bishop and Miglarese 1978). Collins (1981) reported that feeding activity was restricted to daylight hours.

1.3 Habitat

Striped mullet habitat use varies greatly based on life history stages, seasons, and location (Able and Fahay 1998; Pattillo et al. 1999; Cardona 2000; Whitfield et al. 2012). Salinity plays a major role on habitat use and distribution of both adult and juvenile mullet (Cardona 2000). Striped mullet are a highly euryhaline fish and live in a wide range of salinities, based on size and maturity (Pattillo et al. 1999; Cardona 2000; McDonough and Wenner 2003; Górski et al. 2015). The availability of suitable food may also influence habitat use by striped mullet (Moore 1974). Striped mullet are found in almost all shallow marine and estuarine habitats including beaches, tidal flats, lagoons, bays, rivers, channels, marshes, and grassbeds (Moore 1974; Pattillo et al. 1999; Nordlie 2000). They can be found in depths ranging from a few centimeters to over 1,000 m but are mostly collected within 40 m of the surface and prefer depths of 3 m or less.

1.3.1 Spawning Habitat

As discussed in section 1.2.5, the spawning location of striped mullet is thought to be offshore, in and around the edge of the continental shelf (Collins and Stender 1989), from the 20-fathom line to the Gulf Stream in North Carolina to lower Florida (Anderson 1958). Striped mullet spawning migrations are cued by environmental conditions, including northeasterly winds and strong cold fronts with dropping barometric pressure (Thompson et al. 1991; Mahmoudi 1993). These cues may vary due to unseasonably warm temperatures or hurricanes.

1.3.2 Nursery & Juvenile Habitat

Juvenile striped mullet spend most of their life in estuarine rivers and marshes, with abundance highest in May and lowest in September (Bretsch and Allen 2006; McDonough and Wenner 2003). Juvenile striped mullet use wetlands for foraging and refuge from predators. Striped mullet have been observed in both the interior and on the edge of the marsh depending on flows and water levels (Kneib and Wagner 1994; Peterson and Turner 1994; Allen et al. 2007). Larval and juvenile striped mullet are also found in lesser numbers in the surf zone (Modde and Ross 1981; Strydom and d'Hotman 2005; Able et al. 2013; Park et al. 2015).

1.3.3 Adult Habitat

As striped mullet mature, they are more commonly found in polyhaline estuarine and marine waters and may avoid freshwater areas (Cardona 2000; Chang et al. 2004; Górski et al. 2015). Adult striped mullet are found in almost all shallow marine and estuarine habitats including beaches, tidal flats, lagoons, bays, rivers, channels, marshes and grassbeds (Moore 1974; Pattillo et al. 1999; Nordlie 2000), as their high mobility allows them to use a wide range of habitats (Baker et al. 2013). Generally, when adult striped mullet are in the estuaries they are found over soft bottom in the vicinity of freshwater wetlands. As the wetland plant matter dies, it settles on the soft bottom where striped mullet spend most of their time foraging on detritus and benthic invertebrates. Striped mullet will also spend time feeding on epiphytes found in beds of submerged aquatic vegetation (SAV). Once striped mullet are ready to spawn they move offshore to their spawning grounds.

1.3.4 Habitat Issues & Concerns

Suitable habitat is a critical element in the ecology and productivity of estuarine systems. Degradation or improvement in one aspect of habitat may have a corresponding impact on water quality. Maintenance and improvement of estuarine habitat and water quality are probably one of the most important factors in providing sustainable striped mullet stocks. All habitats used by striped mullet are threatened in some way. Water quality degradation through stormwater runoff, discharges, toxic chemicals, sedimentation, and turbidity all have been documented as threats to striped mullet and their habitat. Due to the importance of inlets to larval striped mullet estuarine ingress and adult egress, terminal groins may threaten striped mullet stocks. Wetlands are threatened by human activities, including dredging for marinas and channels, filling for development, ditching and draining for agriculture, silviculture, and development, channelization, and shoreline stabilization. Dredging also threatens soft bottom habitat affecting striped mullet food sources and water quality.

1.4 Description of Fisheries

1.4.1 Commercial Fishery

The striped mullet commercial fishery played a prominent role early in the development of the North Carolina commercial fishing industry. Smith (1907) ranked striped mullet as the most abundant and important saltwater fish of North Carolina in the early 1900s. Woodward (1956) referred to mullet (white and striped combined) as the most important food finfish in North Carolina. The striped mullet commercial fishery operated at an average of over 1,200 metric tons (mt) annually during the late 1800s (Figure 1.6). Peak commercial landings of over 3,000 mt and 2,300 mt were harvested in 1902 and 1908 (Chestnut and Davis 1975). The commercial fishery was highly seasonal and occurred primarily during the fall spawning migration, but commercial landings occurred throughout the year (Taylor 1951; Woodward 1956). Enormous catches—greater than 450 mt (1 million pounds) of mullet landed in a single day—were common during these fall migrations (Smith 1907). These massive pulses were larger than the market's distribution and holding capacity well into the 1950s (Taylor 1951; Woodward 1956). Commercial landings reached their lowest levels from 1964 to 1971, averaging around 515 mt annually (Chestnut and Davis 1975). Strong demand from Asia for striped mullet roe and competing roe-exporting companies combined to create a highly profitable roe fishery in North Carolina in 1988. In 1988, commercial landings exceeded 1,300 mt for the first time in 28 years. From 1988 to 2002, North Carolina's commercial fishery landed an average of 1,032 mt of striped mullet per year. Annual commercial landings ranged from a low 438 mt in 2016 to a high of 945 mt in 2010 between 2003 and 2019. During this same time period, commercial landings averaged 715 mt per year.

Because the commercial fishery primarily targets striped mullet roe, the fishery is seasonal with the highest demand and landings occurring in the fall when large schools form during the spawning migration to the ocean. From 1994 to 2019, a total of 110,220 commercial trips reported striped mullet landings in September, October, and November. A total of 65% of striped mullet commercial landings are reported in the fall months of September, October, and November and the highest commercial landings occur in October (Table 1.4). The percentage of commercial landings that occur during the winter and summer are similar at 13% and 14%, respectively, while spring accounts for 7.4% of the overall commercial landings.

From 1887 to 1978, a total of 60% of the commercial landings were from seines and 39% were from gill nets (Chestnut and Davis 1975; NCDMF, unpublished data). Since 1989, gill nets (runaround, set, and drift) have replaced seines as the dominant gear type in the commercial fishery. Gill nets have been the dominant commercial gear from 1994 through 2019 (Figure 1.7). Although still in use, seines and stop nets account for less than five percent of the commercial landings from 1994 to 2019.

Hurricanes occur frequently in eastern North Carolina, particularly in the fall during peak striped mullet fishing periods and can have significant impacts on the striped mullet fishery, though impacts are inconsistent and largely influenced by timing of the hurricane. Hurricanes can damage fishing gear, prevent fishermen from fishing, or can cause striped mullet to leave the estuarine system earlier than normal (Burgess et al. 2007); however, the potential reduction in fishing mortality during hurricane years would likely have a positive effect on spawning stock biomass of the striped mullet stock in subsequent years.

1.4.2 Recreational Fishery

Striped mullet are not typically targeted by anglers using hook and line. Although, striped mullet and white mullet are commonly used as bait fish by recreational anglers targeting a wide variety of inshore and offshore species (Nickerson 1984; NCDMF 2020). YOY mullet, commonly referred to as finger mullet, caught by cast net are primarily used for bait by recreational anglers. The drying of mullet and their roe for later consumption is also popular with some coastal North Carolina residents. Finger mullet are generally available in the summer and fall with the majority caught in July, August, September, and October (NCDMF 2020).

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 (Figure 1.8). There are no federal or interstate fishery management plans (FMPs) that apply specifically to the striped mullet fishery in North Carolina.

1.5.2 Management Unit Definition

The management unit includes striped mullet and its fisheries in all of North Carolina's coastal fishing waters.

1.5.3 Regulatory History

In 2006, the North Carolina Marine Fisheries Commission (NCMFC) adopted the FMP for striped mullet in joint and coastal waters of North Carolina. The goal of the FMP was to conserve and protect the striped mullet resource to ensure ecological stability while providing for sustainable fisheries. All management authority for North Carolina's striped mullet fishery is vested in the State of North Carolina.

Few regulations exist that pertain directly to striped mullet. Most regulations that affect the striped mullet fishery relate to fishing gear and bait fish in general. Statutes that have been applied to the striped mullet fishery include:

- Recreational fishery limit of two hundred mullet (striped and white combined) per person per day
- It is unlawful to fish in the ocean from vessels or with a net within 750 feet of a properly licensed and marked fishing pier.
- It is unlawful to engage in trash or scrap fishing (the taking of young of edible fish before they are of sufficient size to be of value as individual food fish) for commercial disposition as bait, for sale to any dehydrating or nonfood processing plant, or for sale or commercial disposition in any manner. The NCMFC's rules may authorize the disposition of the young of edible fish taken in connection with the legitimate commercial fishing operations, provided it is a limited quantity and does not encourage scrap fishing.
- It is unlawful for any person without the authority of the owner of the equipment to take fish from nets, traps, pots, and other devices to catch fish, which have been lawfully placed in the open waters of the State.
- It is unlawful for any vessel in the navigable waters of the State to willfully, wantonly, and unnecessarily do injury to any seine, net, or pot.
- It is unlawful for any person to willfully destroy or injure any buoys, markers, stakes, nets, pots, or other devices or property lawfully set out in the open waters of the State in connection with any fishing or fishery.
- It is unlawful to use spotter planes in an operation that takes food fish.
- It shall be unlawful to possess, sell, or purchase fish under four inches in length except:

1. For use as bait in the crab pot fishery in North Carolina with the following provision: such crab pot bait shall not be transported west of U.S. Interstate 95 and when transported, shall be accompanied by documentation showing the name and address of the shipper, the name and address of the consignee, and the total weight of the shipment
2. For use as bait in the finfish fishery with the following provisions:
   - It shall be unlawful to possess more than 200 pounds of live fish or 100 pounds of dead fish.
   - Such finfish bait may not be transported outside the State of North Carolina.
   - Bait dealers who possess valid finfish dealers license from the NCDMF are exempt from sub-items 2(a) and (b) of this Rule. Tolerance of not more than five percent shall be allowed. Menhaden, herring, gizzard shad, pinfish, and live fish in aquaria other than those for which a minimum size exists are exempt from this Rule.

- It is unlawful to possess aboard a vessel or while engaged in fishing any species of finfish that is subject to a size of harvest restriction without having head and tail attached, except:
  1. Mullet when used for bait;
  2. Hickory shad when used for bait provided that not more than two hickory shad per vessel or fishing operation may be cut for bait at any one time; and
  3. Tuna possessed in a commercial fishing operation as provided in 15A NCAC 03M .0520.

1.5.4 Current Regulations

Detailed information regarding North Carolina's current commercial and recreational fishery regulations is available on the NCDMF website (https://deq.nc.gov/about/divisions/marine-fisheries/rules-proclamations-and-size-and-bag-limits).

1.5.4.1 Commercial Fishery

The Standard Commercial Fishing License (SCFL) and Retired Standard Commercial Fishing License are annual licenses issued to commercial fishermen who harvest and sell fish, shrimp, or crab. The number of SCFL licenses is currently capped at 8,896. A Commercial Fishing Vessel Registration is also required for fishermen who use boats to harvest seafood.

The stop net fishery has operated under fixed seasons and net and area restrictions since 1993. Annually, a proclamation is issued by the director of the NCDMF to establish the season, specify net restrictions, and define areas in which stop nets can be used during the beach seine striped mullet fishery. Annually, the season for stop nets is from October 1 through November 30; however, the stop net season was extended to include December 3 to December 17 in 2015 (Proclamation M-28-2015). In 2020, the stop net fishery was open from October 15 through December 31 (Proclamation M-17-2020). Net restrictions include a maximum of four stop nets can be used between Beaufort Inlet and Bogue Inlet at any one time, a combined fishing operation cannot use more than two stop nets at any one time, stop nets cannot exceed 400 yards in length (the inshore 100-yard portion and the offshore 50-yard portion must be constructed of webbing with a minimum of 8 inches stretched mesh and the remaining section of the net must be constructed of webbing with a minimum of 6 inches stretched mesh), and stop nets are not allowed within 880 yards of an existing stop net. The areas where stop nets are allowed include Atlantic

Ocean on Bogue Banks, Carteret County, and between Beaufort Inlet and Bogue Inlet with stop nets prohibited in specified areas on Bogue Banks.

1.5.4.2 Recreational Fishery

Prior to 1999, no recreational fishing license was required unless a vessel was used. After July 1, 1999, the Recreational Commercial Gear License (RCGL) was required when using certain allowable commercial gear to harvest finfish and crustaceans for personal consumption. No license is required for the following non-commercial equipment: collapsible crab traps, cast nets, dip nets, and seines less than 30 feet.

There are currently no size restrictions on striped mullet in North Carolina. As of July 1, 2006, there has been a 200-mullet (white and striped aggregate) daily possession limit per person in the recreational fishery and the mutilated finfish rule was modified to exempt mullet (white and striped) used as bait; however, the NCDMF director may, by proclamation, impose any or all of the following restrictions on the taking of mullet: specify season, specify area, specify quantity, specify means/methods, and specify size.

1.5.5 Management Performance

The North Carolina commercial fishery for striped mullet (*Mugil cephalus*) is one of the largest along the U.S. Atlantic seaboard and is a predominately fall, roe-targeting, gill-net fishery. Strong demand from Asia for striped mullet roe and competing roe-exporting companies combined to create a highly profitable roe fishery in North Carolina. Rapid surges in roe values in the late 1980s, followed by rising commercial fishing effort and landings through the mid-1990s, caused concern for the North Carolina striped mullet stock. Striped mullet was officially recognized as a species of concern by the state of North Carolina in 1999, though no formal stock assessment had been conducted at that time. The North Carolina FMP for Striped Mullet was adopted in April 2006 and reclassified the stock as viable (NCDMF 2006). The first assessment of the North Carolina striped mullet stock was performed in association with the development of the NCDMF Striped Mullet FMP (Wong 2006). The results of the assessment indicated the stock was not undergoing overfishing in the terminal year of the assessment, 2002. Stock status with respect to the overfished condition could not be reliably determined and was considered uncertain.

While the North Carolina striped mullet stock was not experiencing overfishing in 2002, it was being fished near the maximum exploitation level that could maintain sustainability (Wong 2006). The 2006 FMP established minimum and maximum commercial landings thresholds of 1.3 and 3.1 million pounds, respectively (NCDMF 2006). If commercial landings fell below the minimum threshold, the NCDMF would initiate further analysis of the data to determine if the decrease in commercial landings was attributed to a stock decline or decreased fishing effort. If commercial landings exceeded the maximum threshold, the NCDMF would initiate analysis to determine if commercial harvest is sustainable and assess factors that may be driving the increase in harvest.

Amendment 1 to the NCDMF Striped Mullet FMP was adopted in November 2015 (NCDMF 2015). Amendment 1 maintained the stock status classification as viable based on results of the stock assessment completed in 2013. Amendment 1 also raised the fishing mortality target from $F_{30\%}$ spawning potential ratio (SPR) to $F_{35\%}$ SPR to account for the potential role of striped mullet as a forage species. Although overfishing was not occurring in 2011, fishing mortality had been increasing and recruitment had been declining (NCDMF 2013). The 2015 FMP updated the minimum and maximum commercial landings thresholds using commercial landings from 1994 through 2011 (NCDMF 2015). The updated minimum and maximum commercial landings thresholds were set at 1.13 and 2.76 million pounds, respectively. Amendment 1 also implemented adaptive management for striped mullet. This allows management measures, if needed to maintain sustainable harvest, to be implemented using proclamation authority of the NCDMF director. Any potential management measures will be developed by the Plan Development Team (PDT) in conjunction with the advisory committee and approved by the North Carolina Marine Fisheries Commission (NCMFC) prior to implementation.

Commercial landings in 2016 were 965,198 pounds, which is below the minimum landings trigger of 1.13 million pounds. 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 the findings from preliminary analysis and recommendations to the 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 that 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.

The most recent stock assessment of the North Carolina striped mullet stock was completed in 2018 and used data from 1994 through 2017 (NCDMF 2018). Results of the stock assessment indicated that spawning stock biomass increased from 2003 through 2007 but declined through 2017. Recruitment also declined in the latter portion of the time series, though a slight increase was observed in 2017. Fishing mortality (F) had little variation for most of the time series, with a slight increase in 2017. F in the terminal year (F_{2017} = 0.13) was below both the fishing mortality target ($F_{35\%}$ = 0.40) and threshold ($F_{25\%}$ = 0.57). Because F_{2017} was less than the threshold value, the stock was not undergoing overfishing in 2017. Due to the poor stock-recruitment relationship, estimates of a biomass-based reference point were considered unreliable. Therefore, status in relation to the overfished condition was considered unknown.

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 that no management action be taken since the stock assessment update indicated overfishing was not occurring. The NCDMF would continue to monitor trends in the commercial fishery and fisheries-independent indices. The recommendation was approved by the NCMFC.

Review of the 2019 and 2020 commercial landings, while reduced, indicate neither the maximum nor minimum triggers had been exceeded.

1.6 Assessment History

1.6.1 Review of Previous Methods & Results

The first stock assessment of the striped mullet stock in North Carolina waters completed by the NCDMF for management purposes was performed in association with the development of the original Striped Mullet FMP (see section 1.5.5; NCDMF 2006; Wong 2006). The assessment applied a sex-specific, forward-projecting statistical catch-at-age model to estimate population size and fishing mortality rates for the 1994- to 2002-time period. Input data included commercial landings, recreational harvest, three seine surveys, one gill-net survey, and one trammel net survey. Yield-per-recruit and spawning stock biomass-per-recruit analyses were used to estimate appropriate reference points. The results of the assessment indicated the stock was not undergoing overfishing in the terminal year of the assessment, 2002. Stock status with respect to the overfished condition could not be reliably determined and was considered uncertain.

The most recent benchmark stock assessment of North Carolina's striped mullet stock was performed in association with the development of Amendment 1 to the Striped Mullet FMP (see section 1.5.5; NCDMF 2013, 2015). All NCDMF benchmark stock assessments are subject to an external peer review. The 2013 stock assessment applied a sex-specific, forward-projecting statistical catch-at-age model to estimate population size, fishing mortality rates, and reference points (NCDMF 2013). The model incorporated data from commercial fisheries and three fisheries-independent surveys based on the 1994- to 2011-time period. The results of that assessment suggested the stock was not undergoing overfishing in 2011. Estimates of biomass-based reference points were considered unreliable due to the assumed poor stock-recruit relationship and this prevented determination of overfished status. Note that the 2013 NCDMF stock assessment underwent a desk-type peer review. As of 2017, NCDMF stock assessments are reviewed through an in-person process. The reviewers of the 2013 stock assessment ultimately recommended that the stock assessment could be used for management purposes, which the NCDMF agreed.

An update of the 2013 NCDMF stock assessment of striped mullet was completed in 2018 in response to tripping of the minimal commercial landings trigger (section 1.5.5; NCDMF 2018). Since the 2018 stock assessment was an update and not a benchmark, the stock assessment was not subject to peer review. The data used in the 2013 stock assessment were updated through 2017 and applied to the same model as in the 2013 stock assessment. All assumptions made in the 2013 stock assessment were maintained as well. The results of the NCMDF 2013 stock assessment of striped mullet suggested that the stock was not experiencing overfishing in 2017. As with the 2006 and 2013 stock assessment, biomass-based reference point estimates were considered unreliable and so status relative to overfished condition could not be determined.

1.6.2 Progress on Research Recommendations

Research recommendations put forward in the 2018 NCDMF stock assessment of striped mullet (NCDMF 2018) are listed below and progress, if any, is discussed.

- Improve recreational fisheries statistics provided by the MRIP or some other program to reliably characterize the magnitude and length and age structure of recreational fisheries losses

  Historical estimates of recreational fisheries statistics are limited and/or unreliable (see sections 2.1.2 and 2.1.3). The NCDMF began a mail survey in October 2011 to develop catch and effort estimates for recreational cast net and seine use (section 2.1.2). This mail survey was established as a direct response to a lack of precision in the Marine Recreational Information Program (section 2.1.3). While the mail survey provides estimates of recreational harvest, releases, and effort, it does not collect biological data.

- Development of a reliable fisheries-independent index of juvenile abundance

The Beaufort Bridgenet Ichthyoplankton Sampling Program (BBISP) is a volunteer-supported long-term, fixed-site, monitoring survey for larval fish recruitment (see section 2.2.4). The survey began in 1986 and while sampling only occurs at one North Carolina inlet (Beaufort Inlet), it was considered as an index of age-0 recruitment in the initial base run of the current stock assessment; however, the peer review panel had some concerns about the limited spatial scope of the survey and it was not included in the final base run. An expansion of the NCDMF Program 100 seine survey to the Pamlico, Neuse, and Cape Fear rivers occurred in 2017 and may provide juvenile abundance information in the future as the time series builds up.

- Increase the number of age samples from both fisheries-dependent and fisheries-independent sources

  Collection of striped mullet age samples is ongoing through existing fisheries-dependent and fisheries-independent sampling programs and there has been an increased focus on collecting age samples from important commercial fisheries.

- Investigate how catchability of striped mullet by Program 146 (Striped Mullet Electrofishing Survey) is affected by variations in salinity and conductivity

  Surface conductivity has been collected in Program 146 since 2004 (section 2.2.1), but it's impact on catchability has not yet been evaluated.

- Initiate an adult striped mullet survey in the Core and Bogue sound areas where approximately 20% of the striped mullet harvest occurs

  In 2019, Program 915 (Fisheries-Independent Gill-Net Survey; section 2.2.3) was expanded as part of a Coastal Recreational Fishing License grant to include Core Sound, West Bay, Newport River, Bogue Sound, and the White Oak River. Other area segments of this survey are used in this assessment, but the expanded area was not included due to the short time series. The expanded area will be used in future assessments once an adequate time series is achieved. In addition, Program 146 was expanded in October 2021 to include the White Oak River.

- Explore the NOAA Bridgenet Survey as a possible larval/juvenile abundance index for striped mullet

  This survey considered in the initial base run in the current assessment as an index of age-0 recruitment (see sections 2.2.3); however, the peer review panel had some concerns about the limited spatial scope of the survey and it was not included in the final base run.

- Consider sex-specific selectivity curves in future modeling work

  No progress has been made on this recommendation.

- Consider a tagging program, using PIT tags similar to the ongoing PIT-tagging program for striped bass; such a program would provide estimates of stock size, F, and natural mortality (M) that are not dependent on assumptions about steepness; the estimates of M would be based on field data for this species in this state, rather than generic Ms for fish of this size based on a meta-analysis

  No progress has been made on this recommendation; however, the NCDMF has an existing multi-species tagging program that could incorporate striped mullet.

2 DATA

2.1 Fisheries-Dependent

2.1.1 Commercial Fishery Monitoring

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.

2.1.1.1 Survey Design & Methods

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 fisherman to the dealer. The data reported on these forms include transaction date, area fished, gear used, and landed species as well as fisherman and dealer information.

Most 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 increases the accuracy of reporting by documenting the correct relationship between gear and species but is not universally used by finfish dealers in North Carolina.

2.1.1.2 Sampling Intensity

North Carolina dealers are required to record the transaction at the time of the transaction and report trip-level data to the NCDMF on a monthly basis.

2.1.1.3 Biological Sampling

In 1982, the NCDMF initiated a statewide sampling program for the dominant commercial finfish fisheries. The objective was to obtain biological data on economically important fishes for use in management evaluations. Biological data were collected from fish houses for the ocean gill-net, long haul seine, pound net (sciaenid and flounder), beach seine/stop net, estuarine gill-net (began 1990), and cast net (began 2002) commercial fisheries. Similar methods are used across these programs to sample commercial catches. Information gathered from this sampling includes catch composition, poundage landed (from Trip Ticket), area fished, soak time, gear characteristics as well as length, weight, age, and sex information for target species.

2.1.1.4 Potential Biases & Uncertainties

Because trip tickets are only submitted when fish are transferred from fishermen to dealers, records of unsuccessful fishing trips are not available. 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.

A potential bias 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.

Commercial landings do not differentiate between striped mullet and white mullet; however, based on commercial fish house sampling, the proportion of white mullet that occur in North Carolina's commercial landings is considered very small. Striped mullet make up approximately 99% of the total mullet catch based on fishery-dependent sampling (NCDMF, unpublished data).

2.1.1.5 Development of Estimates

Commercial landings were summarized by year using the NCDMF TTP data. Commercial effort was calculated for select gears known to currently or historically target striped mullet. The number of targeted trips for anchored gill nets, runaround gill nets, and stop nets was calculated by year. Targeted trips were defined as those trips that caught only striped mullet or those trips that caught multiple species and at least 100 pounds of striped mullet.

Biological data collected from the NCDMF's Estuarine Gill-Net, Beach Seine, Ocean Gill-Net, Cast Net, Long Haul Seine, Sciaenid Pound Net, and Flounder Pound Net commercial fishery sampling programs were used to compute annual length and age compositions. The age compositions were computed by sex.

2.1.1.6 Estimates of Commercial Fishery Statistics

The NCDMF TTP is considered a census of North Carolina commercial landings. Annual commercial landings of striped mullet ranged from a low of 438 mt in 2016 to a high of 1,283 mt in 2000 between 1994 and 2019 (Table 2.1; Figure 2.1). Most commercial targeted trips for striped mullet in recent years occurred in the runaround gill-net fishery (Table 2.1; Figure 2.2). While the stop net fishery was important historically and can be a high volume striped mullet fishery, it has had relatively few trips since 1994.

The availability of striped mullet length samples from the commercial fishery was relatively low in the mid-1990s but substantially increased after 1996 (Table 2.2). The availability of sex-specific age samples has been low throughout the time series of interest.

Length-frequency distributions of striped mullet from the commercial fishery have been relatively consistent throughout the time series (Figure 2.3). The commercial landings are dominated by age-1 and age-2 striped mullet and there is some evidence the age distribution of the landings has truncated in recent years (Figure 2.4).

2.1.2 Recreational Fishery Mail Survey

2.1.2.1 Survey Design & Methods

Recreational catch data from the NCDMF Recreational Commercial Gear License (RCGL) survey were collected from 2002 to 2008. The program was discontinued in 2009 due to lack of funding and minimal contributions from RCGL to overall harvest. In October 2011, the NCDMF began a mail survey to develop catch and effort estimates for recreational cast net and seine use. The mail survey was established as a direct response to a lack of precision in the Marine Recreational Information Program (see section 2.1.3) estimates for difficult to sample or overlooked recreational fisheries and activities.

2.1.2.2 Sampling Intensity

Surveys are administered at bimonthly intervals or waves. Wave 1 includes January and February, wave 2 includes March and April, and so on. At the conclusion of a particular wave, surveys are mailed to approximately 1,300 randomly selected individuals who indicate participation in the cast net fishery at the time of Coastal Recreational Fishing License (CRFL) purchase. This survey samples approximately 8,000 individuals per year.

2.1.2.3 Biological Sampling

Biological samples have not been collected in conjunction with the mail survey.

2.1.2.4 Potential Biases & Uncertainties

The survey does not distinguish between striped and white mullet and all data should be interpreted with caution because the ratio of striped mullet to white mullet in the recreational catch will differ among seasons and areas of the state (note: most common county and waterbody of cast net/seine effort is asked as part of the survey but estimates are not developed by county).

2.1.2.5 Development of Estimates

Recreational harvest, releases, and effort were summarized by year using the mail survey data.

2.1.2.6 Estimates of Recreational Fishery Statistics

Excluding estimates for 2011, due to only a partial year sampled, annual recreational harvest of mullet (white plus striped) has averaged just over 700 thousand fish per year from 2012 through 2019 (Table 2.3; Figure 2.5). Recreational releases of mullet (white plus striped) have averaged over 230 thousand fish per year during the same time period.

Annual trends in effort have been similar to trends in harvest over the available time series (Figure 2.6). The number of annual recreational trips for mullet (white plus striped) has ranged from nearly 89 thousand trips to over 200 thousand trips between 2012 and 2019 (Table 2.3; Figure 2.6).

2.1.3 Marine Recreational Information Program

2.1.3.1 Survey Design & 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 striped mullet 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.

2.1.3.4 Potential Biases & Uncertainties

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.

The 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. Angler misidentification between striped mullet and white mullet is also common (NCDMF 2006). Bait mullet are usually released by anglers before visual verification by creel clerks and therefore are not identified to the species level in the MRIP data (Type B catch).

2.1.3.5 Development of Estimates

The online MRIP query tool was used to pull annual estimates of recreational harvest (A, B1, A + B1) and associated PSE values for striped mullet, white mullet, and mullet genus (striped or white mullet that could not be identified to species; National Marine Fisheries Service, Fisheries Statistics Division, personal communication). The online query tool was also used to pull annual estimates of the average individual weight of harvested striped mullet. The raw SAS data files were queried to summarize the annual number of assignments and intercepts in North Carolina as well as the number of assignments and intercepts that encountered striped mullet and mullet genus. The raw SAS data files were also queried to summarize the annual number of directed trips where directed trips were defined as those trips targeting striped mullet, white mullet, or mullet genus as well as trips that caught either striped mullet or mullet genus (two different time series). Estimates of live releases were not considered for inclusion in the stock assessment because mullet are primarily captured by recreational anglers for use as live bait and releases are assumed to have no associated post-release mortality and the assessment model only considers dead fish.

2.1.3.6 Estimates of Recreational Fishery Statistics

Annual recreational harvest (Type A + B1) of striped mullet has exhibited high inter-annual variability in terms of both numbers and weight from 1981 through 2019 (Table 2.4; Figures 2.7 and 2.8). The estimates of recreational harvest for striped mullet are associated with high uncertainty as PSE values for both numbers and weight typically exceed 50% (Table 2.4). Estimates of recreational harvest (Type A + B1) for white mullet are also highly variable and associated with high imprecision (Table 2.5; Figures 2.7 and 2.8). The recreational harvest (Type A + B1) estimates of mullet genus are also variable but demonstrate better precision, especially in 2000 and after (Table 2.6; Figures 2.7 and 2.8). Beginning in 2002, APAIS began deferring to mullet genus to classify unobserved type B1 and B2 catch. Similar identification challenges exist for other ambiguous congener species such as flounder and kingfish, which are also recorded to the genus level for both type B1 and B2 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 (Figure 2.7).

A closer inspection of the recreational harvest estimates for striped mullet suggests that a significant proportion of harvest is reported (Type B1; Table 2.7; Figure 2.9). As such, the species is identified by the individual angler and not the APAIS interviewer. In contrast, most of the recreational harvest estimates for white mullet are derived from observed harvest (Type A; Table 2.8). Almost all of the recreational harvest estimates for mullet genus come from reported harvest (Type B1; Table 2.9). This explains why there are so few estimates of recreational harvest in units of weight for mullet genus (Table 2.6) as the fish were not physically available to the interviewer for inspection.

The high uncertainty associated with the estimates of recreational harvest for the mullet species is partly due to the rarity with which they are encountered during APAIS interviews. On average, APAIS interviews encounter striped mullet in 1.5% of their assignments (locations) per year and in only 0.16% of intercepts per year (Table 2.10); however, the mullet genus is encountered more frequently. On average, APAIS interviewers encounter mullet genus in 3.8% of their assignments per year and in 0.64% of intercepts per year (Table 2.11). The higher frequency with which mullet genus are encountered relative to striped mullet suggests anglers have difficulty distinguishing between mullet species (recall that most of the mullet genus harvest is derived from reported harvest—harvest reported by the angler).

An evaluation of directed trips for mullet indicates a significant increase in 2002 relative to the earlier part of the time series (Table 2.12; Figure 2.10). Here, directed trips are defined as those trips that targeted striped mullet, white mullet, or mullet genus or trips that caught striped mullet (one time series) or mullet genus (second time series). Prior to 2002, striped mullet directed trips often exceeded those for mullet genus; this pattern switched in 2002 when mullet genus directed trips exceeded striped mullet directed trips in all remaining years. The deferred classification of mullet to the genus level was driven by concerns regarding species identification and a similar approach was used for unobserved catch for other ambiguous species such as flounder and kingfish.

The APAIS collects data from intercepted anglers concerning the primary fishing gear used. Gear options include hook and line, dip net, cast net, gill net, seine, trawl, trap, spear, hand, and other. Approximately 96% of intercepted anglers with mullet catch reported hook and line as their primary gear (Table 2.13). Gill net and cast net each comprise approximately 2% of reported gear with <1% reporting all other gear types. Trips that targeted mullet and reported mullet harvest indicated cast nets as their primary gear for ~67% of these intercepts (Table 2.14). Additionally, hook-and-line trips with reported mullet harvest predominately targeted flounder, red drum, and spotted seatrout and these trips represented ~85% of all intercepts. These data suggest that mullet are primarily used as baitfish and not necessarily caught using the primary gear reported for most trips (i.e., hook and line). Finally, trips that reported gill nets as their primary gear and targeted or caught mullet of any species represented ~53% of all gear specific intercepts. This suggests that in North Carolina the recreational mullet gill-net fishery is targeted, albeit *de minimis* to the hook-and-line fishery.

The average length of striped mullet encountered in North Carolina’s MRIP survey has ranged from a minimum of 0.61 cm in 1988 to a maximum of 43.2 cm in 1993 (Table 2.15). The average of the annual average lengths over the 1981 to 2019 time series is 27.9 cm, which corresponds to an age of 1.7 years for striped mullet based on the von Bertalanffy age-length function. Average weights have ranged from a minimum of less than 0.1 kg in 1988 to a maximum of 1 kg in 1993, 1994, and 1995. Both the average lengths and the average weights in almost all years of the time series are associated with high degrees of imprecision.

The working group recommended for the base run of the stock assessment that the sum of recreational harvest for striped mullet and a proportion of the recreational harvest for mullet genus be used for removals by the recreational fleet. The proportion of mullet genus recreational harvest that was recommended was 29%, a value derived from a study by the NCDMF of cast net recreational harvest for striped mullet. Sensitivity analyses was performed on this value as well as the overall magnitude of the recreational harvest (section 3.1.7.3).

Historically, the MRFSS was limited in its ability to capture both striped and white mullet as evidenced by annual gaps in the production of estimates and notoriously high PSEs in years with estimates. Additionally, the increased proportion of reported unobserved type B1 harvest further exasperated the uncertainty of species specific contributions. Due to the angling communities perceived inability to differentiate among ambiguous congener species (i.e., white and striped mullet) a methodological improvement was implemented in 2002 where unobserved type B1 and B2 catch is recorded at the genus level. A similar approach was adopted for other ambiguous species including flounder, kingfish, and trout. 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 and estimates prior to 2002 (back to 1950) were be assumed equal to the median of the 2002 to 2019 time series.

The length-frequencies distributions collected in North Carolina’s MRIP survey are considered to be an inaccurate representation of the recreational fishery (Figures 2.11 and 2.12). 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 10 cm in total length are used. The length distribution of striped mullet harvested in the recreational fishery is better represented by the length-frequencies distributions collected from the fishery-independent cast net survey (section 2.2.4). This survey does show catches of the larger fish represented in the MRIP data, but they make up a small proportion of the catch.

2.2 Fisheries-Independent

2.2.1 Striped Mullet Electrofishing Survey (Program 146)

2.2.1.1 Survey Design & Methods

The NCDMF Striped Mullet Electrofishing Survey, also known as Program 146, was initiated in 2003 to produce a fisheries-independent index of relative abundance for striped mullet in the central district of North Carolina. Twelve sampling stations were established among four sites (three per site) in the Neuse River and its tributaries (Batchelor Creek, Hancock Creek, Slocum Creek, and Neuse River in New Bern; Figure 2.13). The Neuse River area is an important year-round habitat and a major migration path for striped mullet in North Carolina.

Electrofishing sampling is conducted over a fixed 500-m stretch of shoreline in linear transects at each station. Electric current is generated from a 16-hp Briggs and Stratton generator (model number 7.5GPP—Smith Root). Sampling is conducted by boat with two netters. Dip-net mesh sizes are ⅛ and ¾ inches, respectively.

2.2.1.2 Sampling Intensity

Samples were collected monthly from 2003 to 2008. As of 2009, sampling has been reduced to January through April (spring) and October through December (autumn); each station is sampled once per month for an annual total of 84 samples; however, sampling deviations have occurred throughout the time series due to mechanical problems and environmental variability beyond the limits of electrofishing gear.

2.2.1.3 Biological Sampling

All species that are netted are identified to the lowest possible taxon and counted. Individual length measurements are recorded for commercially and recreationally important marine species, including striped mullet. All netted fish are held in a holding tub and enumerated and/or measured after the 500-m transect has been sampled.

2.2.1.4 Potential Biases & Uncertainties

Program 146 is the only survey the NCDMF conducts that is designed to target striped mullet. Currently this program covers a small geographic area located within the Neuse River. Electrofishing gear can have biases in species composition, size distribution, and abundance (Reynolds 1983; McInerny and Cross 1996).

Indices based on fixed-station surveys such as Program 146 may not accurately reflect changes in population abundance (Warren 1994, 1995). Accuracy of estimates is tied to the degree of spatial persistence in catch data of the species. An evaluation of the striped mullet data collected from

Program 146 indicated the presence of spatial persistence for striped mullet, suggesting the derived index is reflective of changes in relative abundance (Lee and Rock 2018).

2.2.1.5 Development of Estimates

Indices were calculated for both the spring and autumn components of the survey. Since the survey primarily catches adult striped mullet, juveniles were excluded from the calculations. Only data collected from Hancock and Slocum creeks were included in the development of the index because the original purpose of the upriver stations (the Neuse River in New Bern and Batchelor Creek) was to capture striped mullet during summer sampling. Summer sampling has since been discontinued. Catch of striped mullet in spring and autumn months is low at these stations; only 8% of the total number of striped mullet were caught in Batchelor Creek and 4% in the Neuse River in New Bern. There were 22 sampling trips from 2006 to 2008 that were not attempted due to high salinity and were therefore removed from analysis. There was no sampling conducted during November and December of 2005 and 2006 as well as January 2007 due to the mechanical errors.

A generalized linear model (GLM) framework was used to model the relative abundance of adult striped mullet in Program 146. Potential covariates were evaluated for collinearity by calculating variance inflation factors. Collinearity exists when there is correlation between covariates and its presence causes inflated *p*-values.

The Poisson distribution is commonly used for modeling count data; however, the Poisson distribution assumes equidispersion; that is, the variance is equal to the mean. Count data are more often characterized by a variance larger than the mean, known as overdispersion. Some causes of overdispersion include missing covariates, missing interactions, outliers, modeling non-linear effects as linear, ignoring hierarchical data structure, ignoring temporal or spatial correlation, excessive number of zeros, and noisy data (Zuur et al. 2009, 2012). A less common situation is underdispersion in which the variance is less than the mean. Underdispersion may be due to the model fitting several outliers too well or inclusion of too many covariates or interactions (Zuur et al. 2009).

Data were first fit with a standard Poisson GLM and the degree of dispersion was then evaluated. If over- or underdispersion was detected, an attempt was made to identify and eliminate the cause of the over- or underdispersion (to the extent allowed by the data) before considering alternative models, as suggested by Zuur et al. (2012). In the case of overdispersion, a negative binomial distribution can be used as it allows for overdispersion relative to the Poisson distribution. Alternatively, one can use a quasi-GLM model to correct the standard errors for overdispersion. If the overdispersion results from an excessive number of zeros (more than expected for a Poisson or negative binomial), then a model designed to account for these excess zeros can be applied. There are two types of models that are commonly used for count data that contain excess zeros. Those models are zero-altered (two-part or hurdle models) and zero-inflated (mixture) models (see Minami et al. 2007 and Zuur et al. 2009 for detailed information regarding the differences of these models). Minami et al. (2007) suggests that zero-inflated models may be more appropriate for catches of rarely encountered species; therefore, zero-inflated models were considered here when appropriate.

All available covariates were included in the initial model and assessed for significance ($\alpha = 0.01$) using the statistical test appropriate for the distribution. Non-significant covariates were removed using backwards selection to find the best-fitting predictive model.

Annual length and age compositions were computed based on the same reference data used to calculate the index. The age compositions were computed by sex.

2.2.1.6 Estimates of Survey Statistics

Available covariates were year, area, depth, water temperature, salinity, dissolved oxygen, sediment size, bottom composition, weather, wind direction, wind speed, and precipitation. Year, area, sediment size, bottom composition, weather, and wind direction were treated as categorical variables in the models. Since effort was constant across sampling events, the modeled response variable was counts of striped mullet. The final, best-fitting model for the spring component of the survey was a quasi-Poisson model and included year, area, dissolved oxygen, bottom composition, weather, and wind direction as significant covariates. The spring index is variable and no discernable trend is apparent over the time series (Figure 2.14). For the autumn component of the survey, the best-fitting model was a quasi-Poisson and included year, area, and depth as significant covariates. The autumn index is also variable with no apparent overall trend over the time series (Figure 2.15).

The availability of biological samples from Program 146 has been variable over the years (Table 2.16). The number of annual length samples appears adequate, especially for the spring component of the survey; however, the number of sex-specific age samples, especially for males in both seasons, has been low over the time series and suggests inferences made from the age compositions should be interpreted with caution.

The annual length frequencies of striped mullet observed in the spring component of Program 146 has narrowed in recent years relative to the wider distributions observed in late 2000s through early 2010s (Figure 2.16). The age-frequency distributions of adult striped mullet collected by Program 146 in the spring are dominated by age-2 fish (Figure 2.17). The spring age-frequency distributions have contracted in recent years.

Similar to the length compositions in the spring component, the length-frequency distributions in the autumn component of Program 146 have exhibited a narrower range in recent years than that observed in the late 2000s and early 2010s (Figure 2.18). The age composition data show that the autumn component of the Program 146 survey is dominated by age-1 fish in most years (Figure 2.19). Striped mullet older than age 3 are rarely observed.

2.2.2 Fisheries-Independent Gill-Net Survey (Program 915)

2.2.2.1 Survey Design & Methods

The Fisheries-Independent Gill-Net Survey, also known as Program 915, began on March 1, 2001 and includes Hyde and Dare counties (Figure 2.20). In July 2003, sampling was expanded to include the Neuse, Pamlico, and Pungo rivers (Figures 2.21, 2.22). Additional areas in the Southern District including the New and Cape Fear rivers were added in April 2008 (Figure 2.23).

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. Only shallow water samples are collected in the Cape Fear River. Gill nets are typically deployed within an hour of sunset and fished 11.5 hours later, except from May 1 to August 31 when nets are deployed 1.5 hours prior to sunset. Efforts are made to keep all soak times within 12 hours except in the Southern District where soak times are reduced to four hours from April 1 through September 30 and nets are deployed two hours prior to sunset. 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. In Hyde and Dare counties (Pamlico Sound area), sampling 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 east to west, while the Dare areas are numbered north to south. The river area is divided into four regions in the Neuse River (Upper, Upper-Middle, Lower-Middle, and Lower), three regions in the Pamlico River (Upper, Middle, and Lower), and only one region for the Pungo River. The upper Neuse region was reduced to avoid damage to gear from obstructions, and the lower Neuse was expanded to increase coverage in the downstream area. The Pungo region was expanded to include a greater number of upstream sites where a more representative catch of striped bass may be acquired. The southern area is divided into three regions: upper New River (from Wilson Bay to Hines Point line extending eastward to French's Creek), lower New River (Hines Point to the intersection of the New River and the Intracoastal Waterway), and the Cape Fear River (the northern end of U.S. Army Corps of Engineer's Island 13 south to the mouth of the river).

2.2.2.2 Sampling Intensity

Initially, sampling occurred during all 12 months of the year. In 2002, sampling during December 15 to February 14 was eliminated due to extremely low catches and unsafe working conditions. Sampling delays were extensive in 2003, so this year was excluded from analysis because of the lack of temporal completeness. 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; shallow and deep) in Pamlico Sound. Beginning in 2012 in Pamlico Sound Region 1, Area 1 is not sampled from June 1 through August 31—only 28 samples are collected during these months. In the Pamlico/Pungo and Neuse rivers, a total of 32 samples are completed each month (eight areas × twice a month × two samples; shallow and deep). In the Southern District, a total of 12 samples are completed each month (New River: two areas × twice a month × two samples; shallow and deep; Cape Fear River: one area × four times a month × one shallow sample).

2.2.2.3 Biological Sampling

All fish are sorted by species. A count and a total weight to the nearest 0.01 kg, including damaged (partially eaten or decayed) specimens, are recorded. Length, age, and reproductive samples are taken from selected target species, including striped mullet. Samples are processed according to the ageing project protocols.

2.2.2.4 Potential Biases & Uncertainties

Although striped mullet are considered a target species, this program was not designed to specifically target striped mullet. The sampling effort is designed to gather data on fishes using the estuarine habitats but does not account for nearshore ocean and offshore ocean populations. Also, the range of gill-net mesh sizes used in this survey will exclude the smallest individuals. This survey does not sample the many shallow creeks and tributaries off the main river stems, habitats that are frequently used by striped mullet (NCDMF, unpublished data).

2.2.2.5 Development of Estimates

To provide the most relevant indices, data were limited to those collected from shallow water during August through December, when the majority of striped mullet occur. Separate indices were initially developed for the southern (New River) and northern (Neuse, Pamlico, and Pungo rivers, and Pamlico Sound) areas. A combined index was also calculated. The Cape Fear River was excluded from analysis due to widely varying catches. Since the survey primarily catches adult striped mullet, juveniles were excluded from the calculations. The GLM method used to model the relative abundance of striped mullet in Program 146 (see section 2.2.1.5) was also used to model the relative abundance of adult striped mullet in Program 915.

Annual length and age compositions were computed based on the same reference data used to calculate the index. The age compositions were computed by sex.

2.2.2.6 Estimates of Survey Statistics

Available covariates were year, stratum, stratum weight, depth, water temperature, salinity, dissolved oxygen, sediment size, bottom composition, weather, wind direction, wind speed, and precipitation. Year, stratum, sediment size, bottom composition, weather, and wind direction were treated as categorical variables in the models. Since effort was constant across sampling events, the modeled response variable was counts of striped mullet. The final, best-fitting model for the southern area of the survey assumed a quasi-Poisson distribution and included year and dissolved oxygen as significant covariates. The southern area index exhibits a general declining trend over the time series (Figure 2.24). For the northern area of the survey, the best-fitting model assumed a quasi-Poisson distribution and included year, stratum, depth, salinity, dissolved oxygen, and sediment size as significant covariates. The Program 915 northern area index shows higher values in the early part of the time series and a decrease beginning in 2015 where it remains at lower, but slightly increasing, levels through 2019 (Figure 2.25). For the combined index, the best-fitting model assumed a quasi-Poisson distribution and included year, stratum weight, bottom salinity, bottom DO, and bottom composition as significant covariates. The northern and southern area combined index is higher in the initial part of the time series and shows a decrease to 2015 where it remains at lower, but slightly increasing levels through the end of the time series (Figure 2.26).

Biological samples are available from each area of Program 915 throughout the duration of the survey (area-specific; Table 2.17). The majority of striped mullet length and sex-specific age samples collected in Program 915 were collected from the northern area because of the longer time series and higher striped mullet catches.

Length-frequency distributions of adult striped mullet in the southern area of Program 915 suggest a slight expansion into larger sizes during the early part of the time series before the length-frequency distributions began to truncate in the latter portion of the time series (Figure 2.27). Catches in the southern area of Program 915 are predominantly comprised of age-1 and age-2 fish with few fish over age-3 observed in any year (Figure 2.28).

The lengths of striped mullet observed in the northern area of Program 915 show an expansion in the most recent years of the available time series (Figure 2.29). Northern area catches are dominated by age-1 and age-2 striped mullet and striped mullet older than age 3 are infrequent (Figure 2.30).

2.2.3 Beaufort Bridgenet Ichthyoplankton Sampling Program

2.2.3.1 Survey Design & Methods

The Beaufort Bridgenet Ichthyoplankton Sampling Program (Bridgenet Survey), initiated in 1986, is a volunteer-supported long-term, fixed-site, monitoring survey for larval fish recruitment. The objective of sampling is to contribute to the understanding of estuarine-dependent species including spawning data, larval growth, and age at ingress.

The Bridgenet Survey involves once-weekly, flood-tide, nighttime samples collected at a fixed platform on Pivers Island Bridge, Beaufort, NC (Figure 2.31). The Bridge spans a 40-m wide and 7-m deep (maximum) channel 1.5 km upstream from the Beaufort Inlet. An estimated 10% of the water flowing into the Beaufort Inlet flows through this channel. Temperature (℃), salinity (ppt), and dissolved oxygen (mg/L) are recorded at the beginning and/or end of each sampling event. Note, from 2000 to 2010, temperature and salinity were generally not recorded and missing information was filled in with the closest National Estuarine Research Reserve System System-Wide Monitoring Program or National Oceanographic and Atmospheric Administration (NOAA) National Water Level Observation Network tide gauge station.

The program uses a 2-m^2 neuston plankton net with 1-mm mesh fitted with a General Oceanics' flowmeter that has a digital readout for total distance and tow duration. Tow duration varies according to a target of 50-m distances to achieve a target sampling volume of 100 m^3. Starting in December 2016, tows were targeted at five minutes (or three minutes if large volumes of ctenophores present or other issues). During 2007 and 2008, a 1-m hoop net with 500-um mesh and 10-minute fixed tow duration was used instead of a neuston net.

2.2.3.2 Sampling Intensity

Since November 1986, samples have been collected once weekly during the core sampling season, which is defined as November through April. A sample consists of four replicate net tows; however, prior to November 1988, only three net tows were used in a sample and other inconsistencies in the number of tows in a sampling event exist throughout the time series. The average starting week of the sampling season is defined as week 46 of the calendar year where week one is assigned based on the first week of the year that contains January 1st and weeks start on Sunday. A total of 25 weeks make up the sampling season for a season total of 25 samples, but this number is variable season to season. Sampling outside the core season and additional sampling effort has occurred including year-round sampling in 2003 and 2007 to 2008. Net tows are fished at the surface about 2.5 hours before the predicted high tide.

2.2.3.3 Biological Sampling

After each tow, the net is rinsed through a 1-mm mesh sleeve and the larval catch is preserved in ethanol alcohol. If advanced juvenile or adult forms of fish are collected in the net (>35 mm), they are either discarded or sorted, identified, and measured. Prior to 2001, larvae were sorted, identified, and counted at the NOAA Beaufort Laboratory. Since 2001, fish larvae have been sorted, identified, counted, and measured at the Sea Fisheries Institute, Plankton Sorting and Identification Center (Gdynia and Szczecin, Poland). Starting in 2001, measurements to the nearest

0.1 mm in body length were recorded for up to ten individuals of specific taxa, including striped mullet. Starting in 2017, the maximum number of individuals measured from a net tow increased to 20.

2.2.3.4 Potential Biases & Uncertainties

North Carolina has many coastal inlets where estuarine ingress of striped mullet larvae is likely to occur; however, sampling only occurs at a single, fixed location and may not be representative of striped mullet larval abundance if larval ingress exhibits high spatial and temporal variability. Indices based on fixed-station surveys may not accurately reflect changes in population abundance (Warren 1994, 1995). Accuracy of estimates is tied to the degree of spatial persistence in catch data of the species. There are two years in the time series (2007 and 2008) where changes in sample gear occurred and is not comparable to the standard gear.

2.2.3.5 Development of Estimates

Ten samples from 2007 to 2008 that used only hoop gear instead of neuston gear were removed from the analysis. A nominal index was computed for the Bridgenet Survey as there were insufficient data on covariates collected throughout the time series to apply the GLM approach. Data collected in November and December were grouped with data from January through April of the following year. The average density (numbers of striped mullet/volume filtered) was calculated for each sampling event from the replicate tows. The annual index of relative recruit abundance was calculated as the annual average density of age-0 striped mullet.

Length data collected since 2001 were summarized over the time series to provide an overall representative length-frequency distribution.

2.2.3.6 Estimates of Survey Statistics

The trend in relative abundance of age-0 striped mullet is highly variable and generally declining over the time series (Figure 2.32). The index suggests a relatively low year class occurred in 2000.

Striped mullet observed in the Bridgenet Survey have ranged in length from 11 mm to 33 mm (Figure 2.33). The modal length occurs at 22 mm.

2.2.4 Cast Net Study (Program 121)

2.2.4.1 Survey Design & Methods

Sampling took place in Dare and Carteret counties in 2002 and 2003 and also in New Hanover County in 2003. Fixed stations were chosen based on different habitats (i.e., ocean, inlet and estuarine locations). Ocean stations were located on piers and on the ocean side of inlets. Inlet stations were shallow water habitats located in the sounds and rivers within 5 miles (8 km) from the closest inlet. Estuarine stations were shallow water habitats located in the sounds and rivers greater than 5 miles (8 km) from the closest inlet. A typical, six-foot radius monofilament cast net (3/8 in. bar mesh and ¾ lb. of lead per radius foot) commonly used by recreational bait harvesters was used in the study. Samples were sorted by station location and by month to analyze differences in proportions of striped and white mullet.

2.2.4.2 Sampling Intensity

At total of 72 cast net samples were collected from late August to November 2002 and from June to November 2003. Most samples (n = 37) were collected at near coastal inlets, 25 were estuarine collected at estuarine stations, and 10 were collected from ocean stations. No sampling occurred from December through May because very little cast netting for mullets occurs during these months. Ocean stations were only sampled from August through November, since mullets are typically scarce and are not targeted by cast netters in the ocean in June and July. A target number of 100 mullets and a maximum of 50 cast net throws were made at each station. Water temperature (°C), salinity (ppt), dissolved oxygen (mg/L), bottom substrate, tidal stage (when applicable), and water depth (m) were recorded at each location.

2.2.4.3 Biological Sampling

Finfish and crustaceans were identified to species, enumerated, and measured.

2.2.4.4 Potential Biases & Uncertainties

Fishery-independent cast net samples were used as a proxy for the proportion of striped mullet and white mullet in the recreational cast net mullet harvest. While methodology and gear between recreational cast net sampling and fishery-independent cast net sampling is similar, the true species composition in cast net samples is likely influenced by spatial and temporal patterns in effort, environmental conditions, and fluctuations in recruitment of both mullet species. Sampling was primarily conducted in areas of the sound in the vicinity of coastal inlets (within 5 miles). The furthest west station was located in Adams Creek, a tributary near the mouth of Neuse River whose environmental conditions are also likely influenced by connection to the Intracoastal Waterway. The ratio of striped to white mullet in locations further upriver or in areas more influenced by freshwater inputs may be different than areas closer to the coast.

2.2.4.5 Development of Estimates

Samples were sorted by station location and by month to analyze differences in proportions of striped and white mullet.

2.2.4.6 Estimates of Survey Statistics

White mullet made up the greatest proportion of the samples from June through October, but in November, striped mullet comprised 74% of the mullets in the samples. Across all months, white mullet comprised 93% of the mullets from the ocean stations and 74% of the mullets from the inlet stations, whereas 67% of the mullets from the estuarine stations were striped mullet. Overall survey data identified 29% of the cast netted mullets as striped mullet.

Striped mullet from the independent cast net samples ranged from 5–39 cm FL with 76% of the fish from 7–14 cm FL (Figure 2.34). White mullet from the independent cast net samples ranged from 4–19 cm FL with 98% of the fish between 6 and 15 cm FL. Sub-adult and adult striped mullet were occasionally caught in the independent samples, but no sub-adult or adult white mullet were captured.

3 ASSESSMENT

3.1 Method—Stock Synthesis

3.1.1 Scope

For the purposes of this stock assessment, the unit stock is defined as all striped mullet occurring in North Carolina coastal and inland waters.

3.1.2 Description

This assessment is based on a forward-projecting, length-based, age-structured model. A two-sex model is assumed. The stock was modeled using Stock Synthesis text version 3.30 (SS3) software

(Methot 2000; Methot and Wetzel 2013; Methot et al. 2021). Stock Synthesis is an integrated statistical catch-at-age model that is widely used for stock assessments throughout the world. SS3 was also used to estimate values for established reference points. All SS3 model input files are available upon request.

3.1.3 Dimensions

The assessment model was applied to data collected from within the range of the assumed biological unit stock (North Carolina coastal and inland waters; see section 1.2.1).

The time period modeled was 1950 to 2019 using an annual time step based on the calendar year. The year 1950 was recommend as the start year by the peer review panel because it was the earliest year for which commercial landings were available. The terminal year, 2019, was selected because it was the most recent year from which data were available at the start of the assessment process.

3.1.4 Structure / Configuration

3.1.4.1 Catch

The model incorporated commercial landings and recreational harvest of striped mullet in North Carolina. No commercial discards were included in the model as they are considered minimal. As only dead fish were included in the model, recreational live releases that did not survive were not considered as 100% survival is assumed.

3.1.4.2 Survey Indices

The model incorporated one annual index of relative abundance (and associated standard errors, see section 3.1.5), which was derived from the Program 915 (P915) Survey (see section 5 for decisions regarding indices to include and exclude). As described in detail in section 2.2.1.5, the P915 Survey index was standardized using a GLM approach to attempt to remove some of the factors other than changes in abundance that can influence the observed changes over time (Maunder and Punt 2004).

Catchability, *q*, was assumed to be time-invariant for the P915 Survey. The ‘float’ option within SS3 was selected for the survey catchability, which means SS3 calculates an analytical solution for *q* rather than directly estimating the value.

The P915 Survey index was assumed to have a nonlinear relation to abundance, requiring an additional parameter to be estimated (survey ‘power’). Following a recommendation by the model developer, the power parameter was assigned a prior value (R.D. Methot Jr., NOAA Fisheries, personal communication). The power parameter was assigned a prior value of 0 and assumed to follow a normal distribution.

3.1.4.3 Length Composition

Annual length frequencies were input for the commercial and recreational fleets and the P915 Survey. The P915 Survey length frequencies were calculated using the same reference data (i.e., same months and areas) used to develop the index. Length frequencies were input by 2-cm length bins ranging from 10 cm to 56 cm FL.

3.1.4.4 Age Data

Annual sex-specific age compositions were input for the commercial fishery and the P915 Survey. Age data were not available for the recreational fleet. The age data were input as raw age-at-length data, rather than age compositions generated from applying age-length keys to the catch-at-length compositions. The input compositions are therefore the distribution of ages obtained from samples in each length bin (conditional age-at-length). This is considered a superior approach because it avoids the double use of fish for both age and size information since the age information is considered conditional on the length information, it contains more detailed information about the age-length relationship, and can directly match the protocols of the sampling program when age data are collected using a length-stratified approach (Methot et al. 2021). Making the age composition data conditional on length also has the advantage of linking age data directly to the length data (essentially creating an age-length key) and so provides more detailed information about the relationship between length and age, enhancing the ability to estimate growth parameters (Cass-Calay et al. 2014).

As with length frequencies, the P915 Survey age compositions were calculated using the same reference data used to develop the indices. Age 7 was treated as a plus group that included ages 7 through 15. Ages were assumed to be associated with small bias and negligible imprecision.

3.1.4.5 Biological Parameters

Natural Mortality

The Stock Synthesis model allows for several options regarding natural mortality. For the current assessment, the Lorenzen option was selected. Natural mortality is specified for a given reference age and calculated for other ages based on Lorenzen's (1996) method. The selected reference age was age 2. Based on Lorenzen's (1996) approach, M at age 2 for females was assumed equal to 0.53 and for males was assumed equal to 0.56 (see section 1.2.6; Table 1.3).

Growth

Growth (age-length) was assumed to be sex specific and was modeled using the von Bertalanffy growth curve. In the SS3 model, when fish recruit at the real age of 0.0, their length is set equal to the lower edge of the first population length bin (here, 10 cm; Methot et al. 2021). Fish then grow linearly until they reach a real age equal to a user-specified age (here, age 1). As the fish continue to age, they grow according to the von Bertalanffy growth equation.

Allowing SS3 to estimate the growth curve ensures that the assumptions about selectivity are consistent with other parts of the model and that uncertainty in the growth estimates is incorporated into the estimates of spawning stock biomass, fishing mortality, and reference points (Hall 2013). All age-length growth parameters were estimated for both sexes. The estimated growth parameters for each sex were length at age 1 ($L1$), L_∞, K, coefficient of variation (CV) for $L1$ (CV1), and CV for L_∞ (CV2). Initial values for L_∞ and K were derived by fitting the von Bertalanffy model to the available age-length data by sex (see also section 1.2.4.4; Table 1.1). The initial values for $L1$ were derived based on the estimated von Bertalanffy parameters. Initial values for the CV1 and CV2 were derived empirically for each sex. The initial values for the growth parameters were treated as diffuse priors (prior standard deviation=2.0) assuming a symmetric beta distribution. Examination of the observed data was used to set reasonable bounds on all growth parameters for males and females.

Parameters of the allometric length-weight relationship were fixed (i.e., not estimated) for both females and males. The assumed values were those estimated in this report as described in section 1.2.4.4 (Table 1.2).

Maturity & Reproduction

The length logistic maturity option was selected for defining female maturity. The maturity parameters were fixed in the model at the values estimated using the histological data collected in the NCDMF maturity study (see section 1.2.5).

Reproduction was assumed to occur on January 1 each year.

Fecundity

The SS3 model allows several options for relating fecundity to body size (length or weight). Empirical parameter values describing a linear or non-linear relationship to length or weight can be entered. Alternatively, the user can specify that either eggs or fecundity is equivalent to spawning biomass. Here, the selected fecundity option was that which causes eggs to be equivalent to spawning biomass.

3.1.4.6 Stock-Recruitment

A Beverton-Holt stock-recruitment relationship was assumed. Recruitment varied log-normally about the curve. Preliminary runs suggested that the steepness (*h*) parameter could be estimated. A likelihood profile was run on steepness to obtain a starting value based on the minimum of the profile for the total likelihood component (see section 3.1.7.4 for description of likelihood profiling). This value, 0.77, was set as a prior with a standard deviation of 0.3 and assumed a normal distribution (Figure 3.1).

Virgin recruitment (R_0) was estimated by the model using a symmetric beta prior and the standard deviation of log(recruitment), σ_R, was initially fixed at 0.74 based on the meta-analysis by Thorson et al. (2014). The value of σ_R should be selected to approximate the true average recruitment deviations (Methot et al. 2021). Preliminary runs of the model resulted in an error that the bias adjustment for the main recruitment deviations was greater than two times the ratio of the root mean square error (RMSE) to σ_R. The multivariate hierarchical life history tool FishLife (Thorson et al. 2017) was used to derive a value of σ_R, 0.38, that better aligned with the estimated variance of the recruitment deviations.

There are several options for coding the recruitment deviations. Here, the option for a deviation vector was selected. For this option, the recruitment deviations constrained to sum to zero (Methot et al. 2021). Recruitment deviations were estimated from 1988 to 2019. The expected recruitments require a bias adjustment so that the recruitment level is mean unbiased because SS estimates recruitment on a log scale. Methot and Taylor (2011) recommend that the full bias adjustment be applied to data-rich years. The SS_plots function within the r4ss package (Taylor et al. 2021) can be used to obtain a recommendation for the time period for which to apply the full bias adjustment as well as a recommended value for the maximum bias adjustment parameter. After the recommended value for Francis weights of the composition data were obtained (see section 3.1.5), the model was rerun and the SS_plots function was applied through the R software (version 4.1.2; R Core Team 2021) several times until the recommendations converged on a recommended start (1996.3) and end (2019.2) year and the maximum bias adjustment parameter value (0.8077), which were implemented in the final base model run.

3.1.4.7 Fishing Mortality

SS3 allows several options for reporting fishing mortality (*F*). Based on a recommendation from the model developer (R.D. Methot Jr., NOAA Fisheries, personal communication), the *F* values reported here represent a real annual F calculated as a numbers-weighted F (see Methot et al. 2021) for ages 1–5, the age range that comprises the majority of the commercial landings.

3.1.4.8 Selectivity

Selectivity can be cast as length and/or age specific in the SS3 model. As the length data were considered more reliable, the length-specific option was chosen for both fleets and the fisheries-independent surveys.

It is difficult for a stock assessment model to provide a reliable fit when all selectivity parameters are freely estimated. The working group discussed the probable shapes (dome, asymptotic, or other) of the selectivity curves for the two fleets and each fisheries-independent survey. Initially, the selectivity patterns considered for each fleet and survey were based on the theoretical shape derived from underlying processes and gear experiments. For instance, landings from the commercial fishery come from both small-mesh runaround nets as well as large-mesh nets that select for larger fish. The smallest size striped mullet escape through the small mesh but there is no gear that is believed to exclude larger fish from the landings. For these reasons, an asymptotic selectivity curve was assumed for the commercial fishery fleet.

The P915 Survey is a gill-net survey and gill nets are typically assumed to follow a dome shape (Millar and Fryer 1999); however, the working group believes this survey is capable of catching the largest size striped mullet and so an asymptotic shape was assumed for the P915 Survey.

The recreational fishery targeting mullet typically uses cast nets to target juvenile or “finger mullet” for use as live bait. The mesh sizes used in a typical cast net exclude the smallest sized mullet. Angler preference for smaller mullet excludes the largest mullet from the catch, though they are sometimes encountered. For these reasons the working group believes assuming dome-shaped selectivity for the recreational fishing fleet is most appropriate.

A two-parameter logistic curve was used to describe the selectivity for both the commercial fleet and the P915 Survey. The recommended double normal selectivity pattern was used for the selectivity of the recreational fleet. This pattern is flexible in that it can take on a dome or asymptotic shape. The model had extreme difficulty in estimating the selectivity parameters for the recreational fleet. Following the recommendations of the peer review panel, the selectivity parameters of the recreational fleet were fixed at values that led to a reasonable fit to the recreational length compositions.

3.1.4.9 Equilibrium Catch

The SS3 model needs to assume an initial condition of the population dynamics for the period prior to the estimation period. Typically, two approaches are used to meet this assumption. The first approach starts the model as far back as necessary to satisfy the notion that the period prior to the estimation of dynamics was in an unfished or near unfished state. Reliable catch records back to the start of the fishery are not available for striped mullet. For this reason, the model developer recommended use of the second approach, which is to estimate (where possible) initial conditions assuming equilibrium catch (R.D. Methot Jr., NOAA Fisheries, personal communication). The equilibrium catch is the catch taken from a fish stock when it is in equilibrium with removals and natural mortality balanced by stable recruitment and growth.

The SS3 model estimates initial equilibrium catch and initial fishing mortality for each fleet. The initial fishing mortality rates are estimated based on the level of initial equilibrium catch for each fleet. Providing an initial equilibrium catch allows the model to start in a fished state prior to the start year. For the commercial fleet, the starting value provided to the model for initial equilibrium catch was set as half of the minimum observed annual landings over the 1950- to 2019-time series (161.9 mt) and associated with a standard error, SE, equal to 0.20. The initial equilibrium catch for the recreational fleet was set to half of the minimum observed annual harvest over the time series (244.7 thousand fish) and associated with a SE equal to 0.20. The starting value for the initial fishing mortality of both fleets was set at 0.40.

3.1.5 Optimization & Weighting

SS3 assumes an error distribution for each data component and assigns a variance to each observation. The commercial landings were fit in the model assuming a lognormal error structure. Commercial landings were assumed well known and assigned a minimal observation error (SE = 0.01).

Survey indices were fit assuming a lognormal error distribution. The standard errors estimated either from the GLM standardization or the nominal approach were scaled to an average of 0.2 across the time series, within each survey index, but the relative annual variation was maintained in the scaling. This approach is considered more appropriate than using the standard error from the GLM standardization as it avoids the undue influence of any one index (SEDAR 2019). Because different techniques are used to compute the indices, it is not expected that the estimated standard errors would be directly comparable. Scaling each set of standard errors to a common mean allows them to be placed on equal footing within the assessment.

Composition information was fit assuming a multinomial error structure with variance described by the effective sample size. In the previous NCDMF stock assessments of striped mullet, the effective sample size was set as the number of sampled trips, assuming a maximum of 200 for each fleet or survey observation (NCDMF 2013, 2018). In order to prevent overfitting of the composition data and in order to maintain the inter-annual differences in data quality that would be lost by an arbitrary cap, the input effective sample sizes for the composition data were set equal to the square root of the observed number of sampled trips (SEDAR 2019).

Priors were assumed for the power parameters for the fisheries-independent survey indices (section 3.1.4.2), for the growth parameters (section 3.1.4.5), and for R_0 and the steepness parameter (section 3.1.4.6). Bounds (minimum and maximum values) were established on all estimated parameters to prevent estimation of unrealistic parameter values and convergence problems (Table 3.1).

The objective function for the base model included likelihood contributions from the commercial landings, recreational harvest, fisheries-independent survey index, length compositions, age data, initial equilibrium catch, and recruitment deviations. The total likelihood is the weighted sum of the individual components. All likelihood components, with the exception of the age data, were assigned a lambda weight equal to 1.0 in the base run. Based on a recommendation from the model developer in a similarly structured assessment, the lambdas for the age data were reduced to 0.25 (R.D. Methot Jr., NOAA Fisheries, personal communication).

The model results are dependent, sometimes highly, on the weighting of each data set (Francis 2011). Francis (2011) points out that there is wide agreement on the importance of weighting, but there is lack of consensus as to how it should be addressed. In integrated models that use multiple data sets, it is not uncommon for the composition data to drive the estimation of absolute abundance when inappropriate data weightings are applied or the selectivity process is missspecified (Lee et al. 2014). Francis (2011) argues that abundance information should primarily come from indices of abundance and not from composition data. Following the recommendation of Francis (2011), the model was weighted in two stages. Stage 1 weights were largely empirically derived (standard errors, CVs, and effective sample sizes described earlier in this section) and applied to individual data observations. Stage 2 weights were applied to reweight the length and age composition data by adjusting the input effective sample sizes. The stage 2 weights were estimated based on method TA1.8 (Appendix A in Francis 2011) using the SSMethod.TA1.8 function within the r4ss package (Taylor et al. 2021) in R (R Core Team 2021).

3.1.6 Diagnostics

Several approaches were used to assess model convergence. The first diagnostic was to check whether the Hessian matrix (i.e., matrix of second derivatives of the likelihood with respect to the parameters) inverted (i.e., is positive definite). Next, the model convergence level was compared to the convergence criterion (0.0001, common default value). Ideally, the model convergence level will be less than the criterion. The values of estimated parameters were checked to see if they were estimated at a bound, which could indicate problems with the data or model structure (Carvalho et al. 2021). The correlation matrix was examined to identify highly correlated (e.g., >0.95) parameter pairs. High correlation among parameters can be indicative of poor model stability. Parameters were examined for excessively high variance (>50%), which is an indication that the associated parameter does not influence the fit to the data.

Model stability was further evaluated using a "jitter" analysis. This analysis is a built-in feature of SS3 in which the initial parameter values are varied by a user-specified fraction. This allows evaluation of varying input parameter values on model results to ensure the model has converged on a global minimum. A model that is well behaved should converge on a global solution across a reasonable range of initial parameter estimates (Cass-Calay et al. 2014). Initial parameters were randomly jittered by 10% for a series of 100 random trials. The r4ss package (Taylor et al. 2021) in R (R Core Team 2021) provides tools for automating the jitter analysis and was used for the current stock assessment.

Additional diagnostics included evaluation of fits to commercial landings, recreational harvest, P915 Survey index, length compositions, mean lengths (derived from observed and expected length-composition data), and comparison of estimated growth parameters to their empirically-derived counterparts. The evaluation of fits to the various data components included a visual comparison of observed and predicted values and calculation of standardized residuals for the fits to the P915 Survey index, length composition data, and mean lengths. The standardized residuals were first visually inspected to evaluate whether any obvious patterns were present. If most of the residuals are within one standard deviation of the observed value, there is evidence of under-dispersion. This is indicative of a good predictive model for the data. That is, the model is fitting the data much better than expected, given the assumed sample size.

In a model that is fit well, there should be no apparent trend in the residuals over time. This can be confirmed via the runs test, which was applied to the residuals of the fits to the P915 Survey index and mean lengths using tools in the ss3diags package (Winker et al. 2022). Outliers in the residuals can be detected using the three-sigma limit to identify whether any data point would be unlikely given a random process error in the observed residual distribution if it is further than three standard deviations away from the expected residual process average of zero (see details in Anhøj and Olesen, 2014, cited in Carvalho et al. 2021).

Finally, the SS3 model estimates of the von Bertalanffy age-length growth parameters were compared to the empirically-derived values (section 1.2.4.4).

3.1.7 Uncertainty & Sensitivity Analyses

3.1.7.1 Retrospective Analysis

A retrospective analysis was run to examine the consistency of estimates over time (Mohn 1999). This type of analysis gives an indication of how much recent data have changed our perspective of the past (Harley and Maunder 2003). The analysis is run by removing one year of data from the end of the time series, evaluating results, removing two years of data from the end of the time series, evaluating results, and so on ("peeling" back years of data). Ideally, retrospective patterns are random and do not show a clear bias in any direction. The degree of retrospectivity for a given variable can be described by the Mohn's ρ metric (Mohn 1999). Here, a modified Mohn's ρ (Hurtado-Ferro et al. 2015) was calculated for estimated female spawning stock biomass (SSB) and *F*. Based on the results of simulation studies, Hurtado-Ferro et al. (2015) suggested that values of the modified Mohn's ρ lower than -0.22 or higher than 0.30 for shorter-lived species are indicators of retrospective patterns and should be cause for concern. The results of their work also suggested that positive values of Mohn's ρ for biomass and negative values for fishing mortality imply consistent overestimation of biomass and the highest risk for overfishing. The retrospective analysis was run by peeling back up to five years of data using tools from the r4ss package (Taylor et al. 2021) in R (R Core Team 2021).

3.1.7.2 Sensitivity to Model Start Year

Sensitivity of the model results to the model start year was explored in one alternative model run. In this run, the start year of the model was changed to 1994, the year in which the NCDMF Trip Ticket Program was implemented (section 2.1.1).

3.1.7.3 Alternative Assumptions Regarding Recreational Removals

Two alternative assumptions regarding the magnitude of the recreational removals were considered in two alternative model runs. The first alternative run considered that the proportion of striped mullet occurring in the mullet genus harvest was higher than what was assumed in the base run (29%; section 2.2.4.6). The proportion assumed in the alternative run was assumed equal to the proportion of striped mullet that make up the sum of striped mullet and white mullet Type A recreational catch, a value equal to 86%.

The second alternative run regarding recreational removals assumed no recreational removals at all and so recreational harvest and the associated length compositions were removed for this run.

3.1.7.4 Likelihood Profile

A likelihood component profile was performed to identify potential data conflicts. Likelihood profiling allows the evaluation of model performance across a range of values of an input parameter (Cass-Calay et al. 2014). A profile is conducted by running a series of models in which the parameter of interest is fixed (i.e., not estimated) at a range of values above and below the value estimated in the base model run. The total negative log-likelihood value and the negative log-likelihood value for each data component are plotted against the profiled parameter. Ideally, the shape of the likelihood profile should be smooth whereas the presence of numerous spikes and sawtooths indicates abnormal model behavior.

Virgin recruitment, R_0, is an ideal global scaling parameter that is often profiled because the unfished (virgin) level of recruitment is proportional to unfished biomass (Lee et al. 2014; Carvalho et al. 2017, 2021). Those data components with a large amount of information on population scale will show a significant degradation in fit as the value of population scale moves away from the value estimated in the base model (i.e., the best estimate). Lee et al. (2014) suggests that catch and abundance indices should be the primary sources of information on the population scale in a model. If the base model run is good, the minima of negative log-likelihood values is well defined and has similar R_0 values among data components. If the minimum negative log-likelihood values differ among the data components, there may be either a conflict in the data or model misspecification or both.

3.1.7.5 MCMC Analysis

Monte Carlo Markov Chain (MCMC) is a method of quantifying uncertainty about model parameters and was used in this analysis to estimate uncertainty in terminal year (2019) female SSB and *F*. For three chains, a total of 7,500,000 MCMC iterations were performed but only one out of every 5,000 were saved and the first 500 were discarded to eliminate "burn-in" effects. This resulted in 1,000 samples from the posterior distribution for each parameter and each chain. Convergence of the MCMC chains was assessed by visual inspection of the posterior distributions and whether they were approximately normal, comparison of the mean of posterior distribution to maximum likelihood estimate produced by the SS model, and visual inspection of the trace plots. The Gelman-Rubin multi-chain diagnostic test was applied to compare within-chain variance to among-chain variance (Gelman and Rubin 1992). A value of 1 for the Gelman-Rubin statistic means that between-chain variance and within-chain variance are equal; larger values mean that there is a notable difference between the chains indicating non-convergence of the model. There is a rule of thumb that values less than 1.1 are deemed acceptable.

3.1.8 Results

3.1.8.1 Base Run—Diagnostics

A summary of the input data used in the base run of the striped mullet stock assessment model is shown in Figure 3.2. The final base run resulted in an inverted Hessian matrix, but the model's final convergence level was 0.00300198. This value is higher than the convergence criterion, which was set at 0.0001. It is not unusual for models with large numbers of parameters to produce higher convergence levels and so values less than 1.0 for such models are typically deemed acceptable (R.D. Methot Jr., NOAA Fisheries, personal communication). Additionally, successful model outcomes can be achieved despite larger final gradients (Carvalho et al. 2021). None of the estimated parameters were estimated near their bounds (Table 3.2) and no highly correlated parameter pairs were detected. None of the estimated parameters were found to have excessively high variance (proportional standard error > 50%). The parameter for virgin recruitment was associated with a large gradient (absolute value > 0.001).

Five of the 100 runs that jittered initial values by 10% did not successfully converge (Hessian did not invert). The remaining runs resulted in inverted Hessian matrices and small (<1.0) convergence values. The majority of the jitter runs resulted in an objective function value similar to that obtained in the base run of the model (Figure 3.3). The predicted estimates of female SSB and *F* were identical or very similar to the estimates from the base run in the majority of the jitter trials (Figure 3.4).

The results of the base model show good agreement between observed and predicted removals for the commercial (Figure 3.5) and recreational (Figure 3.6) fleets. This is not unexpected given the small amount of error assumed for these data. The fit to the P915 Survey index was deemed reasonable (Figures 3.7). All the standardized residuals from the fit to the P915 Survey index are within one standard deviation of the observed values, suggesting good fits to the observed index. No significant trends are apparent in the standardized residuals over the various time series and this was confirmed via the runs test. No outliers are evident in the P915 Survey index residuals.

The fits to the length compositions aggregated across time provide fair fits to the observed length compositions for the commercial and recreational fleets and the P915 Survey (Figure 3.8). The observed annual length compositions in the commercial fishery were fit well by the model despite low observed effective sample sizes[1] (less than 35 each year; Figures 3.9 and 3.10). Examination of the residuals suggests the model tended to overestimate the proportions at length for commercial fishery lengths 22 cm and smaller in most years (Figure 3.11). With only two years of available length data, the fits to the recreational fishery length compositions are difficult to interpret (Figures 3.12 and 3.13). The P915 Survey observed annual length compositions are associated with effective sample sizes slightly higher than those observed for the commercial fishery length compositions (less than 50 each year) and the fits are reasonable (Figure 3.14). Evaluation of the residuals suggests no consistent patterns in over- or underestimation for the P915 Survey lengths (Figure 3.15).

Observed and predicted mean lengths were derived from observed and expected length-composition data. The comparison of observed to predicted mean lengths for the commercial fishery indicated the model tended to overestimate mean length from the mid-1990s through the early 2000s (Figure 3.16), though the results of the runs tests did not indicate any temporal trend in the residuals (Figure 3.17). One of the mean length residuals for the commercial fishery (1998) fell outside three residual standard deviations from zero, suggesting the point is an outlier. The comparison of observed and predicted mean lengths for the P915 Survey suggest consistent overestimation of mean length from 2011 through 2015 (Figure 3.18). The runs test applied to the residuals of the mean lengths for the P915 Survey suggested no temporal trends and no outliers (Figure 3.19).

Most of the von Bertalanffy age-length growth parameter values estimated by SS3 were similar to those derived empirically (Table 3.3; Figure 3.20). The SS3 model did underestimate K for females and overestimate K for males, relative to the empirically-derived values. The values for CV2 for both females and males were underestimated as well, suggesting precision is higher for the length at older ages than what was derived empirically.

3.1.8.2 Base Run—Selectivity & Population Estimates

The predicted selectivity curves for the fleets and surveys are shown in Figure 3.21. The recreational fishery selects for the smallest size striped mullet relative to the commercial fishery and P915 Survey. The commercial fishery selects for larger striped mullet relative to the P915 Survey and recreational fishery.

The predicted recruitment deviations vary randomly about zero with no apparent trend throughout the time series (Tables 3.4 and 3.5; Figure 3.22). Annual predicted recruitment shows a variable but generally declining trend starting in the late 1980s (Tables 3.4 and 3.5; Figure 3.23). Female

[1] Observed effective sample sizes were input as the square root of the number of sampled trips; see section 3.1.5

SSB shows an initial drop at the start of the time series through the mid-1960s followed by an increase through the mid-1970s (Tables 3.4 and 3.5; Figure 3.24). The trend in female SSB through the remainder of the time series is generally declining. Estimates of spawning potential ratio (SPR) vary between 0.096 (2002) and 0.64 (1971) over the time series (Tables 3.4 and 3.5; Figure 3.25). SPR peaked in 1971 and generally declined to its lowest point in 2002. Since 2004, estimates of SPR have been variable without obvious trend.

Predicted stock numbers at age for striped mullet indicate the stock has been dominated by age-0 fish over time (Tables 3.6–3.9). Predictions of stock biomass at age indicate that most of the population's biomass is found in age classes 1, 2, and 3 (Tables 3.10–3.13).

The predictions of commercial landings at age demonstrate that fish age 1 and 2 dominate the commercial landings (Tables 3.14 and 3.15). Fish at ages 1 through 5 make up the majority (>95%) of the commercial landings. The recreational harvest is dominated by age-0 fish while fish older than age 3 are rarely captured (Tables 3.16 and 3.17).

Estimates of fishing mortality (numbers-weighted, ages 1–5) show a decrease from the early 1960s through the early 1970s (Tables 3.18 and 3.19; Figure 3.26). Starting in the mid-1980s, *F* is variable but increasing through the rest of the time series, though shows evidence of a decrease in 2018 and 2019.

3.1.8.3 Retrospective Analysis

The results of the retrospective analysis do not suggest an obvious consistent bias in estimates of female SSB or *F* in the terminal year of the base model (Figure 3.27). The calculated values of the modified Mohn's ρ for female SSB (0.22) and *F* (-0.22) are just within the "acceptable" range (-0.22 to 0.30) for shorter-lived species and provide further evidence for a lack of a retrospective pattern in these estimates.

3.1.8.4 Sensitivity to Model Start Year

The model results were relatively insensitive to model start year (Figure 3.28). There were some differences in female SSB and *F* between the base model run and the run that started in 1994 during the mid- to late 1990s, but predicted values between the two runs were similar for the remaining years.

3.1.8.5 Alternative Assumptions Regarding Recreational Removals

Changing the assumption regarding the magnitude of recreational removals had a negligible impact on model results (Figure 3.29). The run in which the proportion of striped mullet occurring in the mullet genus harvest was assumed to be 86% resulted in a slightly lower estimate of *F* in the terminal year (2019). Assuming no recreational fishery had nearly identical results to the results of the base run.

3.1.8.6 Likelihood Profile

The base model run estimated a value of 9.73 for $\log_e[R_0]$. The likelihood profile on R_0 for the total objective function is consistent with the model having converged to a global optimum (Figure 3.30). The estimate from the base model run is also supported by the profiles for the length and age data. The survey and recruitment profiles support a smaller value for R_0 than the length and age data.

3.1.8.7 MCMC Analysis

Convergence diagnostics indicated that the MCMC simulation to estimate the posterior distribution of SS3 model parameters converged. The posterior distributions for the terminal year (2019) estimate of female SSB (Figure 3.31) and fishing mortality (Figure 3.32) are approximately normally distributed across all three chains. The SS3 model estimate of female SSB in 2019 (263 mt) is similar to the mean estimate from the MCMC posterior distributions (220 mt), which is an indication of the robustness of the model. Likewise, fishing mortality in 2019 estimated from the SS3 model (0.42) is similar to the mean estimate from the MCMC posterior distributions (0.43). No issues were detected in the trace plots for female SSB in 2019 (Figure 3.31) or fishing mortality in 2019 (Figure 3.32). The Gelman-Rubin multi-chain diagnostic test for these parameters also supported model convergence. The Gelman-Rubin statistic for female SSB in 2019 is 1.09 and for fishing mortality the value is 1.08.

3.2 Discussion of Results

The model performed well and showed good stability across most of the diagnostics. Fits to the commercial landings and P915 fisheries-independent survey are generally good and the length compositions were also fit well.

Not all likelihood components for the various data sources are consistent with the estimate of population scale. While the likelihood profiles for the length and age data are consistent with the profile for the total likelihood, the likelihood profile for the survey data suggests a smaller estimate of population scale. This is an indication of conflicting signals between the composition data and the survey index data. Francis (2011) has argued that information on abundance should primarily come from abundance indices and not the composition data. Future stock assessment modeling work may want to consider alternative weightings of the different data sources.

The striped mullet resource in North Carolina has been fished since at least the late 1800s and has historically supported catches larger than those observed in recent years. The P915 Survey index started in the late 2000s and both the observed and predicted index suggest current relative abundance is lower than what was observed in the late 2000s and early 2010s. Length-frequencies from the fisheries-independent surveys and age composition data from both the commercial fishery and fisheries-independent surveys suggest a truncation of the length and age structure in recent years. Few fish older than age 3 have been observed in North Carolina’s monitoring programs and this is concerning for a species that has been observed to live 15 years. The predicted numbers and biomass at age further suggest a truncation of the population age distribution in the last two decades. Predicted declines in recruitment and female SSB coupled with an increasing trend in predicted fishing mortality are further warning signs of a declining stock. The results of the retrospective analysis suggest consistent overestimation of biomass and the highest risk for overfishing (positive values of Mohn’s ρ for biomass and negative values for fishing mortality). Concerns for the population are warranted given both the observed data and model predictions.

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.”

Amendment 1 to the NCDMF FMP for striped mullet adopted a fishing mortality threshold of $F_{25\%}$ and a fishing mortality target of $F_{35\%}$ (NCDMF 2015). Stock Synthesis computed a value of 0.37 for $F_{25\%}$ and a value of 0.26 for $F_{35\%}$. These estimates are numbers-weighted values for ages 1–5 and so are consistent with the reported *F* values. Predicted *F* in 2019 is 0.42. As such, overfishing is currently occurring in the striped mullet stock ($F_{2019} > F_{25\%}$; Figure 4.1).

The corresponding spawning stock reference points were also estimated by the Stock Synthesis model. The spawning stock biomass threshold, $SSB_{25\%}$, was estimated at 619 mt while the spawning stock biomass target, $SSB_{35\%}$, was estimated at 1,015 mt. The stock assessment model estimate of spawning stock biomass in 2019 is 263 mt, which is less than the threshold value and indicates the stock is currently overfished ($SSB_{2019} < SSB_{25\%}$; Figure 4.2).

The probabilities associated with overfishing and the overfished state were calculated based on the posterior distributions of spawning stock biomass, fishing mortality, and the associated thresholds across all three chains from the MCMC analysis (section 3.1.7.5). There is a 95% probability that the stock is overfished based on the MCMC results. The probability that the stock is undergoing overfishing is 80%.

5 SUITABILITY FOR MANAGEMENT

Stock assessments performed by the NCDMF in support of management plans are subject to an extensive review process, including a review by an external panel of experts. 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 stock assessment results are based on the best science available 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 to better understand the development of stock assessments.

The external peer review panel first met with the working group via webinar in November 2021. The working group gave formal presentations on life history and stock structure, fisheries and management, fisheries-dependent monitoring, fisheries-independent sampling, stock assessment history, input data to the stock assessment model, stock assessment model structure, stock assessment model results, stock status, and research recommendations. The main concern identified by the peer review panel was the lack of inclusion of recreational removals in the original base run of the model. Despite the high uncertainty associated with the recreational data, the peer review panel pointed out that it was important to include all substantial sources of removals because they characterize absolute losses (i.e., deaths) from the population, rather than providing a relative measure of some aspect of the population like other data sources (i.e., indices and compositions). Additionally, despite the uncertainty of the recreational data, it was deemed the best available characterization of recreational losses.

At this first peer review workshop, the peer review panel also recommended removal of the P146_spring and P146_autumn indices and associated biological data. The P146 Survey is spatially limited and the same sampling area is already covered by the P915 survey. The review panel also suggested changing the start year from 1994 to 1950, which required extending the time series of commercial landings and recreational harvest back in time. The peer review panel recommended implementing Francis (2011) reweighting of the length and age composition data. The working group agreed with the peer reviewers recommended changes, including some minor changes to the configuration of input parameters, and a second peer review workshop was scheduled for February 2022.

At the second peer review workshop, the base run of the model was further refined. One of the new major changes was the exclusion of the Bridgenet Survey. The peer review panel, and working group agreed, that the survey was geographically limited—only operating at a single point in the dynamic estuarine waters of North Carolina—and likely not representative of the entire stock area. The removal of the Bridgenet Survey also improved model fit and stability. The final major change was the combining of the P915 northern and southern area indices into a single, combined index. The recommendation to combine these indices was based on the likelihood that the fish being encountered in the northern and southern areas mix substantially over the course of the year and their selectivity patterns were already being described by the same function and parameter values.

Overall, the peer review panel concluded that the assessment model and results represent the best scientific information available and are suitable for providing management advice.

6 RESEARCH RECOMMENDATIONS

The following research recommendations are offered to improve future stock assessments of the North Carolina striped mullet stock:

<u>High</u>

- 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

<u>Medium</u>

- Consider a tagging program to provide estimates of stock size, *F*, and *M*
- Consider a 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

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8 TABLES

Table 1.1. Estimated parameter values of the von Bertalanffy age-length model fit to striped mulled data from this and previous studies, where length is measured as fork length in centimeters. FI = fishery-independent; FD = fishery-dependent.

Location	**Collection Period**	**Gear**	**Type**	**n**	**Sex**	L_∞	K	t_0	**Reference**
North Carolina	Oct–Nov	Various	FI & FD	934	Female	35.4	1.07	0	Bichy 2004
North Carolina	Oct–Nov	Various	FI & FD	641	Male	29.6	1.74	0.01	Bichy 2004
North Carolina	1997–2002	Various	FI & FD	2,480	Female	50.4	0.43	-0.11	Wong 2006
North Carolina	1997–2002	Various	FI & FD	1,200	Male	40.3	0.50	-0.38	Wong 2006
North Carolina	1996–2011	Various	FI & FD	6,831	Female	45.2	0.503	-1.06	NCDMF 2013
North Carolina	1996–2011	Various	FI & FD	2,820	Male	33.6	1.11	-0.703	NCDMF 2013
North Carolina	1996–2017	Various	FI & FD	10,096	Female	45.2	0.496	-1.14	NCDMF 2018
North Carolina	1996–2017	Various	FI & FD	4,782	Male	50.7	0.195	-2.73	NCDMF 2018
North Carolina	1996–2019	Various	FI & FD	12,647	Female	48.7	0.401	-0.410	current study
North Carolina	1996–2019	Various	FI & FD	6,942	Male	42.2	0.430	-0.571	current study

Table 1.2. Estimated parameter values of the length-weight function fit to striped mulled data from this and previous studies, where length is measured as fork length in centimeters and weight is measured in kilograms. FI = fishery-independent; FD = fishery-dependent.

Location	**Collection Period**	**Gear**	**Type**	**n**	**Sex**	***a***	***b***	**Reference**
North Carolina	May 1997–Apr 1999	Various	FI & FD	447	Female	1.42E-05	3.00	Bichy 2000
North Carolina	May 1997–Apr 1999	Various	FI & FD	210	Male	1.14E-05	3.08	Bichy 2000
North Carolina	Jul 1996–Apr 2000	Various	FI & FD	2,238	Female	1.61E-05	2.98	Bichy 2004
North Carolina	Jul 1996–Apr 2000	Various	FI & FD	1,144	Male	1.43E-05	3.01	Bichy 2004
North Carolina	1996–2011	Various	FI & FD	6,482	Female	1.63E-05	2.97	NCDMF 2013
North Carolina	1996–2011	Various	FI & FD	2,465	Male	1.92E-05	2.92	NCDMF 2013
North Carolina	1996–2017	Various	FI & FD	13,937	Female	1.83E-05	2.94	NCDMF 2018
North Carolina	1996–2017	Various	FI & FD	7,338	Male	1.71E-05	2.95	NCDMF 2018
North Carolina	1996–2019	Various	FI & FD	13,128	Female	1.82E-05	2.94	current study
North Carolina	1996–2019	Various	FI & FD	6,002	Male	2.02E-05	2.91	current study

Table 1.3. Sex-specific estimates of age-specific, instantaneous natural mortality for striped mullet calculated using the method of Lorenzen (1996).

Age	Female	Male
0	1.8	1.4
1	0.72	0.72
2	0.53	0.56
3	0.45	0.49
4	0.41	0.45
5	0.39	0.43
6	0.38	0.42
7	0.37	0.41
8	0.36	0.41
9	0.36	0.40
10	0.36	0.40
11	0.35	0.40
12	0.35	0.40
13	0.35	0.40
14		0.40

Table 1.4. Total number of striped mullet commercially landed (metric tons) and total number of commercial fishery trips reporting landings of striped mullet by season and month summed over 1994 to 2019.

Season	Month	Commercial Landings (mt)	Commercial Trips (number)
Winter	December	869	13,877
	January	1,124	16,773
	February	780	19,994
Spring	March	529	17,521
	April	484	16,768
	May	534	12,619
Summer	June	675	12,333
	July	936	13,834
	August	1,425	19,037
Autumn	September	1,572	22,048
	October	7,476	50,030
	November	4,667	38,142

Table 2.1. Annual commercial landings (metric tons) of striped mullet and effort (number of trips, by select gears) in North Carolina, 1994–2019.

Year	Commercial Landings (metric tons)	Commercial Effort (n trips)		
		Anchored Gill Net	Runaround Gill Net	Stop Net
1994	783.0	2,276	1,488	32
1995	1,043	2,465	2,301	17
1996	796.9	2,352	2,408	14
1997	1,108	2,488	2,796	44
1998	1,006	2,128	2,282	19
1999	662.6	1,991	1,473	10
2000	1,283	3,183	2,273	29
2001	1,051	1,852	2,153	21
2002	1,178	1,975	1,972	25
2003	739.1	1,814	1,390	4
2004	725.1	1,356	1,484	28
2005	735.0	1,055	1,662	12
2006	784.1	999	1,671	13
2007	757.0	1,087	1,631	7
2008	760.2	968	1,585	5
2009	764.6	848	1,532	3
2010	944.8	1,208	2,248	2
2011	738.4	1,238	1,632	2
2012	843.5	1,090	1,956	6
2013	702.7	905	1,930	17
2014	829.3	1,089	1,705	10
2015	565.7	767	1,668	6
2016	437.9	547	1,392	6
2017	619.8	568	1,632	10
2018	595.2	636	1,595	2
2019	617.9	527	1,724	6

Table 2.2. Number of available biological samples of striped mullet sampled from North Carolina commercial fisheries' landings, 1990–2019.

Year	Length	Age	
	pooled	female	male
1990	102		
1991	526		
1992	310		
1993	383		
1994	198		
1995	227		
1996	89	108	51
1997	1,367	183	69
1998	1,186	276	130
1999	1,283	185	118
2000	4,866	173	71
2001	3,591	77	51
2002	6,131	95	30
2003	4,438	119	32
2004	7,117	94	36
2005	5,636	44	10
2006	7,199	56	11
2007	7,340	8	1
2008	8,341		
2009	5,693		
2010	7,561	13	7
2011	5,339	15	4
2012	8,796		
2013	6,488	27	7
2014	5,390	11	
2015	5,373	40	74
2016	5,388	25	3
2017	4,119	22	5
2018	3,489	59	24
2019	4,758	87	36

Table 2.3. Annual harvest (numbers of fish), releases (numbers of fish), effort (number of trips) and associated estimates of proportional standard error (PSE) for mullet (white plus striped) in North Carolina's recreational fishery, 2011–2019. Note that the mail survey from which the estimates were derived began in October 2011 so the estimates for 2011 are not for the entire year.

Year	Harvest	PSE[Harvest]	Release	PSE[Release]	Effort	PSE[Effort]
2011	74,461	25	31,210	36	16,007	17
2012	693,262	8.9	220,205	12	125,623	6.2
2013	711,307	10	229,509	14	139,286	6.3
2014	783,058	9.4	251,504	11	197,257	6.8
2015	942,521	8.4	296,039	12	206,876	6.0
2016	748,394	11	219,892	14	191,922	6.4
2017	722,929	8.8	239,998	11	182,861	6.7
2018	347,187	30	108,904	45	88,939	12
2019	688,815	10	320,885	16	162,941	7.1

Table 2.4. Annual recreational harvest (Type A + B1) estimates for striped mullet in North Carolina as estimated by the MRIP, 1981–2019. Proportional standard error (PSE) values greater than 50 indicate an imprecise estimate and are highlighted in pink.

Year	Numbers	PSE[Numbers]	Weight (kg)	PSE[Weight]
1981	11,528	95.8	4,846	95.8
1982	694,103	51.8	160,883	49.1
1983	1,180,943	94.4	146,231	86.7
1984	880,129	21.1	46,182	19.9
1985	721,090	67.6	258,393	64.1
1986	92,858	61.7	37,132	59.4
1987	3,093,510	70.7	275,299	64.4
1988	555,518	59.9	4,527	80.6
1989	192,232	41.9	68,012	38.7
1990	307,489	84.3	79,754	81.1
1991	52,759	46.2	17,865	45.4
1992	1,543,433	88.5	536,262	87.6
1993	295,610	57.5	306,828	70.4
1994	280,168	59.5	271,330	55.4
1995	113,207	64.2	108,174	77.4
1996	35,762	49.9	31,150	54.2
1997	91,702	69.1	78,328	82.4
1998	18,609	66.3	6,163	66.5
1999	17,674	57.3	5,198	55.7
2000	142,083	73.5	85,332	83
2001	2,734,116	38.9	953,028	43.1
2002	4,668,427	18	848,923	24.2
2003	3,368,881	29.6	737,422	38.8
2004	5,496	101.7	1,231	101.7
2005	10,795	61.5	6,200	63.1
2006	15,706	63.5	6,945	53.7
2007	301,004	81.3	93,766	74.8
2008	3,458	65	1,111	63.1
2009	83,480	90.6	9,996	62.5
2010	126,250	44.7	46,340	58
2011	80,267	28.6	28,048	38.5
2012	351,960	79.5	100,621	80
2013	150,020	53.9	56,754	54.8
2014	50,381	67	26,962	70.1
2015	142,696	64.5	82,492	69.6
2016	29,965	50.6	13,444	51.7
2017	37,791	43.9	12,479	43.5
2018	35,565	59.3	11,380	56.7
2019	324,986	52	158,475	56.7

Table 2.5. Annual recreational harvest (Type A + B1) estimates for white mullet in North Carolina as estimated by the MRIP, 1981–2019. Proportional standard error (PSE) values greater than 50 indicate an imprecise estimate and are highlighted in pink.

Year	Numbers	PSE[Numbers]	Weight (kg)	PSE[Weight]
1981	10,848	99.6	3,471	99.6
1982	86,103	98.3	25,877	98.1
1983	8,403	100.2	1,700	100.2
1984	2,725	104.6	275	104.6
1985	241,352	36.3	40,933	35.5
1986				
1987	2,092,801	90.2	93,472	89.3
1988				
1989	10,060	61.9	2,886	63.2
1990				
1991				
1992				
1993				
1994	6,475	98.4	647	98.4
1995	4,785	100.3	1,587	100.3
1996				
1997				
1998				
1999				
2000				
2001				
2002				
2003				
2004				
2005				
2006	50,742	95.3	13,193	95.3
2007				
2008				
2009	1,759	100	528	100
2010	7,176	78.2	1,560	83.9
2011	38,562	67.2	2,468	63.6
2012	25,295	71.8	1,569	67.8
2013	68,205	83	12,554	95.3
2014	11,676	44.6	934	44.6
2015	6,535	99.6	5,947	99.6
2016				
2017	4,680	100.9	622	100.9
2018	79,863	51.8	14,594	81.4
2019	98,134	26.6	2,933	40.6

Table 2.6. Annual recreational harvest (Type A + B1) estimates for the mullet genus in North Carolina as estimated by the MRIP, 1981–2019. Proportional standard error (PSE) values greater than 50 indicate an imprecise estimate and are highlighted in pink.

Year	Numbers	PSE[Numbers]	Weight (kg)	PSE[Weight]
1981				
1982	9,118	94.9	912	94.9
1983	625,777	105.3	15,145	105.3
1984	11,372	71.9	1,137	71.9
1985	21,999	67.7	2,778	64.9
1986	1,047	99.8	209	99.8
1987	47,552	60.6	0	
1988				
1989	28,848	107.2	1,731	107.2
1990				
1991				
1992				
1993				
1994				
1995	108,218	67.8	0	
1996	1,894	70.8	0	
1997	923	74.6	0	
1998				
1999				
2000	479,051	47.4	0	
2001				
2002	4,480,197	36.3	0	
2003	2,487,885	20.4	0	
2004	4,790,382	16.1	0	
2005	4,487,719	21.4	0	
2006	3,599,098	21.4	0	
2007	5,052,995	22.3	0	
2008	4,097,156	14.4	0	
2009	3,736,571	14.3	0	
2010	4,113,171	14.3	0	
2011	3,653,514	14.3	0	
2012	3,510,395	16.3	0	
2013	4,493,166	20.5	0	
2014	4,490,722	26.2	0	
2015	4,405,800	21.5	0	
2016	5,039,891	55.6	0	
2017	5,170,318	55.2	0	
2018	1,564,676	31.7	0	
2019	817,596	25.3	0	

Table 2.7. Annual recreational observed (Type A) and reported (Type B1) harvest estimates for striped mullet in North Carolina as estimated by the MRIP in units of numbers of fish, 1981–2019. Proportional standard error (PSE) values greater than 50 indicate an imprecise estimate and are highlighted in pink.

Year	Observed Harvest	PSE[Observed]	Reported Harvest	PSE[Reported]
1981	1,637	95.8	9,891	95.8
1982	139,069	71.2	555,034	59.4
1983	1,026,962	93.4	153,981	101
1984	265,394	51.8	614,735	20.2
1985	77,703	60.1	643,387	75.4
1986	5,924	79	86,933	66.1
1987	3,035,900	71.4	57,610	67
1988	241,623	89.3	313,895	78.4
1989	88,022	45.5	104,210	67.2
1990	45,484	58.5	262,005	98.5
1991	25,536	63.9	27,224	63.4
1992	1,405,151	97	138,282	56
1993	155,746	51.6	139,864	70.3
1994	277,218	60.1	2,950	102.8
1995	102,249	70.6	10,959	76.1
1996	13,865	59.7	21,897	73.5
1997	91,702	69.1		
1998	1,899	72.4	16,710	73.4
1999	11,740	70.1	5,934	100.4
2000	3,769	88.9	138,314	75.4
2001	98,848	86.6	2,635,268	37.4
2002	419,828	45.7	4,248,599	19.2
2003	159,467	91.3	3,209,414	30.7
2004			5,496	101.7
2005	10,795	61.5		
2006	6,945	65.1	8,761	101.4
2007	277,160	87.8	23,844	101.1
2008	3,458	65		
2009	83,480	90.6		
2010	67,261	45.8	58,989	53.5
2011	27,793	44.6	52,474	33.6
2012	199,033	83.7	152,927	76.9
2013	54,100	58.8	95,920	66.4
2014	49,011	68.8	1,370	101
2015	126,328	71.7	16,368	72.3
2016	29,965	50.6		
2017	35,627	46.1	2,164	99.9
2018	31,224	66.9	4,341	70.4
2019	9,572	64.1	315,414	53.6

Table 2.8. Annual recreational observed (Type A) and reported (Type B1) harvest estimates for white mullet in North Carolina as estimated by the MRIP in units of numbers of fish, 1981–2019. Proportional standard error (PSE) values greater than 50 indicate an imprecise estimate and are highlighted in pink.

Year	Observed Harvest	PSE[Observed]	Reported Harvest	PSE[Reported]
1981			10,848	99.6
1982	86,103	98.3		
1983	8,403	100.2		
1984	2,725	104.6		
1985	163,264	40.1	78,088	49.2
1986				
1987	2,092,801	90.2		
1988				
1989	9,285	66.5	775	100.3
1990				
1991				
1992				
1993				
1994	6,475	98.4		
1995	4,785	100.3		
1996				
1997				
1998				
1999				
2000				
2001				
2002				
2003				
2004				
2005				
2006	14,754	95.3	35,988	95.3
2007				
2008				
2009	1,759	100		
2010	7,176	78.2		
2011	38,562	67.2		
2012	25,295	71.8		
2013	68,205	83		
2014	11,676	44.6		
2015	6,535	99.6		
2016				
2017	468	100.9	4,212	100.9
2018	20,960	101.9	58,903	60.1
2019	93,378	27.5	4,756	100.8

Table 2.9. Annual recreational observed (Type A) and reported (Type B1) harvest estimates for the mullet genus in North Carolina as estimated by the MRIP in units of numbers of fish, 1981–2019. Proportional standard error (PSE) values greater than 50 indicate an imprecise estimate and are highlighted in pink.

Year	Observed Harvest	PSE[Observed]	Reported Harvest	PSE[Reported]
1981				
1982			9,118	94.9
1983	625,777	105.3		
1984			11,372	71.9
1985			21,999	67.7
1986			1,047	99.8
1987			47,552	60.6
1988				
1989	28,848	107.2		
1990				
1991				
1992				
1993				
1994				
1995			108,218	67.8
1996			1,894	70.8
1997			923	74.6
1998				
1999				
2000			479,051	47.4
2001				
2002			4,480,197	36.3
2003			2,487,885	20.4
2004			4,790,382	16.1
2005			4,487,719	21.4
2006			3,599,098	21.4
2007			5,052,995	22.3
2008			4,097,156	14.4
2009			3,736,571	14.3
2010			4,113,171	14.3
2011			3,653,514	14.3
2012			3,510,395	16.3
2013			4,493,166	20.5
2014			4,490,722	26.2
2015			4,405,800	21.5
2016			5,039,891	55.6
2017			5,170,318	55.2
2018			1,564,676	31.7
2019			817,596	25.3

Table 2.10. Annual number of assignments total and with striped mullet and annual number of intercepts total and with striped mullet in North Carolina's MRIP survey, 1981–2019.

	Assignments			Intercepts		
Year	**n Total**	**n with Striped Mullet**	**% with Striped Mullet**	**n Total**	**n with Striped Mullet**	**% with Striped Mullet**
1981	89	1	1.1	1,077	3	0.28
1982	164	7	4.3	1,989	12	0.60
1983	104	4	3.8	1,308	6	0.46
1984	104	4	3.8	1,518	6	0.40
1985	145	8	5.5	1,980	11	0.56
1986	188	4	2.1	2,470	6	0.24
1987	547	9	1.6	7,347	17	0.23
1988	568	8	1.4	8,054	9	0.11
1989	697	17	2.4	10,851	19	0.18
1990	655	13	2.0	10,898	17	0.16
1991	843	6	0.71	15,569	7	0.045
1992	761	12	1.6	12,876	15	0.12
1993	839	14	1.7	13,728	17	0.12
1994	1,061	14	1.3	19,158	16	0.084
1995	1,128	14	1.2	20,124	14	0.070
1996	1,259	8	0.64	24,296	10	0.041
1997	1,317	6	0.46	22,757	7	0.031
1998	1,271	4	0.31	21,200	4	0.019
1999	1,080	4	0.37	17,729	5	0.028
2000	966	7	0.72	17,849	8	0.045
2001	1,188	29	2.4	21,305	78	0.37
2002	1,145	53	4.6	17,840	121	0.68
2003	1,035	42	4.1	16,021	93	0.58
2004	978	1	0.10	15,052	1	0.0066
2005	822	3	0.36	13,651	3	0.022
2006	907	6	0.66	14,760	6	0.041
2007	887	3	0.34	14,571	3	0.021
2008	1,044	3	0.29	16,134	3	0.019
2009	1,030	5	0.49	12,893	5	0.039
2010	1,834	14	0.76	21,647	16	0.074
2011	1,771	17	0.96	20,757	18	0.087
2012	2,072	12	0.58	24,471	13	0.053
2013	1,469	11	0.75	13,339	12	0.090
2014	1,273	5	0.39	13,635	6	0.044
2015	1,274	11	0.86	14,040	12	0.085
2016	1,224	5	0.41	14,257	6	0.042
2017	1,488	10	0.67	16,345	11	0.067
2018	1,442	7	0.49	16,705	8	0.048
2019	1,438	12	0.83	14,966	15	0.10

Table 2.11. Annual number of assignments total and with mullet genus and annual number of intercepts total and with mullet genus in North Carolina's MRIP survey, 1981–2019.

	Assignments			Intercepts		
Year	**n Total**	**n with Mullet genus**	**% with Mullet genus**	**n Total**	**n with Mullet genus**	**% with Mullet genus**
1981	89			1,077		
1982	164	1	0.61	1,989	1	0.050
1983	104	1	0.96	1,308	1	0.076
1984	104	2	1.9	1,518	2	0.13
1985	145	2	1.4	1,980	4	0.20
1986	188	1	0.53	2,470	1	0.040
1987	547	4	0.73	7,347	4	0.054
1988	568			8,054		
1989	697	1	0.14	10,851	1	0.0092
1990	655			10,898		
1991	843			15,569		
1992	761			12,876		
1993	839			13,728		
1994	1,061			19,158		
1995	1,128	2	0.18	20,124	2	0.0099
1996	1,259	2	0.16	24,296	3	0.012
1997	1,317	2	0.15	22,757	2	0.0088
1998	1,271			21,200		
1999	1,080			17,729		
2000	966	5	0.52	17,849	12	0.067
2001	1,188			21,305		
2002	1,145	24	2.1	17,840	47	0.26
2003	1,035	35	3.4	16,021	61	0.38
2004	978	91	9.3	15,052	242	1.6
2005	821	62	7.6	13,651	140	1.0
2006	907	86	9.5	14,760	214	1.4
2007	887	82	9.2	14,571	230	1.6
2008	1,044	85	8.1	16,134	220	1.4
2009	1,030	76	7.4	12,893	203	1.6
2010	1,834	116	6.3	21,647	306	1.4
2011	1,771	98	5.5	20,757	222	1.1
2012	2,073	129	6.2	24,471	257	1.1
2013	1,469	78	5.3	13,339	180	1.3
2014	1,273	64	5.0	13,635	130	0.95
2015	1,274	70	5.5	14,040	177	1.3
2016	1,224	41	3.3	14,257	76	0.53
2017	1,488	51	3.4	16,345	77	0.47
2018	1,442	29	2.0	16,705	44	0.26
2019	1,438	37	2.6	14,966	55	0.37

Table 2.12. Annual number of directed trips for mullet species in North Carolina as estimated by the MRIP, 1981–2019. Directed trips are defined as those trips that target striped mullet, white mullet, or mullet genus or trips that catch the specified species (striped mullet or mullet genus). Proportional standard error (PSE) values greater than 50 indicate an imprecise estimate and are highlighted in pink.

	Striped Mullet		Mullet genus	
Year	**n Trips**	**PSE**	**n Trips**	**PSE**
1981				
1982	38,644	41.4	12,781	76.9
1983	101,118	51.8	32,623	70.8
1984	46,305	32.5	21,854	45.1
1985	113,446	31.9	98,682	40.9
1986	16,093	48.6	524	100
1987	77,760	49.1	4,119	63
1988	69,339	61.4	39,785	100
1989	33,519	41.3	8,757	41.8
1990	22,378	35.1	2,679	67.8
1991	18,819	27	11,814	32.5
1992	27,380	35	1,563	68.7
1993	45,226	30.9	22,990	38.3
1994	35,846	30.2	6,108	48.2
1995	43,895	29.5	26,102	36.8
1996	18,854	29.5	50,748	21.7
1997	20,693	32.9	31,192	28.2
1998	9,891	44.3	5,116	51.8
1999	15,876	35.3	28,225	30.2
2000	17,823	40.4	34,225	27.6
2001	86,461	20.9	24,260	62.4
2002	187,692	14.8	117,033	26.8
2003	163,191	17.4	114,626	17.5
2004	916	100	248,564	12.6
2005	5,573	65.2	196,281	14.8
2006	10,773	45.9	278,899	17.5
2007	13,148	59.3	322,750	13.1
2008	4,365	45.3	290,531	12.5
2009	10,321	57.3	292,348	13.4
2010	21,705	30	257,473	12.5
2011	27,503	34.7	240,957	12.2
2012	35,160	34.1	204,069	11.8
2013	36,487	33.7	299,809	15.3
2014	25,126	56.1	276,872	21.2
2015	39,956	36.8	284,786	17.1
2016	27,229	47.2	166,027	22.3
2017	151,399	79.4	307,579	53.2
2018	26,903	46.7	127,213	26.8
2019	39,665	20.3	124,124	22.1

Table 2.13. Number of intercepts in which the indicated species was harvested by gear type, summed over 1981–2019.

Gear	Striped Mullet	White Mullet	Mullet genus	Total
Cast Net	37	5	22	64
Gill Net	43	4	12	59
Hook & Line	367	41	2,363	2,771
Other	2			2
Spear	2		1	3
Trawl	1			1
Total	452	50	2,398	2,900

Table 2.14. Number of intercepts in which the indicated species was harvested by gear type and primary target species, summed over 1981–2019.

Primary Target Species	Species Harvested by Gear Type						Total
	Striped Mullet		White Mullet		Mullet genus		
	Cast Net	Hook & Line	Cast Net	Hook & Line	Cast Net	Hook & Line	
Lefteye Flounder genus	2	196		3	4	1,710	1,915
Red Drum	4	41		7	1	297	350
Spotted Seatrout	1	18		3		119	141
Spanish Mackerel	1	14		1		52	68
Bluefish	5	16	1	2		42	66
King Mackerel		18		2		45	65
Mullet genus	9	5	3	2	16	7	42
Spot	1	3	1	10		12	27
Sheepshead		11		1		13	25
Striped Mullet	11	8					19
Seatrout genus		7				10	17
Summer Flounder		5		5		4	14
Mackerel genus						10	10
Unidentified (Sharks)						10	10
Weakfish		2				7	9
Black Drum		4				4	8
Kingfish genus		3				4	7
Mullet family	2	3			1		6
Lefteye Flounder family		5					5
White Mullet				4		1	5
Atlantic Croaker		1				3	4
Cobia		1				3	4
Striped Bass		3					3
Black Sea Bass						2	2
Southern Flounder		1				1	2
Atlantic Sharpnose Shark						1	1
Atlantic Spadefish						1	1
Atlantic Tarpon		1					1
Cero						1	1
Dolphin		1					1
Drum family						1	1
Florida Pompano						1	1
Gulf Menhaden	1						1

Table 2.15. Average length and weight of individual striped mullet intercepted by APAIS interviewers in North Carolina, 1981–2019. Proportional standard error (PSE) values greater than 50 indicate an imprecise estimate and are highlighted in pink.

Year	Avg Length (cm)	PSE[Length]	Avg Weight (kg)	PSE[Weight]
1981	29.2	135.4	0.4	135.4
1982	23.59	73.7	0.2	71.3
1983	20.57	132.2	0.1	128.2
1984	12.4	29.5	0.1	29
1985	28.26	93.9	0.4	93.2
1986	29.91	86.7	0.4	85.6
1987	15.31	97.4	0.1	95.7
1988	0.61	99.7	0	100.4
1989	29.48	57.5	0.4	57.1
1990	25.39	117.7	0.3	117
1991	26.24	64.7	0.3	64.7
1992	28.1	125	0.3	124.5
1993	43.17	84.6	1	90.9
1994	41.67	82.7	1	81.3
1995	40.35	95.8	1	100.5
1996	37.94	71.8	0.9	73.7
1997	37.76	102	0.9	107.6
1998	29.18	93.6	0.3	93.9
1999	28.75	79.6	0.3	79.9
2000	32.94	103.9	0.6	110.9
2001	30.39	55	0.3	58
2002	20.75	26	0.2	30.2
2003	23.46	44.9	0.2	48.8
2004	25.3	143.8	0.2	143.8
2005	34.48	87.2	0.6	88.1
2006	30.17	86.4	0.4	83.1
2007	26.89	113.5	0.3	110.4
2008	27.55	90.9	0.3	90.6
2009	18.17	122.9	0.1	110.1
2010	26.31	63.7	0.4	73.2
2011	27.22	41.4	0.3	48
2012	26.6	112.5	0.3	112.8
2013	27.39	74.9	0.4	76.8
2014	32.76	96.4	0.5	97
2015	31.61	91.7	0.6	94.9
2016	30.25	71.7	0.4	72.3
2017	27.41	62.3	0.3	61.8
2018	27.58	83.3	0.3	82
2019	31.82	73.9	0.5	77

Table 2.16. Number of available biological samples of striped mullet sampled from Program 146, 2003–2019.

	Spring			Autumn		
	Length	Age		Length	Age	
Year	pooled	female	male	pooled	female	male
2003	413	39	5	580	48	18
2004	776	139	8	881	69	3
2005	1,462	64	3	57		
2006	1,636	44	8	61		
2007	957	83	4		13	2
2008	1,719	60	3	635	36	2
2009	1,150	61	4	494		
2010	864	22	5	601		
2011	1,452	47	9	520	33	4
2012	454	42	2	656		
2013	1,368			627	37	26
2014	829	50	8	435	13	2
2015	606			328	14	
2016	710	54	5	158	62	14
2017	562	69	15	470	46	19
2018	1,010	45	18	21	17	1
2019	452	34	3	769	34	2

Table 2.17. Number of available biological samples of striped mullet sampled from Program 915 by area, 1994–2019.

	Southern			Northern		
	Length	Age		Length	Age	
Year	pooled	female	male	pooled	female	male
2004				824	54	12
2005				574	32	11
2006				559	27	18
2007				791	40	21
2008	167	68	26	521	39	19
2009	134	61	19	619	49	22
2010	356	63	21	854	135	46
2011	91	49	23	898	109	50
2012	95	54	26	803	204	143
2013	105	36	19	784	232	118
2014	215	72	45	740	177	134
2015	77	38	20	272	88	78
2016	156	35	16	307	110	63
2017	53	25	32	321	101	67
2018	50	26	15	477	146	91
2019	21	10	2	347	131	66

Table 3.1. Initial values, bounds (min and max), and prior types assumed for estimated parameters in the base run of the stock assessment model.

Type	Parameter	Initial Value	Min	Max	Prior Type
Growth	L1, female	21.0	10	40	Sym_Beta
	Linf, female	48.7	20	70	Sym_Beta
	K, female	0.40	0.05	0.8	Sym_Beta
	CV1, female	0.28	0.01	0.5	Sym_Beta
	CV2, female	0.21	0.01	0.5	Sym_Beta
	L1, male	20.7	10	40	Sym_Beta
	Linf, male	42.2	20	70	Sym_Beta
	K, male	0.43	0.05	0.8	Sym_Beta
	CV1, male	0.25	0.01	0.5	Sym_Beta
	CV2, male	0.14	0.01	0.5	Sym_Beta
Initial conditions	SR_LN(R0)	10	6	20	Sym_Beta
	SR_BH_steep	0.77	0.2	1	Normal
	InitF_seas_1_flt_1Comm	0.4	0	1	No_prior
	InitF_seas_1_flt_2Rec	0.4	0	1	No_prior
Catchability	LnQ_base_P915(3)	0	-25	25	No_prior
	Q_power_P915(3)	0	-25	25	Normal
Selectivity	Size_inflection_Comm(1)	32	0	60	No_prior
	Size_95%width_Comm(1)	6.2	0.01	40	No_prior
	Size_inflection_P915_north(3)	29	0	60	No_prior
	Size_95%width_P915_north(3)	2.6	0.01	40	No_prior

Table 3.2. Estimated values, standard deviations (SD), bounds (min and max), and phase of estimation for parameters in the base run of the stock assessment model. Standard deviation values marked with an asterisk (*) indicate excessively large (>100%) proportional standard errors.

Type	Parameter	Estimated Value	SD[Value]	Phase
Growth	L1, female	21	1.2	2
	Linf, female	50	2.6	4
	K, female	0.39	0.064	4
	CV1, female	0.25	0.024	3
	CV2, female	0.091	0.021	3
	L1, male	22	1.4	2
	Linf, male	41	0.97	5
	K, male	0.66	0.077	5
	CV1, male	0.28	0.029	3
	CV2, male	0.042	0.012	3
Initial conditions	SR_LN(R0)	9.7	0.092	1
	SR_BH_steep	0.73	0.043	3
	InitF_seas_1_flt_1Comm	0.027	0.0069	1
	InitF_seas_1_flt_2Rec	0.023	0.0055	1
Catchability	LnQ_base_P915(3)	-11		-8
	Q_power_P915(3)	0.69	0.28	9
Selectivity	Size_inflection_Comm(1)	31	0.43	5
	Size_95%width_Comm(1)	5.8	0.48	6
	Size_inflection_P915_north(3)	28	0.25	3
	Size_95%width_P915_north(3)	2.3	0.39	4

Table 3.3. Comparison of empirically-derived estimates of the von Bertalanffy age-length parameters to those estimated by the base run of the Stock Synthesis model.

Sex	Parameter	Empirical	Stock Synthesis
female	$L1$ (cm)	21	21
	L_∞ (cm)	49	50
	K	0.40	0.39
	CV1	0.28	0.25
	CV2	0.21	0.091
male	$L1$ (cm)	21	22
	L_∞ (cm)	42	41
	K	0.43	0.66
	CV1	0.25	0.28
	CV2	0.14	0.042

Table 3.4. Annual estimates of recruitment (thousands of fish), female spawning stock biomass (SSB; metric tons), and spawning potential ratio (SPR) and associated standard deviations from the base run of the stock assessment model, 1950–1984.

	Recruitment		SSB		SPR	
Year	**Value**	**SD**	**Value**	**SD**	**Value**	**SD**
1950	16,710	1,520	3,222	350	0.46	0.034
1951	16,352	1,462	2,657	336	0.37	0.037
1952	15,746	1,396	2,019	320	0.32	0.042
1953	15,021	1,363	1,539	303	0.37	0.049
1954	14,721	1,356	1,392	293	0.44	0.052
1955	14,722	1,347	1,392	288	0.42	0.051
1956	14,671	1,338	1,370	283	0.38	0.051
1957	14,497	1,332	1,296	276	0.38	0.052
1958	14,366	1,327	1,245	271	0.36	0.052
1959	14,203	1,326	1,185	266	0.34	0.053
1960	14,005	1,329	1,119	262	0.25	0.050
1961	13,304	1,378	923	252	0.31	0.059
1962	13,264	1,383	913	251	0.30	0.059
1963	13,136	1,408	883	252	0.33	0.063
1964	13,229	1,412	905	256	0.44	0.065
1965	13,696	1,379	1,025	266	0.45	0.061
1966	14,025	1,361	1,125	272	0.44	0.058
1967	14,205	1,350	1,186	274	0.52	0.053
1968	14,524	1,335	1,307	277	0.52	0.050
1969	14,737	1,327	1,399	277	0.55	0.047
1970	14,936	1,323	1,494	277	0.55	0.044
1971	15,086	1,321	1,573	276	0.64	0.037
1972	15,322	1,328	1,712	277	0.57	0.040
1973	15,383	1,327	1,751	276	0.58	0.038
1974	15,453	1,330	1,798	275	0.44	0.042
1975	15,234	1,312	1,658	270	0.45	0.044
1976	15,090	1,304	1,576	267	0.42	0.045
1977	14,929	1,296	1,491	264	0.44	0.046
1978	14,866	1,293	1,460	263	0.45	0.047
1979	14,839	1,291	1,447	261	0.45	0.047
1980	14,808	1,289	1,432	260	0.39	0.047
1981	14,614	1,283	1,345	257	0.50	0.047
1982	14,789	1,286	1,423	259	0.48	0.046
1983	14,859	1,287	1,456	259	0.56	0.043
1984	15,049	1,293	1,553	261	0.47	0.044

Table 3.5. Annual estimates of recruitment (thousands of fish), female spawning stock biomass (SSB; metric tons), and spawning potential ratio (SPR) and associated standard deviations from the base run of the stock assessment model, 1985–2019.

	Recruitment		SSB		SPR	
Year	**Value**	**SD**	**Value**	**SD**	**Value**	**SD**
1985	15,008	1,289	1,531	260	0.50	0.044
1986	15,037	1,290	1,547	260	0.44	0.045
1987	14,922	1,284	1,487	258	0.36	0.045
1988	14,578	1,275	1,330	253	0.30	0.046
1989	14,032	1,280	1,128	246	0.36	0.052
1990	12,472	3,545	1,117	246	0.27	0.044
1991	12,804	3,366	952	231	0.40	0.048
1992	11,694	3,011	1,005	210	0.35	0.039
1993	10,006	2,307	984	182	0.22	0.029
1994	10,633	2,079	736	136	0.29	0.031
1995	14,849	2,401	682	99	0.23	0.028
1996	14,431	2,361	580	83	0.29	0.032
1997	8,827	1,759	694	102	0.23	0.029
1998	16,898	2,431	719	114	0.26	0.032
1999	9,430	1,975	659	113	0.33	0.028
2000	13,923	1,809	807	93	0.23	0.021
2001	9,063	1,847	672	75	0.22	0.017
2002	16,856	1,970	630	45	0.096	0.015
2003	12,621	1,867	457	27	0.13	0.017
2004	9,433	1,758	424	50	0.21	0.021
2005	11,894	1,807	411	51	0.22	0.023
2006	10,764	1,503	420	51	0.24	0.023
2007	7,451	1,029	484	59	0.20	0.019
2008	12,582	1,175	520	53	0.25	0.021
2009	9,586	1,186	468	46	0.24	0.018
2010	9,469	912	507	40	0.20	0.016
2011	9,095	905	474	32	0.24	0.017
2012	9,453	763	471	31	0.19	0.015
2013	8,312	760	424	27	0.20	0.014
2014	5,801	572	419	24	0.15	0.013
2015	6,673	605	334	16	0.16	0.014
2016	9,137	746	270	18	0.20	0.015
2017	6,673	535	267	21	0.15	0.012
2018	7,333	550	270	16	0.21	0.015
2019	8,315	3,134	263	15	0.21	0.018

Table 3.6. Predicted stock numbers (thousands of fish) at age at the beginning of the year from the base run of the stock assessment model, 1950–1984. Values rounded to the nearest integer.

Year	0	1	2	3	4	5	6	7+
1950	16,710	6,604	3,406	1,937	1,150	700	432	735
1951	16,352	5,942	3,107	1,636	927	555	341	579
1952	15,746	5,787	2,685	1,348	685	388	234	394
1953	15,021	5,543	2,545	1,089	517	261	148	244
1954	14,721	5,259	2,512	1,121	466	221	113	172
1955	14,722	5,140	2,447	1,188	527	221	106	138
1956	14,671	5,138	2,380	1,143	549	245	104	116
1957	14,497	5,116	2,340	1,066	499	240	108	99
1958	14,366	5,047	2,326	1,045	464	218	106	92
1959	14,203	4,994	2,274	1,015	441	196	93	85
1960	14,005	4,928	2,226	966	414	179	80	74
1961	13,304	4,842	2,054	796	314	132	57	50
1962	13,264	4,571	2,113	832	305	120	51	41
1963	13,136	4,551	1,977	837	310	113	44	34
1964	13,229	4,502	2,014	832	337	125	46	32
1965	13,696	4,543	2,093	962	396	162	61	38
1966	14,025	4,727	2,125	1,012	465	194	80	49
1967	14,205	4,859	2,202	1,014	481	223	94	64
1968	14,524	4,934	2,317	1,115	521	251	118	84
1969	14,737	5,061	2,353	1,170	570	270	132	107
1970	14,936	5,147	2,430	1,208	611	303	145	130
1971	15,086	5,227	2,475	1,251	633	326	163	151
1972	15,322	5,289	2,559	1,333	696	360	187	184
1973	15,383	5,381	2,553	1,326	705	374	196	205
1974	15,453	5,406	2,607	1,336	710	384	207	225
1975	15,234	5,430	2,523	1,237	629	337	184	210
1976	15,090	5,344	2,538	1,204	587	301	163	193
1977	14,928	5,286	2,477	1,185	556	273	141	169
1978	14,866	5,222	2,465	1,178	560	265	131	152
1979	14,839	5,197	2,441	1,180	561	269	129	139
1980	14,808	5,186	2,426	1,164	560	269	130	131
1981	14,614	5,171	2,369	1,094	513	247	120	118
1982	14,789	5,099	2,456	1,183	551	262	128	125
1983	14,859	5,166	2,408	1,207	584	275	132	129
1984	15,049	5,197	2,487	1,244	636	313	149	144

Table 3.7. Predicted stock numbers (thousands of fish) at age at the beginning of the year from the base run of the stock assessment model, 1985–2019. Values rounded to the nearest integer.

Year	0	1	2	3	4	5	6	7+
1985	15,008	5,269	2,446	1,210	605	313	155	148
1986	15,037	5,255	2,499	1,214	604	306	160	158
1987	14,921	5,264	2,447	1,182	570	286	146	154
1988	14,578	5,215	2,370	1,061	495	238	121	128
1989	14,032	5,075	2,259	933	391	181	87	92
1990	12,472	4,863	2,286	987	395	166	77	78
1991	12,804	4,244	2,052	853	340	134	56	53
1992	11,694	4,371	1,941	944	387	155	62	51
1993	10,006	3,938	1,954	849	401	165	67	49
1994	10,632	3,264	1,576	656	255	118	48	34
1995	14,849	3,498	1,400	630	248	96	44	31
1996	14,431	5,146	1,419	466	187	71	28	22
1997	8,827	5,013	2,220	553	170	67	26	18
1998	16,898	2,834	2,045	793	180	54	22	14
1999	9,430	5,949	1,190	736	260	58	17	12
2000	13,923	3,088	2,629	516	309	109	25	12
2001	9,063	4,779	1,247	869	152	89	31	11
2002	16,856	2,916	1,925	430	271	46	27	13
2003	12,621	3,462	958	545	106	65	11	10
2004	9,433	2,858	1,248	321	167	32	19	6
2005	11,894	2,997	1,135	418	97	49	9	8
2006	10,764	4,004	1,204	376	123	28	14	5
2007	7,451	3,715	1,636	409	115	37	8	6
2008	12,582	2,082	1,467	596	138	38	12	5
2009	9,586	4,327	861	515	189	43	12	5
2010	9,469	3,205	1,778	304	165	60	14	5
2011	9,095	3,059	1,251	563	85	45	16	5
2012	9,453	3,006	1,253	442	181	27	14	7
2013	8,312	3,020	1,168	395	123	49	7	6
2014	5,801	2,539	1,194	399	122	37	15	4
2015	6,673	1,614	915	344	99	29	9	4
2016	9,137	1,880	603	286	95	27	8	4
2017	6,673	2,804	743	205	88	28	8	3
2018	7,333	1,858	1,010	213	51	21	7	3
2019	8,315	2,642	724	294	53	12	5	2

Table 3.8. Predicted stock numbers (thousands of fish) at age at mid-year from the base run of the stock assessment model, 1950–1984. Values rounded to the nearest integer.

Year	0	1	2	3	4	5	6	7+
1950	9,964	4,530	2,360	1,340	799	488	303	519
1951	9,727	3,994	2,046	1,058	599	360	222	379
1952	9,342	3,837	1,710	835	423	240	145	246
1953	8,888	3,731	1,689	712	338	171	98	162
1954	8,699	3,587	1,728	768	321	153	78	120
1955	8,698	3,498	1,672	807	359	151	73	96
1956	8,664	3,468	1,592	755	363	163	69	78
1957	8,554	3,450	1,563	703	330	159	72	66
1958	8,470	3,388	1,536	679	301	142	69	61
1959	8,366	3,334	1,482	648	281	125	60	55
1960	8,235	3,182	1,331	551	234	101	45	42
1961	7,798	3,198	1,307	493	194	82	36	31
1962	7,769	3,006	1,330	508	185	73	31	25
1963	7,690	3,027	1,282	531	196	72	28	22
1964	7,752	3,070	1,392	574	234	87	32	23
1965	8,047	3,107	1,455	669	277	114	43	27
1966	8,255	3,227	1,468	698	322	135	56	35
1967	8,372	3,355	1,567	727	347	162	68	47
1968	8,573	3,407	1,646	797	375	182	86	62
1969	8,709	3,507	1,685	846	415	198	97	80
1970	8,835	3,569	1,743	874	446	222	107	97
1971	8,932	3,657	1,817	933	477	247	124	116
1972	9,080	3,674	1,842	970	510	265	139	137
1973	9,119	3,746	1,846	970	520	278	146	154
1974	9,160	3,693	1,796	917	489	266	144	157
1975	9,023	3,712	1,743	852	435	234	129	147
1976	8,931	3,638	1,735	818	400	206	112	134
1977	8,829	3,610	1,708	815	383	189	98	119
1978	8,789	3,571	1,705	813	388	184	92	107
1979	8,772	3,551	1,686	812	388	187	90	98
1980	8,750	3,505	1,629	773	372	179	87	89
1981	8,632	3,563	1,674	776	367	178	86	86
1982	8,741	3,504	1,721	831	389	186	91	90
1983	8,787	3,585	1,730	876	427	203	98	96
1984	8,905	3,565	1,735	868	446	220	106	103

Table 3.9. Predicted stock numbers (thousands of fish) at age at mid-year from the base run of the stock assessment model, 1985–2019. Values rounded to the nearest integer.

Year	0	1	2	3	4	5	6	7+
1985	8,880	3,629	1,723	855	431	224	112	107
1986	8,897	3,586	1,719	831	416	212	111	110
1987	8,821	3,532	1,611	765	369	186	95	101
1988	8,601	3,432	1,486	644	299	144	73	78
1989	8,261	3,406	1,493	607	255	118	57	61
1990	7,275	3,159	1,396	580	230	97	45	46
1991	7,481	2,870	1,392	575	230	91	38	36
1992	6,786	2,922	1,284	615	252	102	41	34
1993	5,715	2,491	1,132	466	217	89	36	27
1994	6,098	2,137	996	403	156	72	30	21
1995	8,742	2,228	807	343	133	51	24	17
1996	8,506	3,380	886	281	112	43	17	13
1997	5,002	3,202	1,326	316	96	38	15	10
1998	10,026	1,837	1,226	454	102	31	12	8
1999	5,397	3,954	784	477	168	38	11	8
2000	8,157	1,962	1,511	280	165	58	13	7
2001	5,141	3,033	732	485	84	49	17	6
2002	7,639	1,671	1,024	214	132	23	13	6
2003	6,006	2,079	555	302	58	35	6	5
2004	5,317	1,801	723	176	91	17	11	3
2005	6,901	1,900	653	227	52	26	5	4
2006	6,323	2,560	702	207	67	15	8	3
2007	3,939	2,334	987	238	66	21	5	3
2008	7,379	1,339	869	336	77	21	7	3
2009	5,543	2,774	511	292	106	24	7	3
2010	5,382	2,002	1,000	160	86	31	7	3
2011	5,229	1,957	743	319	47	25	9	3
2012	5,343	1,874	704	233	94	14	7	4
2013	4,593	1,899	683	220	67	27	4	3
2014	3,059	1,524	641	199	60	18	7	2
2015	3,542	986	512	181	51	15	5	2
2016	5,061	1,182	351	158	52	15	4	2
2017	3,521	1,683	398	102	43	14	4	2
2018	4,401	1,160	545	106	25	10	3	1
2019	4,991	1,649	391	147	26	6	2	1

Table 3.10. Predicted stock biomass (metric tons) at age at the beginning of the year from the base run of the stock assessment model, 1950–1984. Values rounded to the nearest integer.

Year	0	1	2	3	4	5	6	7+
1950	431	1,149	1,584	1,423	1,089	773	528	1,025
1951	422	1,034	1,444	1,202	878	613	417	807
1952	406	1,007	1,248	991	650	429	286	549
1953	388	964	1,183	801	491	289	181	340
1954	380	915	1,168	825	442	246	138	239
1955	380	894	1,138	874	500	245	130	192
1956	379	894	1,106	840	521	272	127	161
1957	374	890	1,088	783	474	266	133	136
1958	371	878	1,081	768	440	241	130	127
1959	367	869	1,057	746	419	217	114	117
1960	361	857	1,035	710	393	199	98	101
1961	343	842	955	585	299	147	70	68
1962	342	795	982	612	290	133	62	57
1963	339	792	919	616	295	125	55	47
1964	341	783	936	612	321	138	56	44
1965	353	790	973	707	376	180	74	52
1966	362	823	988	744	441	215	99	67
1967	367	845	1,024	745	456	247	115	86
1968	375	858	1,077	820	494	277	144	114
1969	380	880	1,094	860	541	299	161	146
1970	385	895	1,130	887	579	335	178	177
1971	389	909	1,151	919	600	360	200	205
1972	395	920	1,190	980	659	398	229	250
1973	397	936	1,187	974	668	414	239	280
1974	399	941	1,212	981	673	425	252	307
1975	393	945	1,173	909	596	373	225	287
1976	389	930	1,180	885	556	333	199	265
1977	385	920	1,152	871	527	302	173	233
1978	384	909	1,146	866	531	293	161	208
1979	383	904	1,135	867	532	298	158	192
1980	382	902	1,128	856	531	297	160	181
1981	377	900	1,101	804	487	274	147	162
1982	382	887	1,142	869	523	290	157	171
1983	383	899	1,120	887	554	305	162	177
1984	388	904	1,157	914	602	346	183	197

Table 3.11. Predicted stock biomass (metric tons) at age at the beginning of the year from the base run of the stock assessment model, 1985–2019. Values rounded to the nearest integer.

Year	0	1	2	3	4	5	6	7+
1985	387	917	1,137	889	574	346	190	202
1986	388	914	1,162	892	573	339	196	215
1987	385	916	1,138	869	540	316	179	210
1988	376	907	1,102	780	470	264	148	175
1989	362	883	1,050	686	372	200	107	126
1990	322	846	1,063	726	375	184	95	106
1991	330	738	954	628	323	149	69	73
1992	302	761	903	694	368	172	76	70
1993	258	685	908	624	381	183	82	67
1994	274	568	732	482	243	131	59	47
1995	383	609	651	463	236	106	54	43
1996	372	895	659	342	177	79	34	30
1997	228	872	1,032	407	161	75	32	25
1998	436	493	950	583	172	60	27	19
1999	243	1,035	553	541	247	65	22	16
2000	359	537	1,222	380	294	122	30	17
2001	234	831	579	639	144	98	38	14
2002	435	507	895	317	258	51	33	17
2003	326	603	445	401	101	72	14	13
2004	243	498	580	236	159	36	24	8
2005	307	522	528	308	92	55	12	10
2006	278	697	559	276	117	31	17	7
2007	192	646	760	301	109	41	10	8
2008	325	362	682	438	131	42	15	6
2009	247	753	400	379	180	48	15	7
2010	244	558	826	223	157	66	17	7
2011	235	532	581	414	81	50	20	7
2012	244	523	582	325	172	30	17	9
2013	214	526	543	291	117	54	9	8
2014	150	442	555	294	116	41	18	5
2015	172	281	425	253	94	32	11	6
2016	236	327	280	210	90	30	10	5
2017	172	488	345	150	83	32	10	5
2018	189	323	470	157	48	23	8	4
2019	215	460	337	217	50	13	6	3

Table 3.12. Predicted stock biomass (metric tons) at age at mid-year from the base run of the stock assessment model, 1950–1984. Values rounded to the nearest integer.

Year	0	1	2	3	4	5	6	7+
1950	718	1,434	1,431	1,137	825	570	384	737
1951	700	1,264	1,241	899	619	421	282	539
1952	673	1,214	1,037	709	437	280	184	349
1953	640	1,181	1,024	605	350	201	124	230
1954	626	1,136	1,047	653	332	180	99	170
1955	626	1,107	1,014	686	372	177	93	136
1956	624	1,098	966	641	376	191	88	111
1957	616	1,092	948	597	341	187	92	93
1958	610	1,072	932	577	312	166	88	85
1959	602	1,055	899	551	291	147	76	77
1960	593	1,007	807	468	242	119	58	59
1961	562	1,012	793	419	201	96	45	43
1962	559	952	806	432	192	86	39	35
1963	554	958	778	452	204	84	36	31
1964	558	972	844	488	242	102	41	32
1965	579	984	883	568	287	134	55	38
1966	594	1,022	890	592	333	158	72	48
1967	603	1,062	950	617	359	190	87	65
1968	617	1,079	998	677	388	212	109	85
1969	627	1,110	1,022	718	429	232	123	110
1970	636	1,130	1,057	742	461	260	136	134
1971	643	1,158	1,101	791	493	289	158	161
1972	654	1,163	1,117	823	527	310	176	191
1973	657	1,186	1,120	823	537	325	185	215
1974	660	1,169	1,089	778	505	311	182	219
1975	650	1,175	1,057	723	449	274	163	206
1976	643	1,152	1,052	694	413	241	142	187
1977	636	1,143	1,035	692	397	221	125	166
1978	633	1,130	1,034	690	402	216	117	150
1979	632	1,124	1,022	690	401	219	114	137
1980	630	1,110	988	656	385	210	111	124
1981	622	1,128	1,015	659	379	208	110	120
1982	629	1,109	1,044	705	403	218	116	125
1983	633	1,135	1,049	743	442	237	124	135
1984	641	1,129	1,052	736	460	258	134	143

Table 3.13. Predicted stock biomass (metric tons) at age at mid-year from the base run of the stock assessment model, 1985–2019. Values rounded to the nearest integer.

Year	0	1	2	3	4	5	6	7+
1985	640	1,149	1,045	726	445	261	142	149
1986	641	1,135	1,042	706	429	247	141	153
1987	635	1,118	977	650	381	217	121	141
1988	619	1,086	901	547	309	169	93	109
1989	595	1,078	906	516	264	138	73	85
1990	524	1,000	847	493	238	113	57	64
1991	539	909	844	488	238	107	49	51
1992	489	925	779	523	261	119	52	47
1993	412	788	686	396	225	105	46	37
1994	439	677	604	343	162	85	38	29
1995	630	705	489	292	138	60	30	24
1996	613	1,070	537	239	116	51	21	19
1997	360	1,013	804	269	100	45	19	14
1998	722	581	744	386	106	36	16	11
1999	389	1,252	475	406	175	45	15	11
2000	587	621	916	238	172	69	17	9
2001	370	960	444	413	87	58	22	8
2002	550	529	621	182	137	27	17	9
2003	433	659	336	257	61	42	8	7
2004	383	570	438	150	94	20	14	5
2005	497	601	396	193	54	31	6	6
2006	455	810	426	176	70	18	10	4
2007	284	739	599	202	68	25	6	5
2008	531	424	527	286	80	25	9	4
2009	399	878	310	248	110	28	9	4
2010	388	634	606	136	89	36	9	4
2011	377	620	451	271	49	29	12	4
2012	385	593	427	198	97	16	9	5
2013	331	601	414	187	70	32	5	4
2014	220	482	388	169	62	21	9	3
2015	255	312	310	154	53	18	6	3
2016	365	374	213	135	54	17	5	3
2017	254	533	241	87	44	16	5	2
2018	317	367	331	90	26	12	4	2
2019	359	522	237	125	27	7	3	2

Table 3.14. Predicted commercial landings (thousands of fish) at age from the base run of the stock assessment model, 1950–1984. Values rounded to the nearest integer.

Year	0	1	2	3	4	5	6	7+
1950	11	326	441	328	210	131	82	141
1951	16	448	599	407	248	152	94	162
1952	19	533	622	399	217	126	77	130
1953	14	395	466	258	132	68	39	65
1954	10	279	349	203	91	44	23	35
1955	11	289	360	228	109	47	23	30
1956	13	345	413	257	133	61	26	29
1957	13	347	410	242	122	60	27	25
1958	14	372	440	255	122	59	29	25
1959	15	401	465	267	125	57	27	25
1960	23	602	663	363	166	73	33	31
1961	16	446	476	236	100	43	19	16
1962	17	445	515	259	102	41	17	14
1963	14	375	415	226	90	33	13	10
1964	9	225	265	143	63	24	9	6
1965	8	213	260	156	70	29	11	7
1966	9	239	282	176	87	37	16	10
1967	6	170	206	125	64	31	13	9
1968	7	177	221	140	71	35	17	12
1969	6	159	198	130	69	33	16	14
1970	6	158	200	132	72	37	18	16
1971	4	97	124	84	46	24	12	11
1972	6	153	199	137	77	41	22	21
1973	5	142	182	125	72	39	21	22
1974	10	283	357	239	137	76	41	45
1975	10	276	337	216	118	65	36	41
1976	11	301	373	231	121	64	35	42
1977	10	273	336	210	106	53	28	34
1978	10	261	324	203	104	50	25	29
1979	10	264	326	206	106	52	25	27
1980	13	339	410	256	132	65	32	32
1981	7	201	245	149	75	37	18	18
1982	8	219	280	177	89	43	21	21
1983	6	154	193	128	67	32	16	16
1984	9	238	300	197	109	55	26	26

Table 3.15. Predicted commercial landings (thousands of fish) at age from the base run of the stock assessment model, 1950–1984. Values rounded to the nearest integer.

Year	0	1	2	3	4	5	6	7+
1985	8	214	263	171	92	49	25	24
1986	10	279	347	220	118	61	32	32
1987	15	396	471	294	152	78	40	43
1988	19	518	588	336	168	83	42	45
1989	13	371	424	227	102	48	24	25
1990	19	542	629	345	147	63	30	30
1991	10	253	319	173	74	30	13	12
1992	11	316	361	227	100	41	17	14
1993	18	532	638	348	175	73	30	22
1994	13	307	374	199	83	39	16	12
1995	28	487	466	262	110	43	20	14
1996	20	524	360	150	64	25	10	8
1997	14	604	658	207	68	27	11	8
1998	28	344	604	295	72	22	9	6
1999	9	440	227	181	69	16	5	3
2000	27	433	882	216	138	50	11	6
2001	16	614	390	342	64	38	14	5
2002	33	463	749	208	139	24	14	7
2003	19	434	303	218	45	28	5	4
2004	17	385	408	132	73	14	9	3
2005	23	418	380	175	43	22	4	3
2006	20	536	388	152	53	12	6	2
2007	11	417	462	147	44	14	3	2
2008	22	263	450	230	57	16	5	2
2009	16	538	261	197	77	18	5	2
2010	19	476	629	134	77	28	7	3
2011	15	379	379	215	34	19	7	2
2012	19	447	444	195	85	13	7	3
2013	14	390	369	157	52	21	3	2
2014	13	418	467	193	63	19	8	2
2015	13	237	325	152	47	14	4	2
2016	16	246	193	115	41	12	3	2
2017	15	463	291	99	45	15	4	2
2018	18	317	397	103	26	11	4	1
2019	20	450	285	142	27	6	3	1

Table 3.16. Predicted recreational harvest (thousands of fish) at age from the base run of the stock assessment model, 1950–1984. Values rounded to the nearest integer.

Year	0	1	2	3	4	5	6	7+
1950	1,185	161	13	1	0	0	0	0
1951	1,200	147	12	1	0	0	0	0
1952	1,202	148	11	1	0	0	0	0
1953	1,199	150	11	1	0	0	0	0
1954	1,201	147	11	1	0	0	0	0
1955	1,205	144	11	1	0	0	0	0
1956	1,206	144	11	1	0	0	0	0
1957	1,205	145	11	1	0	0	0	0
1958	1,206	144	11	1	0	0	0	0
1959	1,206	143	10	1	0	0	0	0
1960	1,210	140	10	1	0	0	0	0
1961	1,203	147	10	1	0	0	0	0
1962	1,210	140	10	1	0	0	0	0
1963	1,209	142	10	1	0	0	0	0
1964	1,208	142	10	1	0	0	0	0
1965	1,211	139	10	1	0	0	0	0
1966	1,209	141	10	1	0	0	0	0
1967	1,206	144	11	1	0	0	0	0
1968	1,206	142	11	1	0	0	0	0
1969	1,205	144	11	1	0	0	0	0
1970	1,204	145	11	1	0	0	0	0
1971	1,202	146	12	1	0	0	0	0
1972	1,204	145	12	1	0	0	0	0
1973	1,202	147	12	1	0	0	0	0
1974	1,204	145	11	1	0	0	0	0
1975	1,202	147	11	1	0	0	0	0
1976	1,203	146	11	1	0	0	0	0
1977	1,202	146	11	1	0	0	0	0
1978	1,203	145	11	1	0	0	0	0
1979	1,204	145	11	1	0	0	0	0
1980	1,205	144	11	1	0	0	0	0
1981	1,201	147	11	1	0	0	0	0
1982	1,205	144	11	1	0	0	0	0
1983	1,203	146	11	1	0	0	0	0
1984	1,205	144	11	1	0	0	0	0

Table 3.17. Predicted recreational harvest (thousands of fish) at age from the base run of the stock assessment model, 1985–2019. Values rounded to the nearest integer.

Year	0	1	2	3	4	5	6	7+
1985	1,203	146	11	1	0	0	0	0
1986	1,204	145	11	1	0	0	0	0
1987	1,205	144	11	1	0	0	0	0
1988	1,206	144	10	1	0	0	0	0
1989	1,202	148	11	1	0	0	0	0
1990	1,194	155	11	1	0	0	0	0
1991	1,211	138	11	1	0	0	0	0
1992	1,196	153	11	1	0	0	0	0
1993	1,193	156	12	1	0	0	0	0
1994	1,223	128	10	1	0	0	0	0
1995	1,258	96	6	0	0	0	0	0
1996	1,211	144	6	0	0	0	0	0
1997	1,130	216	15	1	0	0	0	0
1998	1,282	70	8	0	0	0	0	0
1999	1,111	242	8	1	0	0	0	0
2000	1,258	91	12	0	0	0	0	0
2001	1,149	203	8	1	0	0	0	0
2002	5,584	353	36	1	0	0	0	0
2003	3,701	371	16	1	0	0	0	0
2004	1,259	127	8	0	0	0	0	0
2005	1,206	100	6	0	0	0	0	0
2006	939	114	5	0	0	0	0	0
2007	1,487	260	18	1	0	0	0	0
2008	1,124	61	7	0	0	0	0	0
2009	1,011	151	5	0	0	0	0	0
2010	1,176	131	11	0	0	0	0	0
2011	1,018	114	7	1	0	0	0	0
2012	1,232	129	8	0	0	0	0	0
2013	1,285	158	9	1	0	0	0	0
2014	1,167	173	12	1	0	0	0	0
2015	1,302	107	9	1	0	0	0	0
2016	1,390	97	5	0	0	0	0	0
2017	1,339	190	7	0	0	0	0	0
2018	450	36	3	0	0	0	0	0
2019	509	51	2	0	0	0	0	0

Table 3.18. Annual estimates of fishing mortality (numbers-weighted, ages 1–5) and associated standard deviations from the base run of the stock assessment model, 1950–1984.

	Fishing Mortality	
Year	**Value**	**SD**
1950	0.17	0.018
1951	0.25	0.031
1952	0.29	0.043
1953	0.22	0.036
1954	0.17	0.028
1955	0.18	0.030
1956	0.21	0.035
1957	0.21	0.036
1958	0.23	0.040
1959	0.25	0.044
1960	0.36	0.072
1961	0.27	0.056
1962	0.29	0.062
1963	0.25	0.054
1964	0.16	0.033
1965	0.15	0.030
1966	0.16	0.030
1967	0.12	0.021
1968	0.12	0.020
1969	0.11	0.017
1970	0.11	0.016
1971	0.074	0.0099
1972	0.10	0.014
1973	0.097	0.012
1974	0.17	0.023
1975	0.17	0.023
1976	0.18	0.026
1977	0.17	0.024
1978	0.16	0.024
1979	0.17	0.024
1980	0.21	0.031
1981	0.13	0.019
1982	0.14	0.021
1983	0.11	0.015
1984	0.15	0.021

Table 3.19. Annual estimates of fishing mortality (numbers-weighted, ages 1–5) and associated standard deviations from the base run of the stock assessment model, 1985–2019.

	Fishing Mortality	
Year	**Value**	**SD**
1985	0.14	0.019
1986	0.17	0.024
1987	0.24	0.035
1988	0.30	0.049
1989	0.22	0.038
1990	0.34	0.059
1991	0.19	0.031
1992	0.23	0.031
1993	0.43	0.055
1994	0.30	0.030
1995	0.40	0.048
1996	0.27	0.031
1997	0.35	0.040
1998	0.38	0.051
1999	0.21	0.016
2000	0.44	0.043
2001	0.37	0.016
2002	0.61	0.033
2003	0.45	0.035
2004	0.40	0.038
2005	0.39	0.041
2006	0.35	0.035
2007	0.36	0.023
2008	0.40	0.031
2009	0.33	0.019
2010	0.44	0.025
2011	0.36	0.019
2012	0.44	0.024
2013	0.39	0.017
2014	0.53	0.022
2015	0.49	0.029
2016	0.39	0.023
2017	0.47	0.020
2018	0.46	0.023
2019	0.42	0.024

9 FIGURES

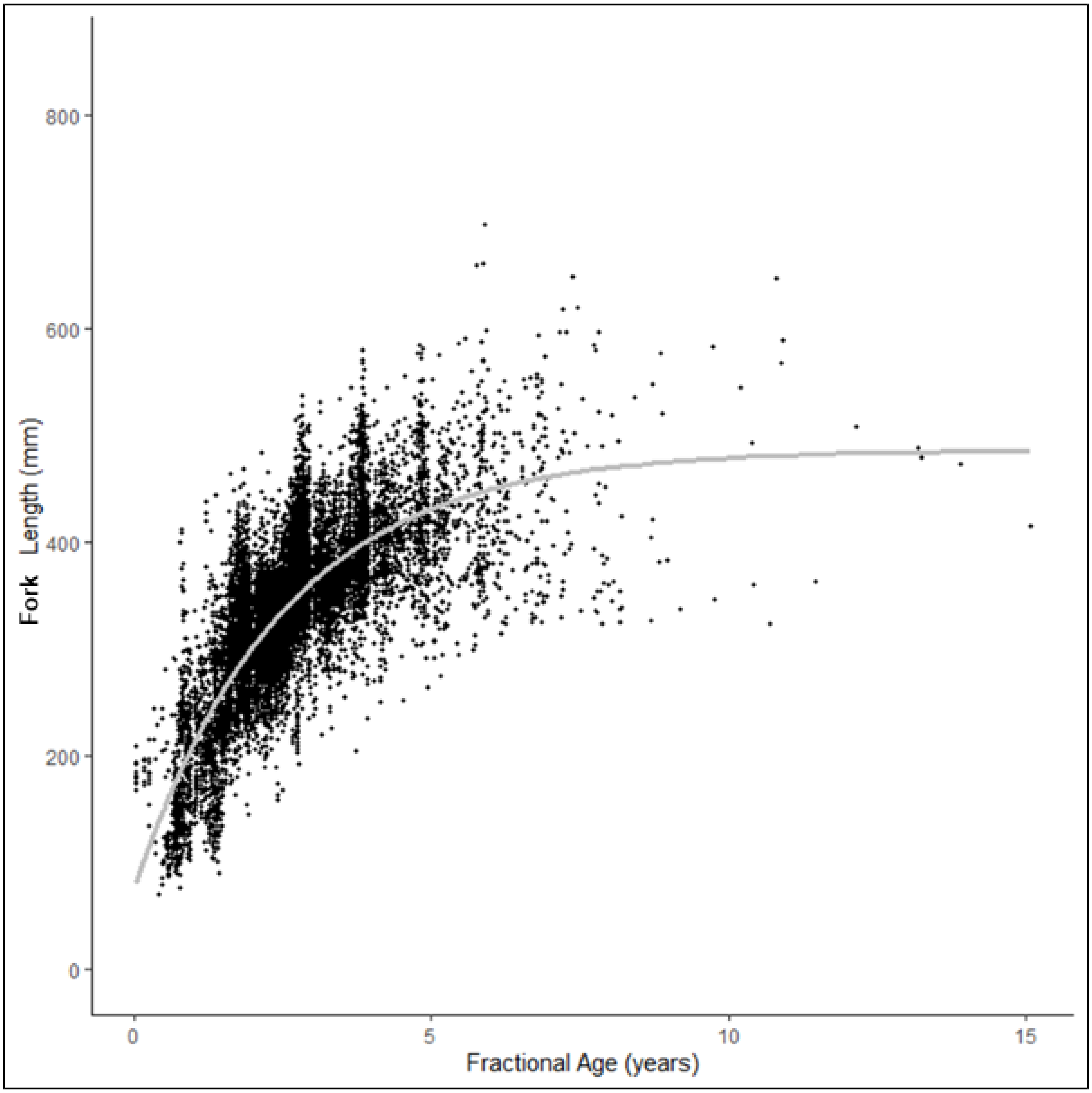


Figure 1.1. Fit of the von Bertalanffy age-length model to available biological data for female and unknown sex striped mullet.

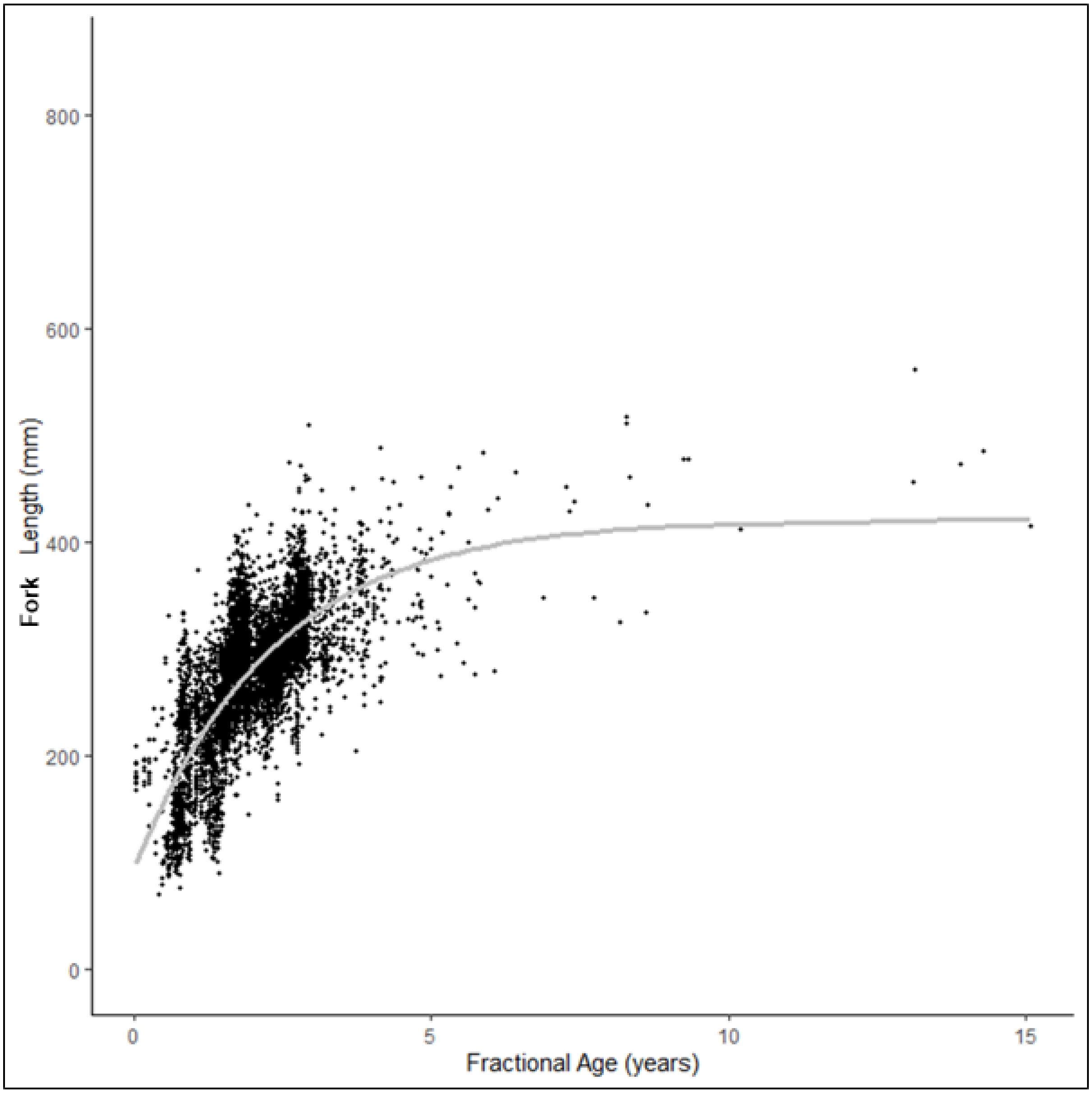


Figure 1.2. Fit of the von Bertalanffy age-length model to available biological data for male and unknown sex striped mullet.

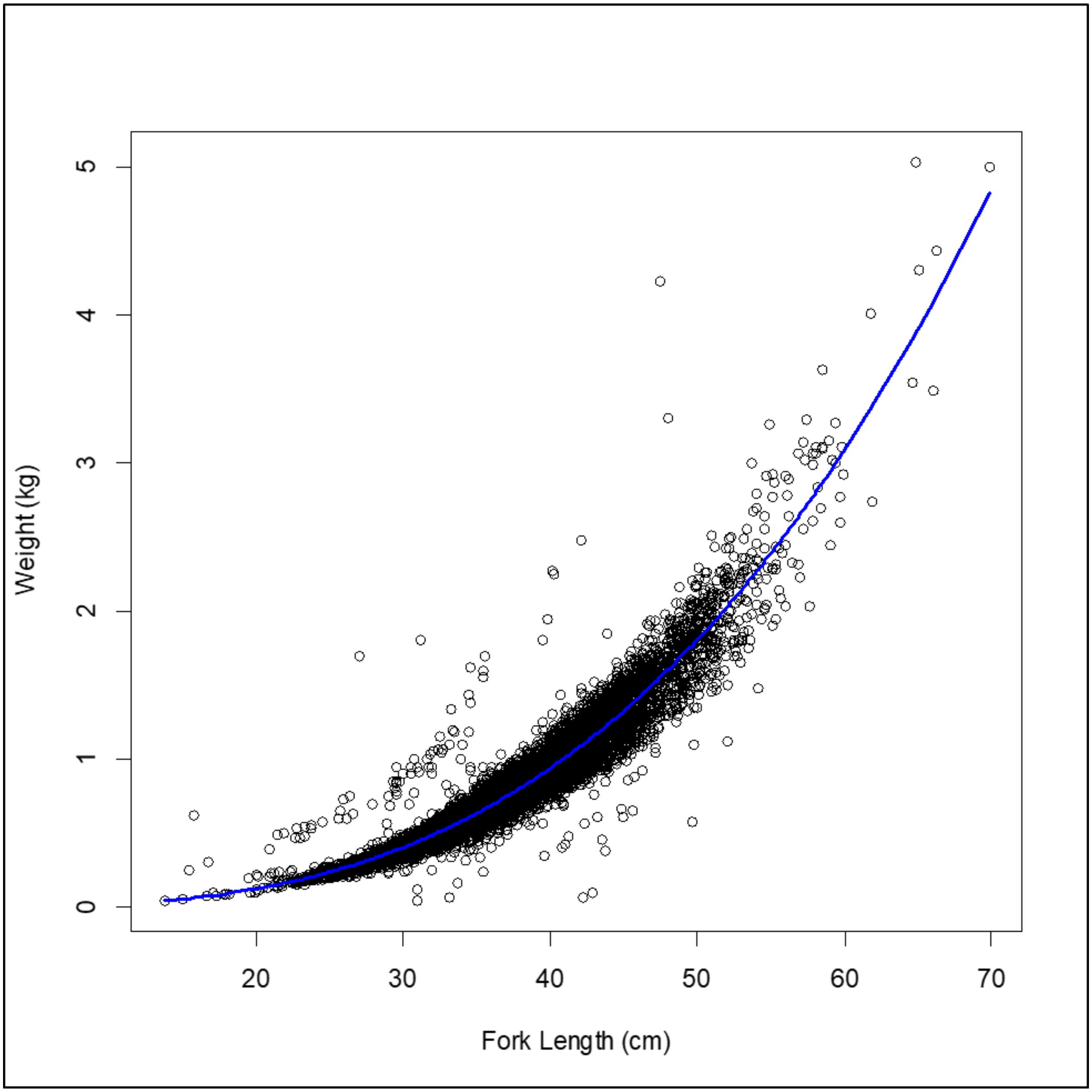


Figure 1.3. Fit of the length-weight model to female striped mullet data collected in North Carolina.

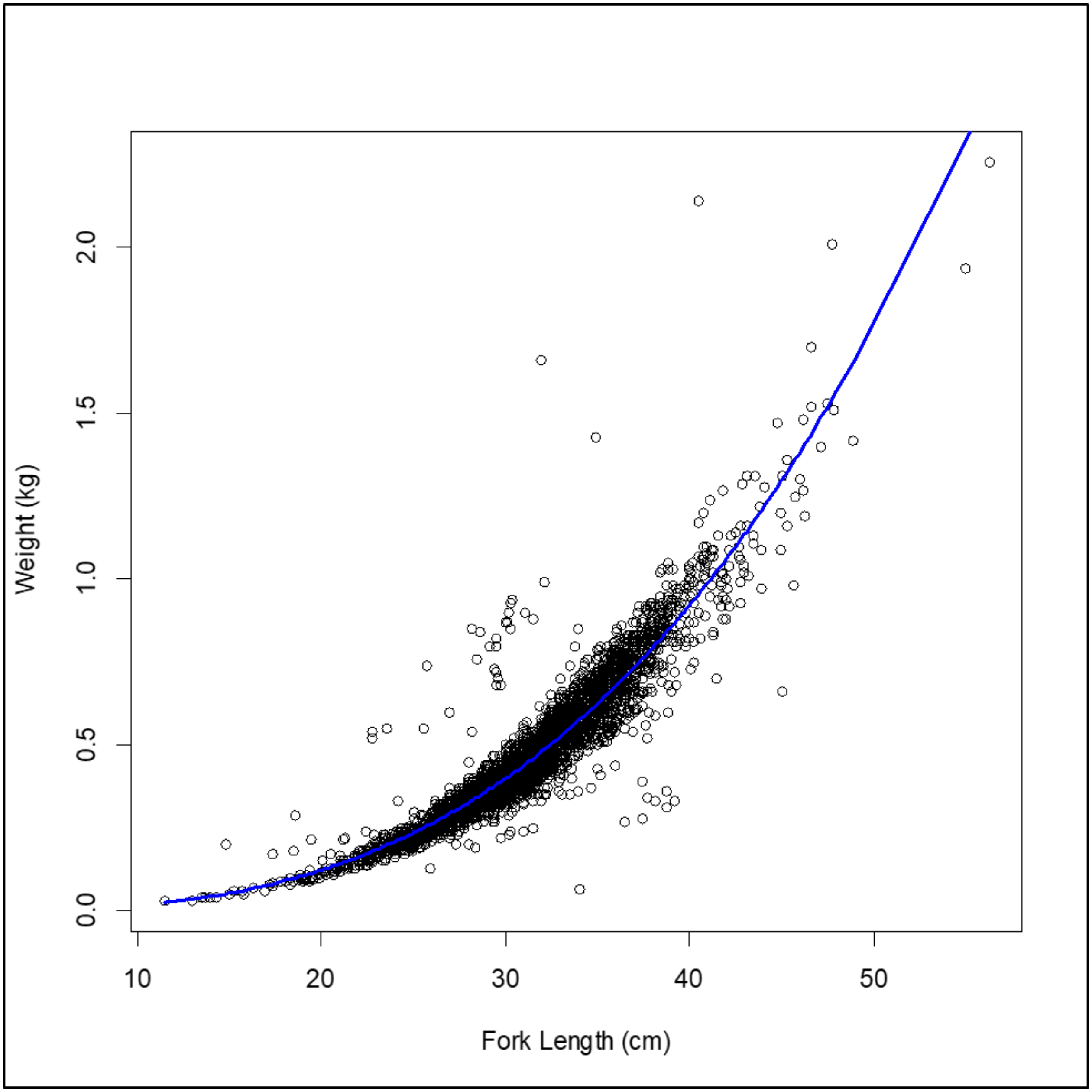


Figure 1.4. Fit of the length-weight model to male striped mullet data collected in North Carolina.

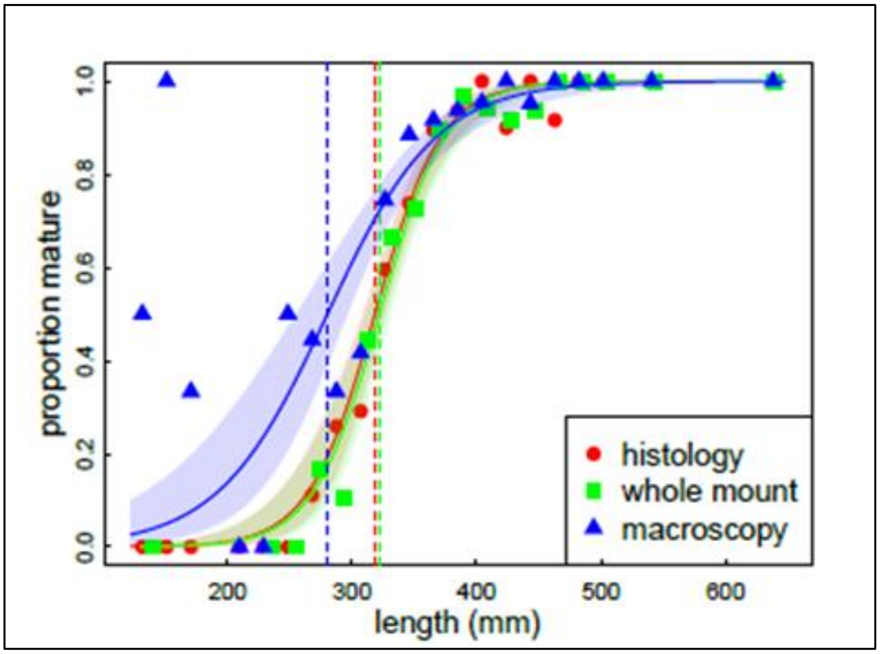


Figure 1.5. Fit of maturity curves to female striped mullet data collected in North Carolina for three maturity staging methods. The solid lines represent the best-fitting logistic regression and the shaded area represent the 95% confidence bands. The vertical dashed lines represent the predicted length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

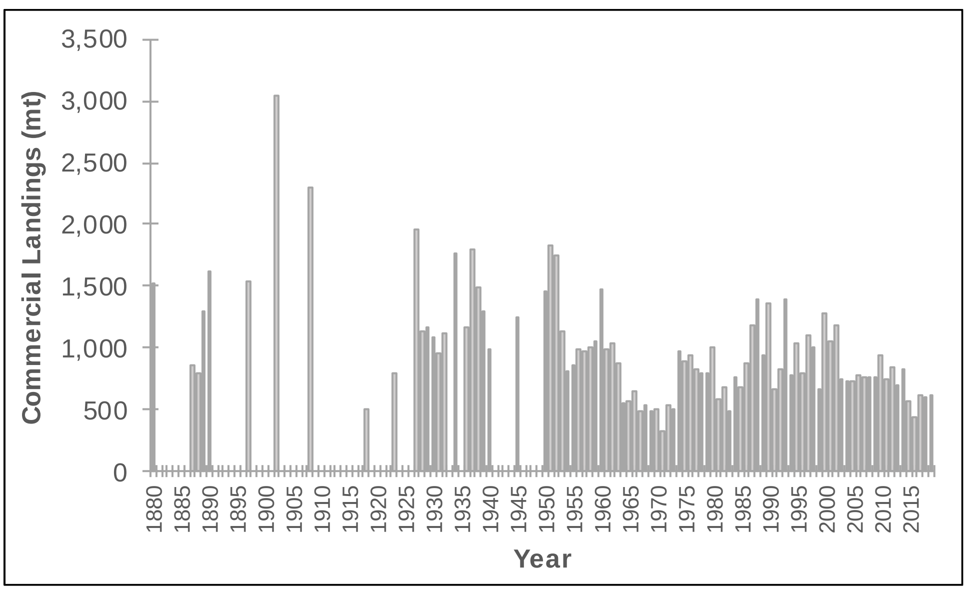


Figure 1.6. Annual commercial landings of striped mullet in North Carolina, 1880–2019. Note that commercial landings data were not available for all years.

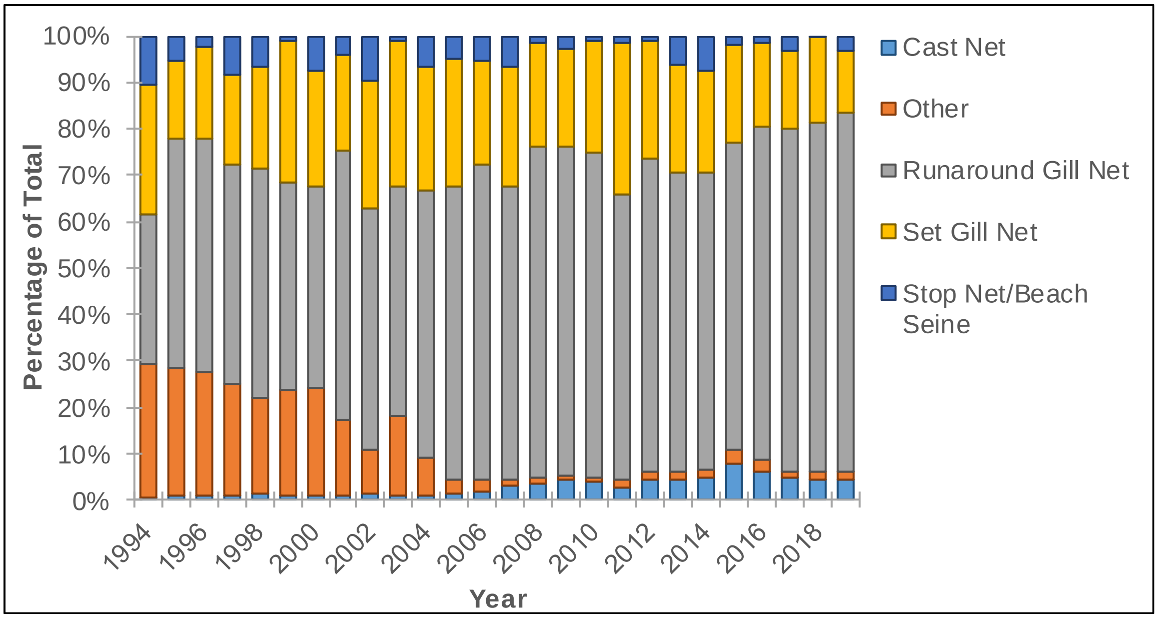


Figure 1.7. Percentages of North Carolina's commercial landings of striped mullet attributed to major commercial gear types, 1994–2019.

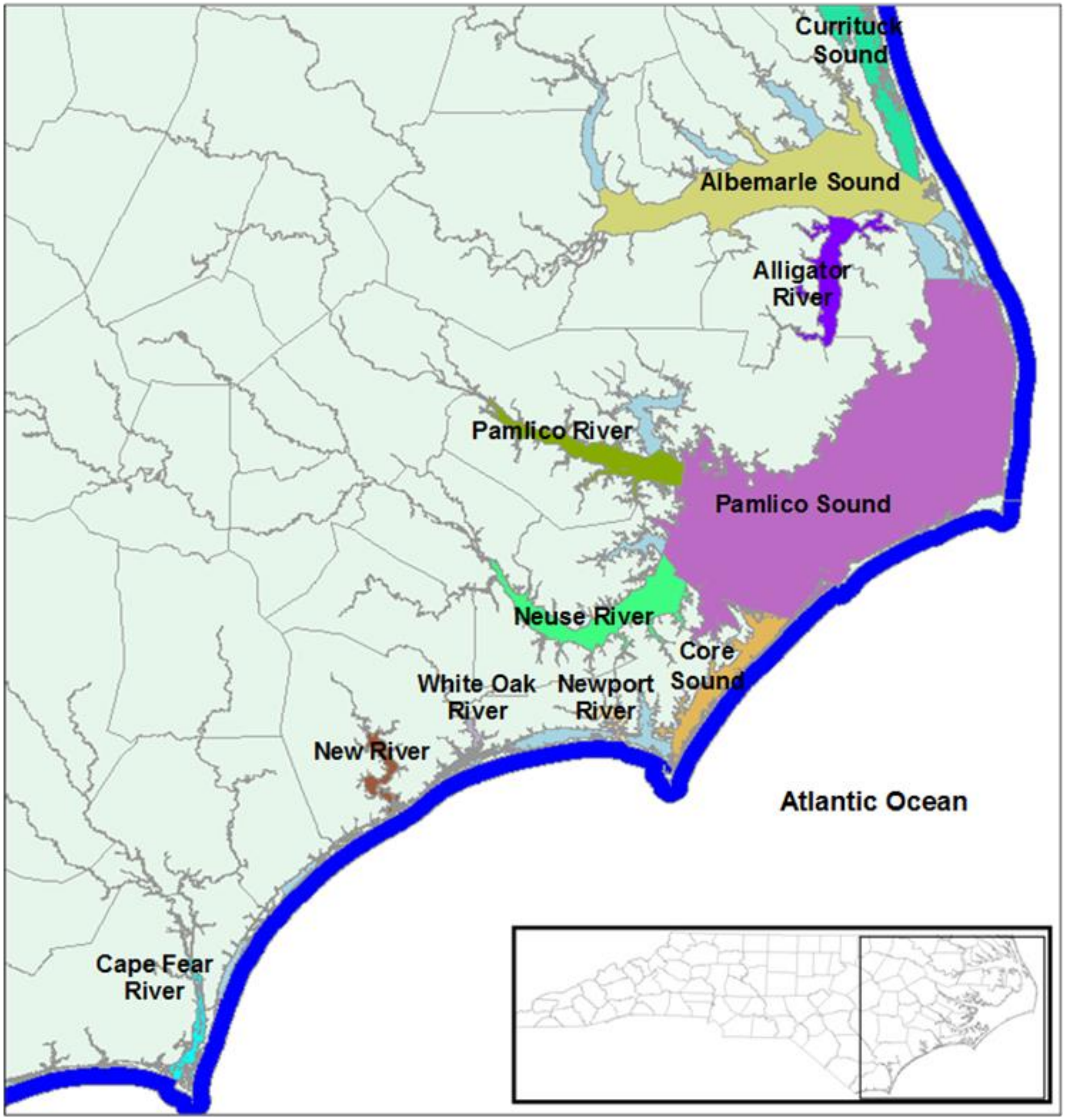


Figure 1.8. Major water bodies within and around North Carolina. The dark blue area represents the extent of the state's coastal fishing waters, which extend to three miles offshore.

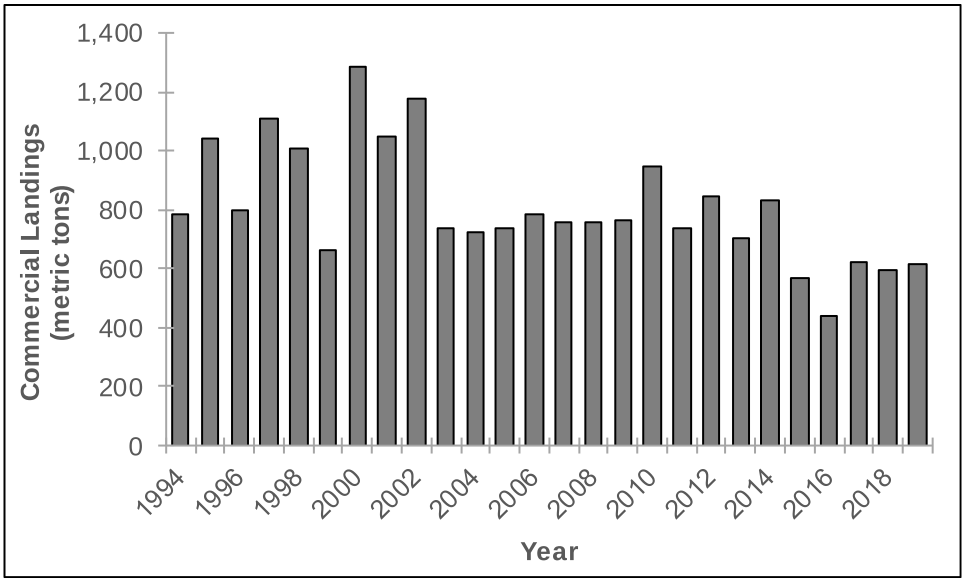


Figure 2.1. Annual commercial landings of striped mullet in North Carolina, 1994–2019.

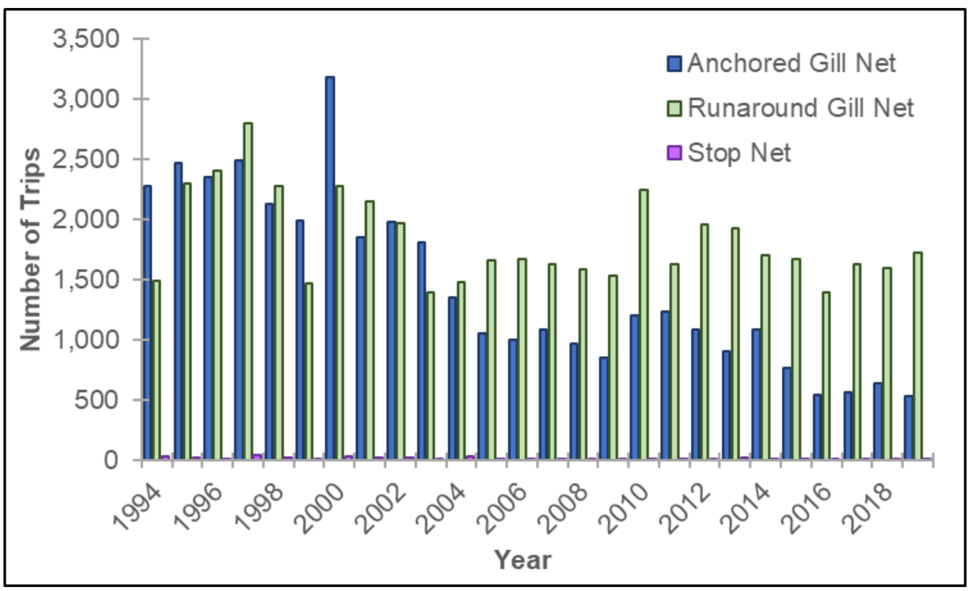


Figure 2.2. Commercial effort for striped mullet in North Carolina by select gears, 1994–2019.

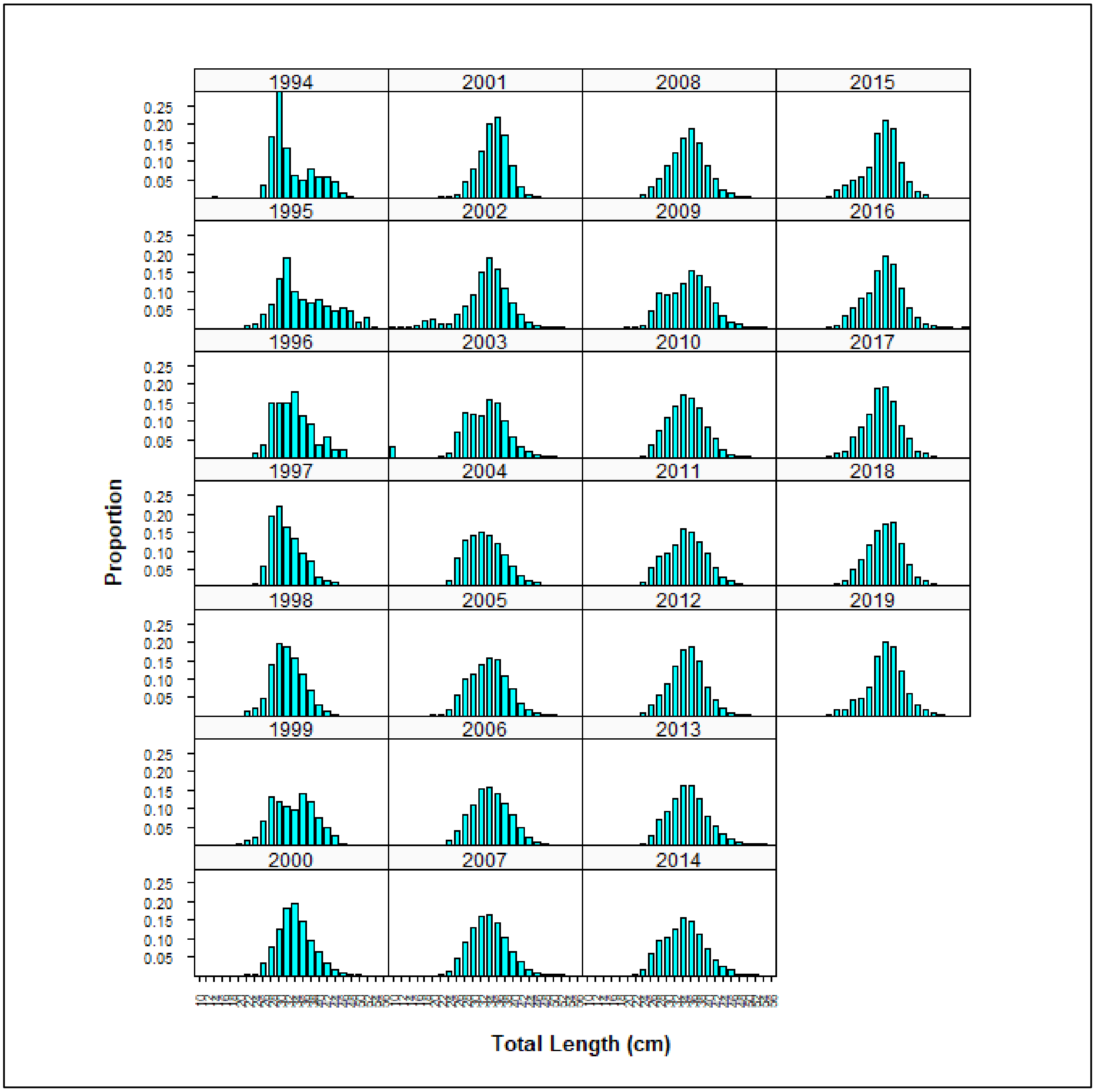


Figure 2.3. Annual length-frequency distributions of striped mullet sampled from North Carolina commercial fisheries' landings, 1994–2019.

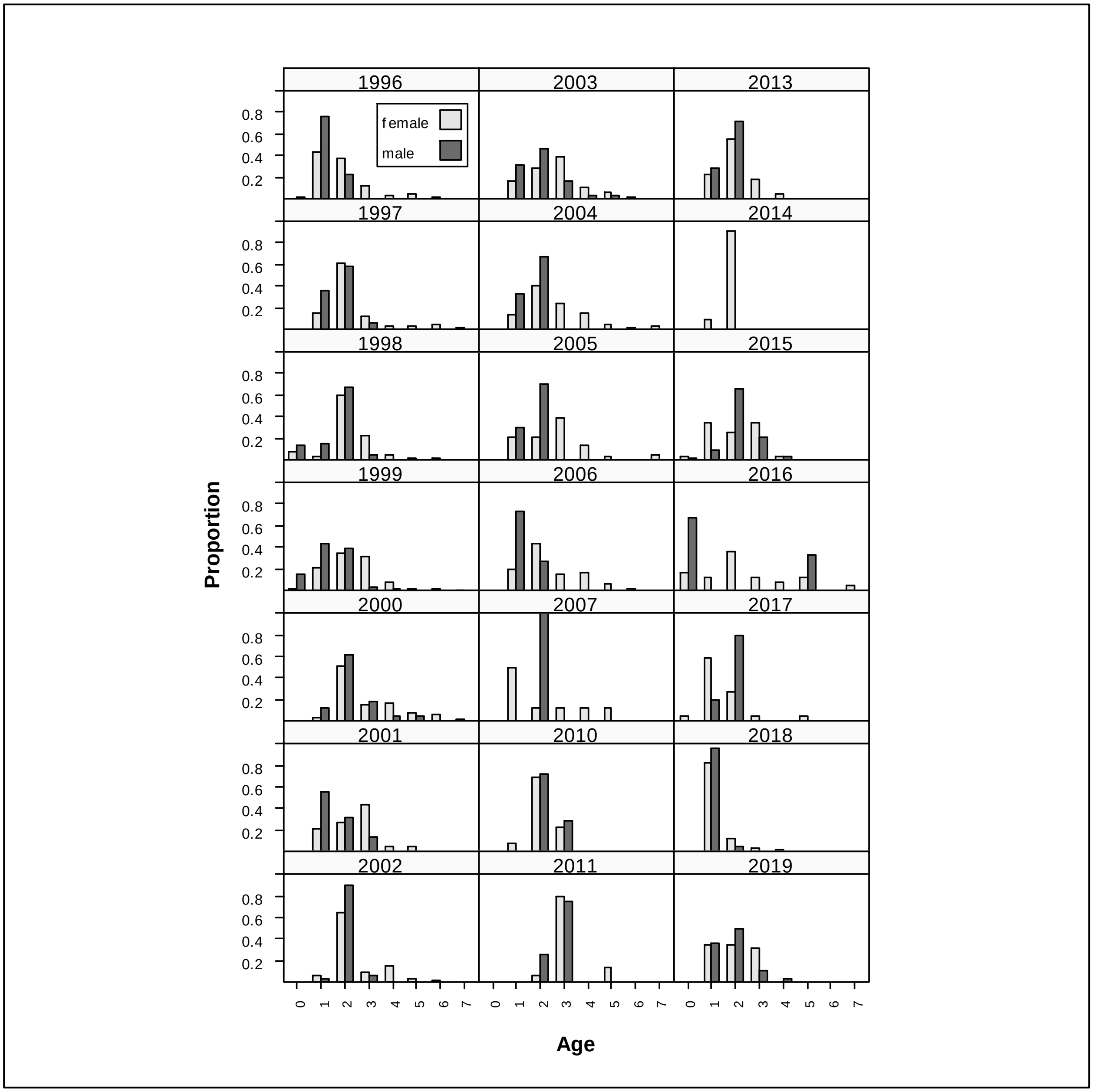


Figure 2.4. Annual age-frequency distributions of striped mullet sampled from North Carolina commercial fisheries' landings by sex, 1996–2019. Note that age 7 represents a plus group.

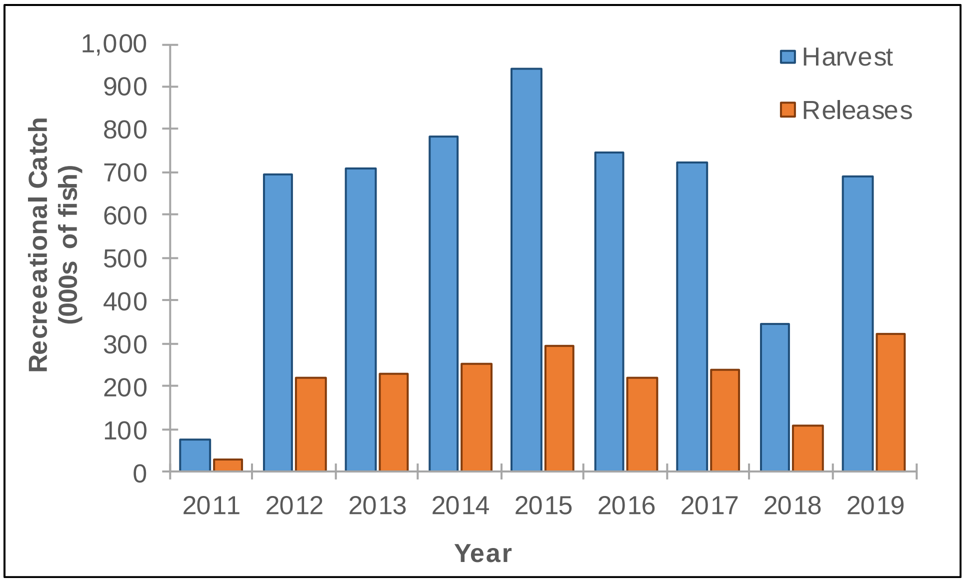


Figure 2.5. Annual harvest and releases of mullet (white plus striped) in North Carolina's recreational fishery, 2011–2019. Note that the mail survey from which the estimates were derived began in October 2011 so the estimates for 2011 are not for the entire year.

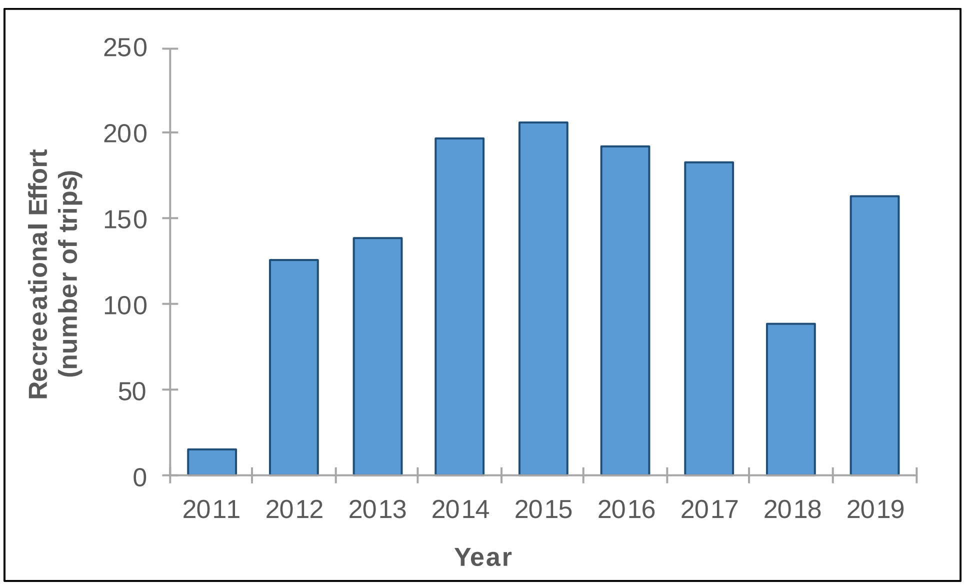


Figure 2.6. Annual effort for mullet (white plus striped) in North Carolina's recreational fishery, 2011–2019. Note that the mail survey from which the estimates were derived began in October 2011 so the estimates for 2011 are not for the entire year.

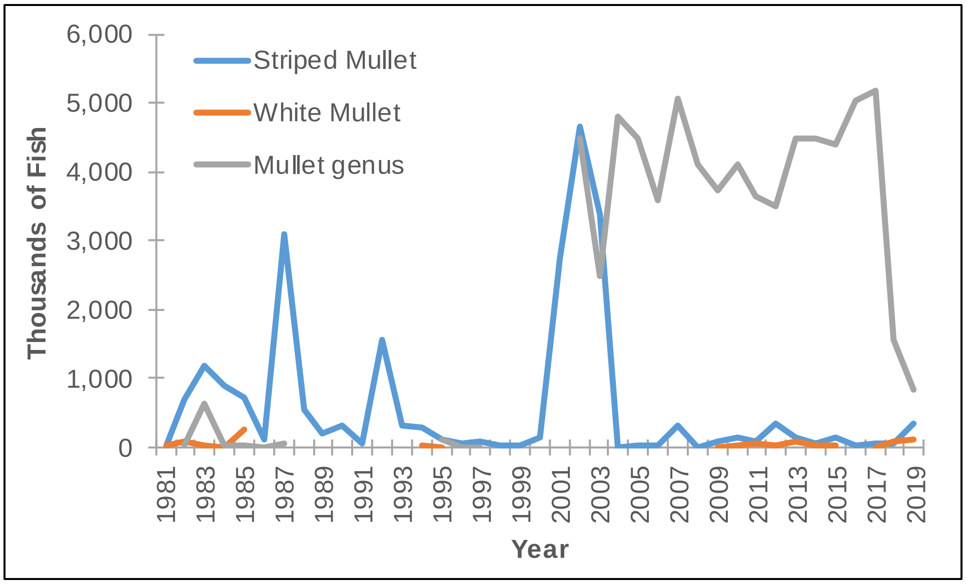


Figure 2.7. Annual recreational harvest (Type A + B1) estimates in numbers of fish for select species in North Carolina as estimated by the MRIP, 1981–2019.

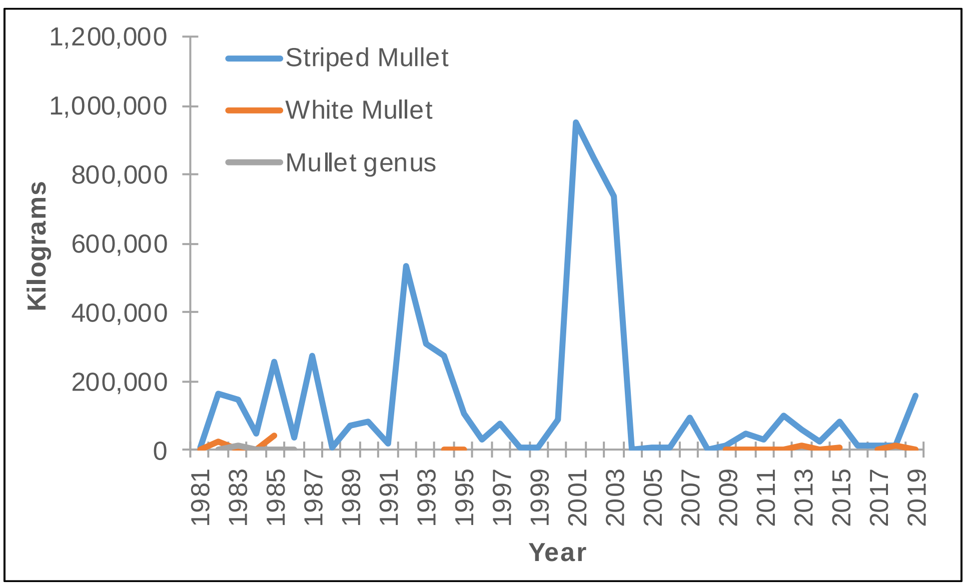


Figure 2.8. Annual recreational harvest (Type A + B1) estimates in weight (kilograms) for select species in North Carolina as estimated by the MRIP, 1981–2019.

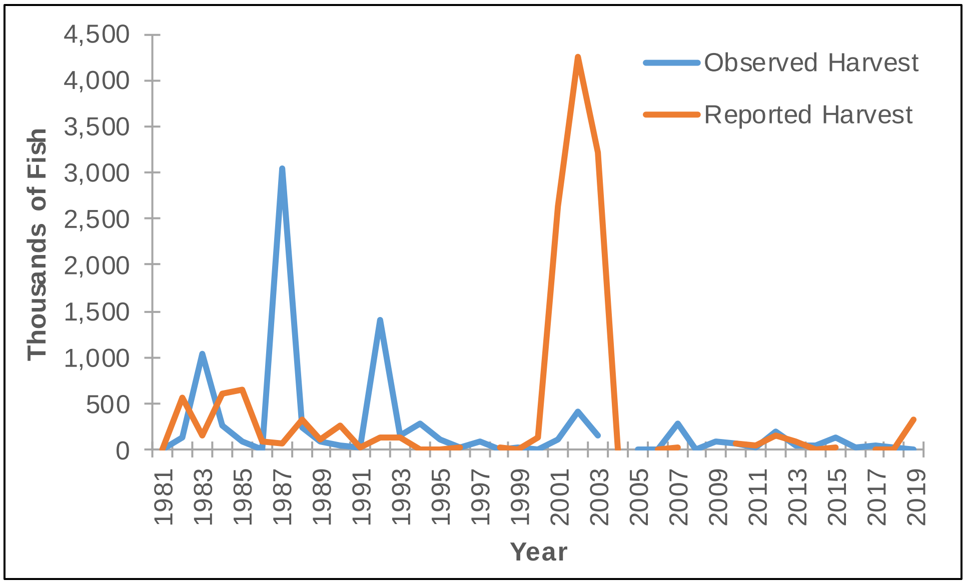


Figure 2.9. Annual recreational observed (Type A) and reported (Type B1) harvest estimates in numbers of fish for striped mullet in North Carolina as estimated by the MRIP, 1981–2019.

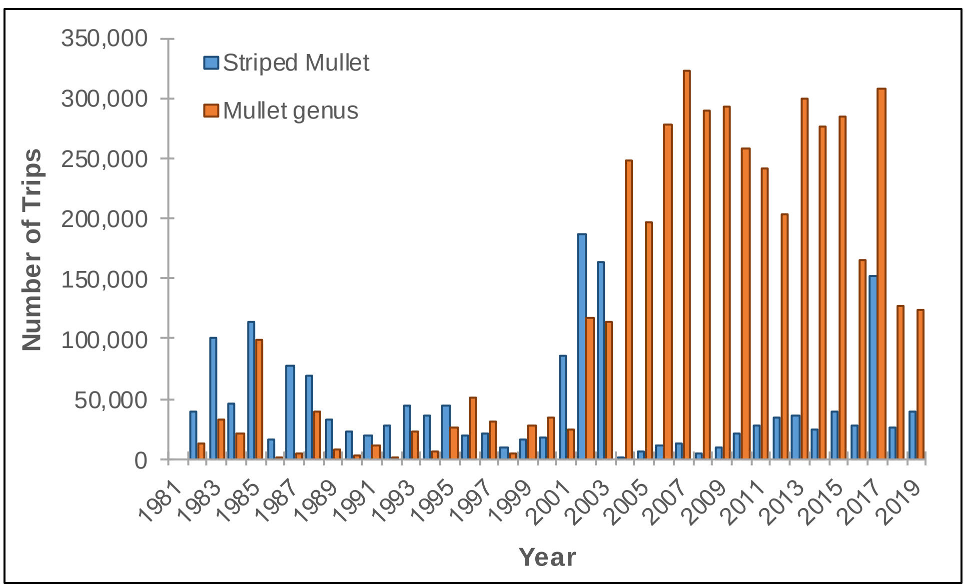


Figure 2.10. Annual number of directed trips for mullet species in North Carolina as estimated by the MRIP, 1981–2019. Directed trips are defined as those trips that target striped mullet, white mullet, or mullet genus or trips that catch the specified species (striped mullet or mullet genus).

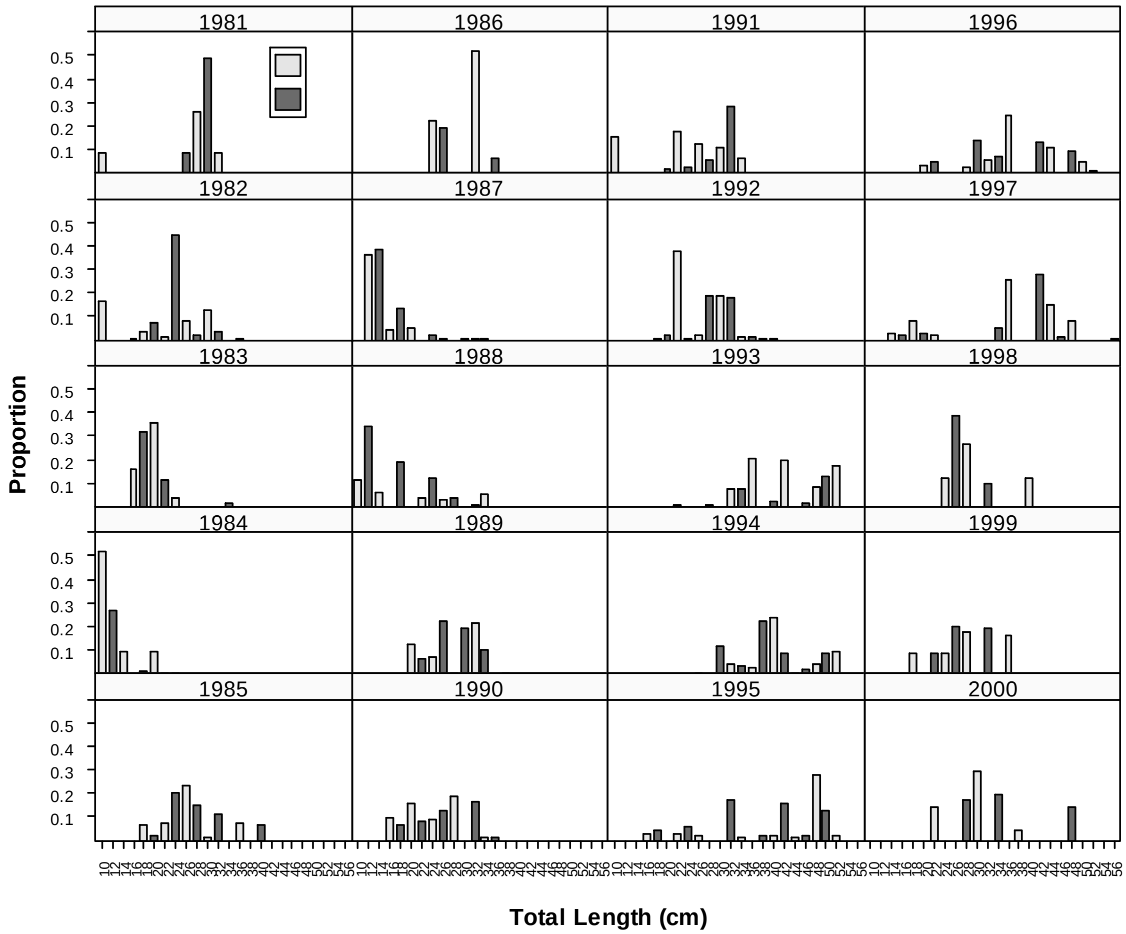


Figure 2.11. Expanded length-frequency distributions of striped mullet harvested by North Carolina's recreational fishery as estimated by the MRIP, 1981–2000.

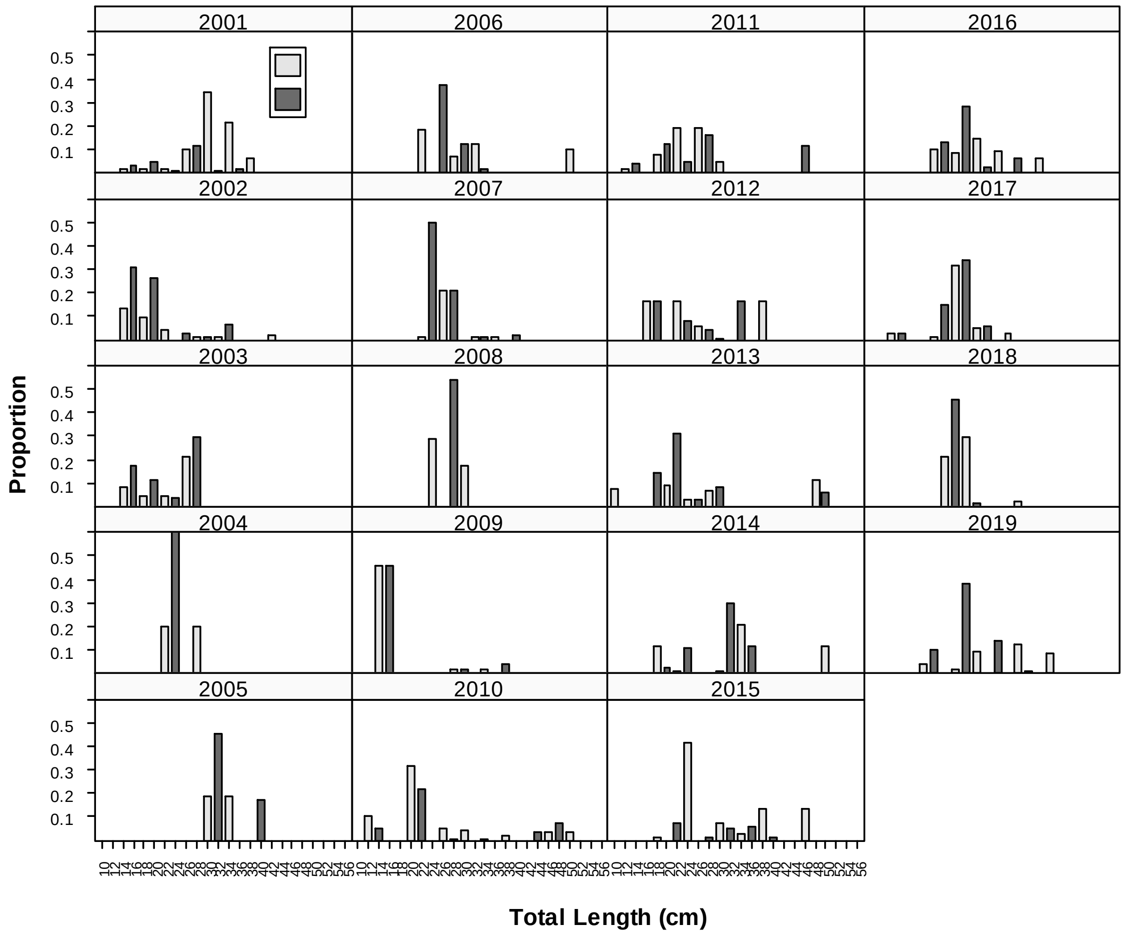


Figure 2.12. Expanded length-frequency distributions of striped mullet harvested by North Carolina's recreational fishery as estimated by the MRIP, 2001–2019.

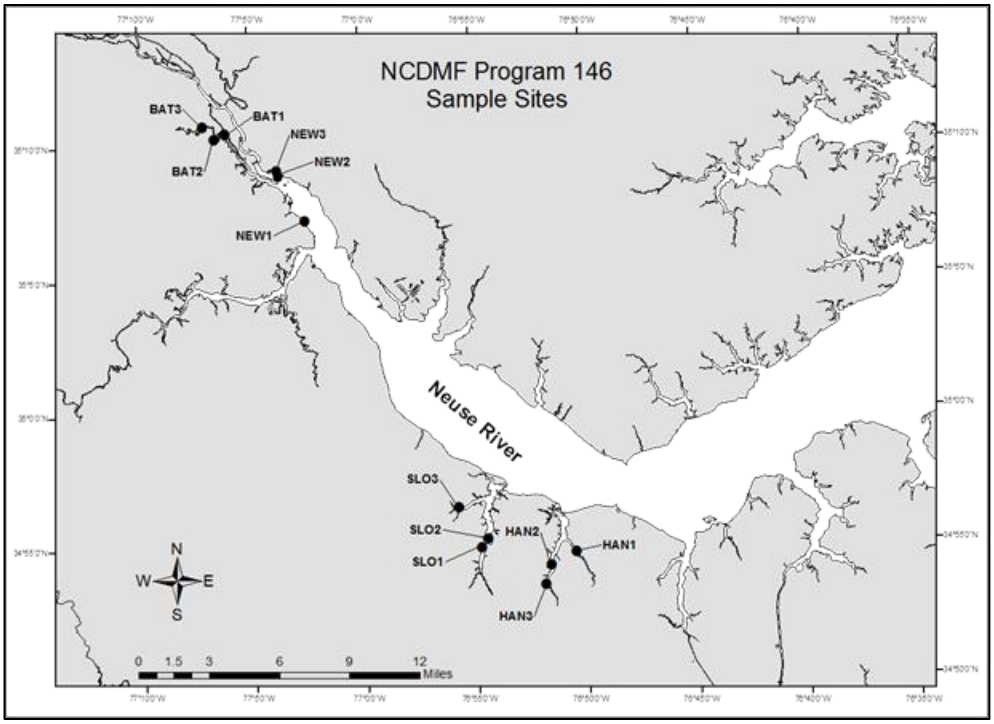


Figure 2.13. Map of sampling locations for Program 146.

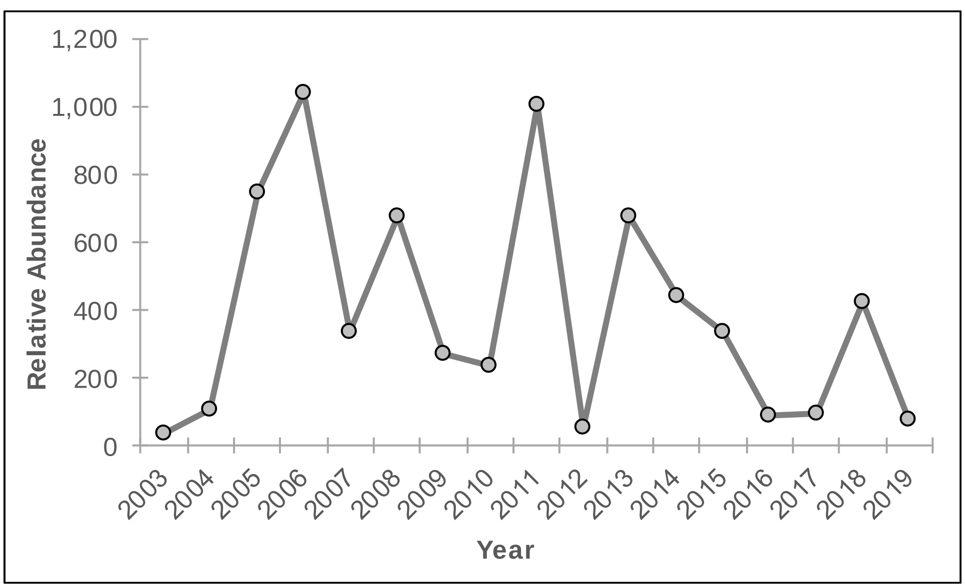


Figure 2.14. GLM-standardized index of relative abundance for adult striped mullet collected in the spring component of Program 146, 2003–2019.

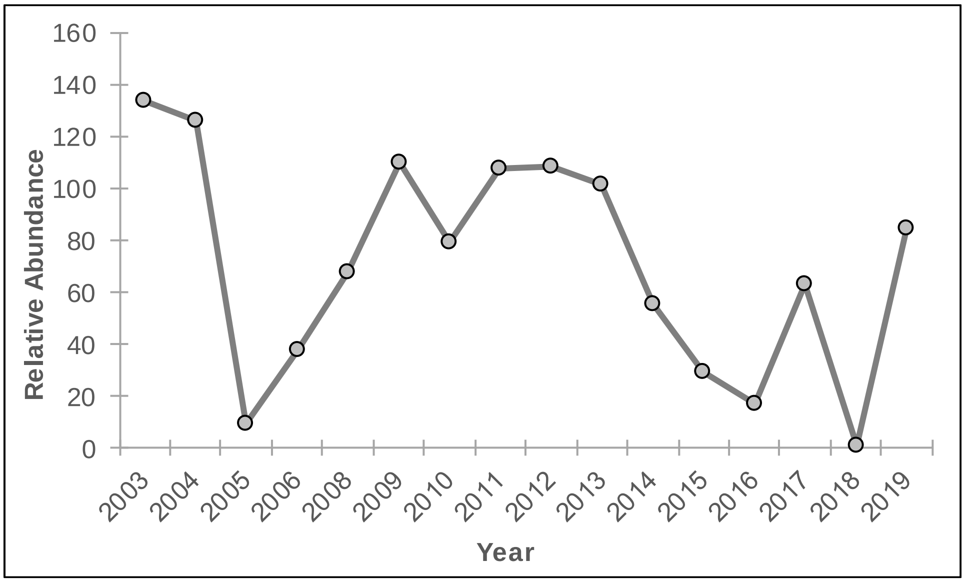


Figure 2.15. GLM-standardized index of relative abundance for adult striped mullet collected in the autumn component of Program 146, 2003–2019.

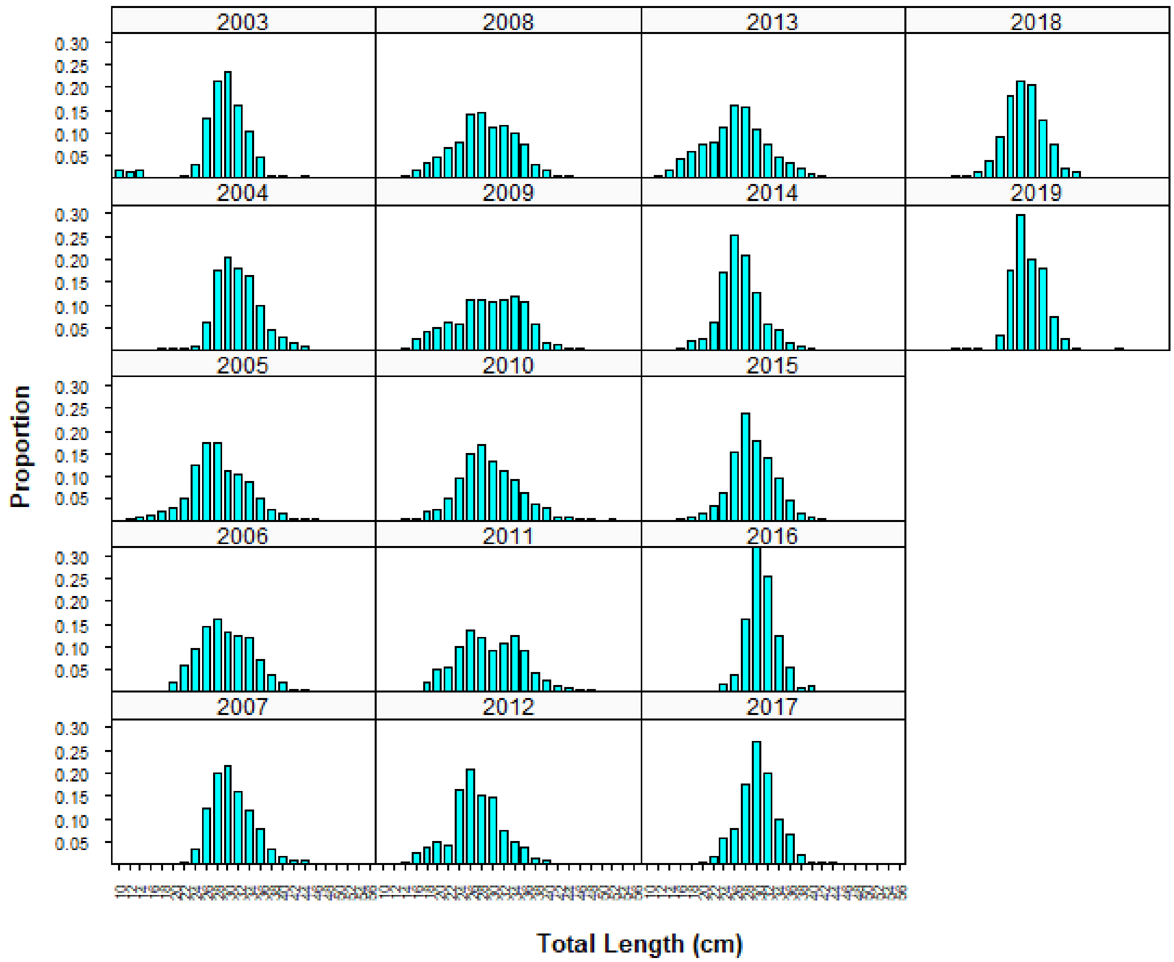


Figure 2.16. Annual length-frequency distributions of adult striped mullet collected in the spring component of Program 146, 2003–2019.

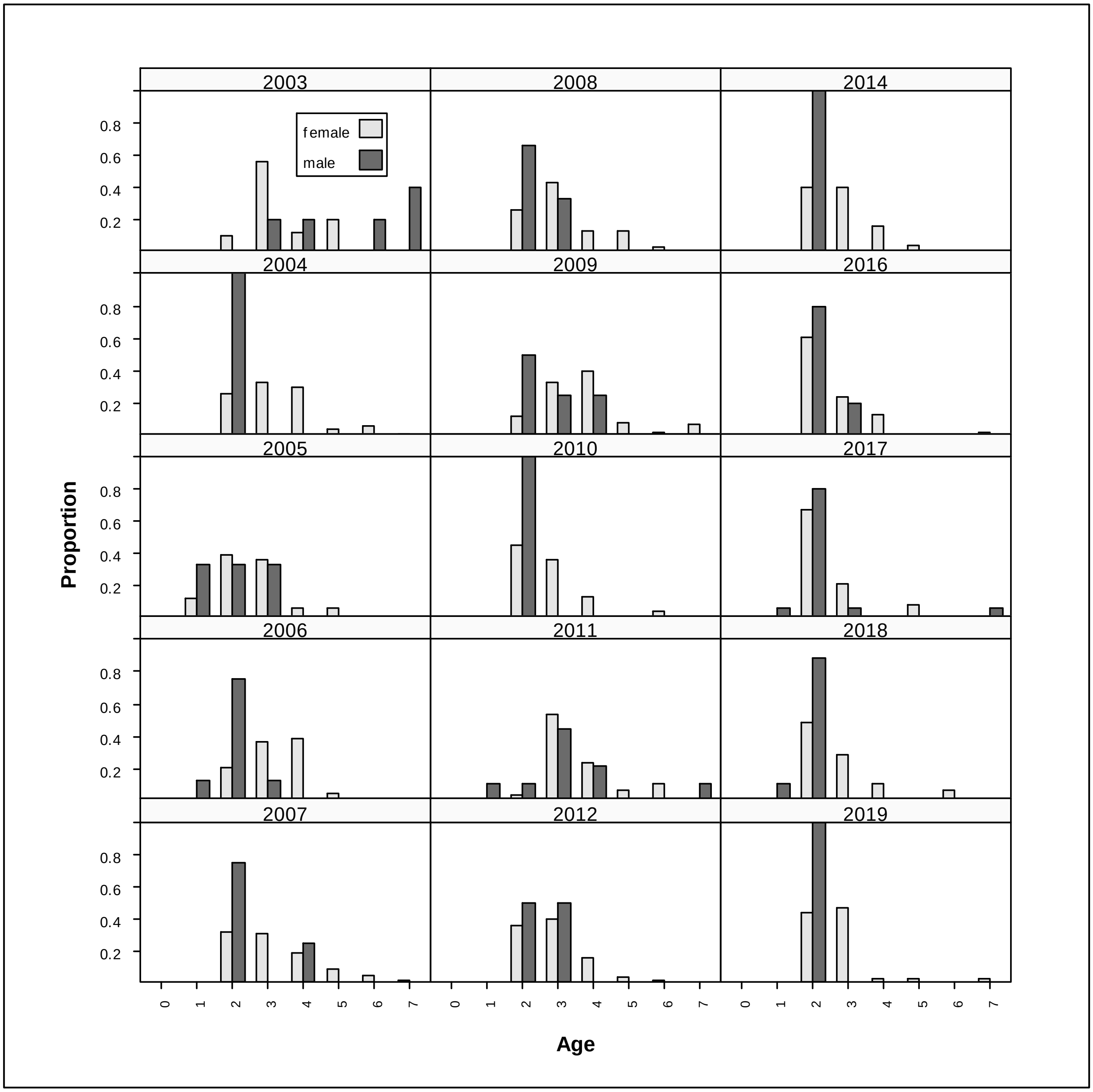


Figure 2.17. Annual age-frequency distributions of adult striped mullet collected in the spring component of Program 146 by sex, 2003–2019. Note that age 7 represents a plus group.

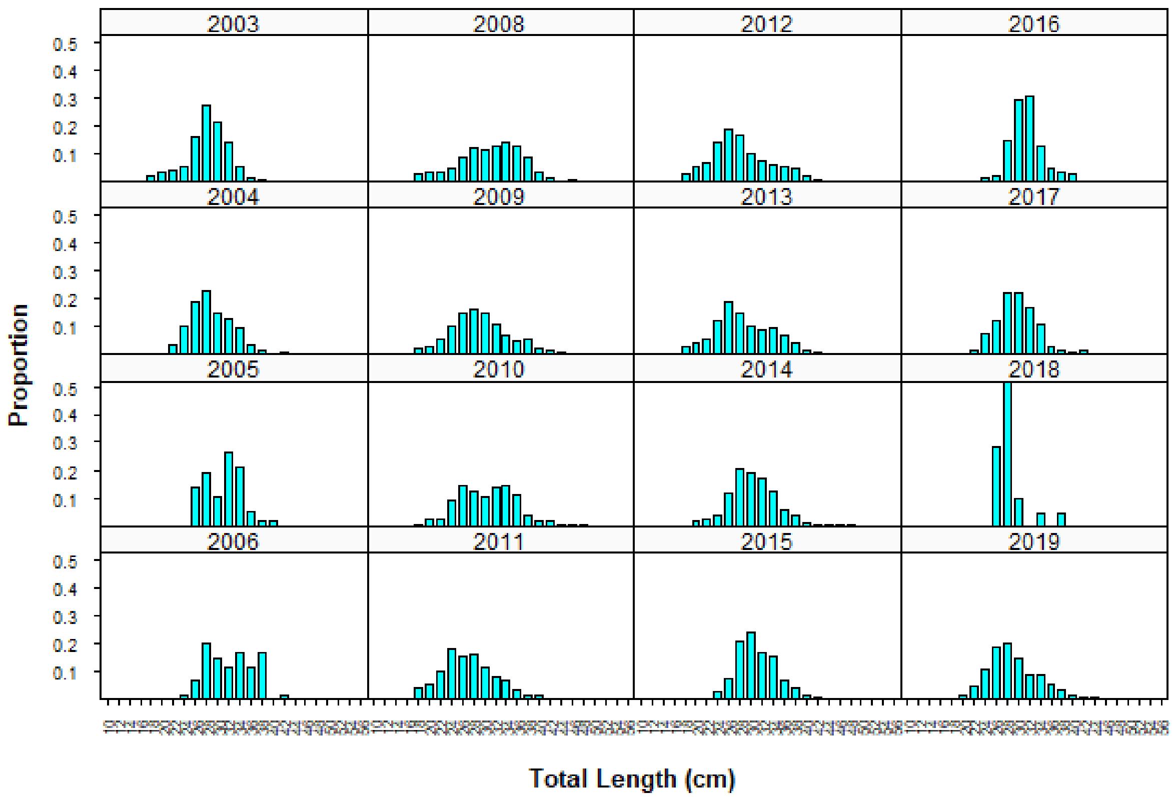


Figure 2.18. Annual length-frequency distributions of adult striped mullet collected in the autumn component of Program 146, 2003–2019.

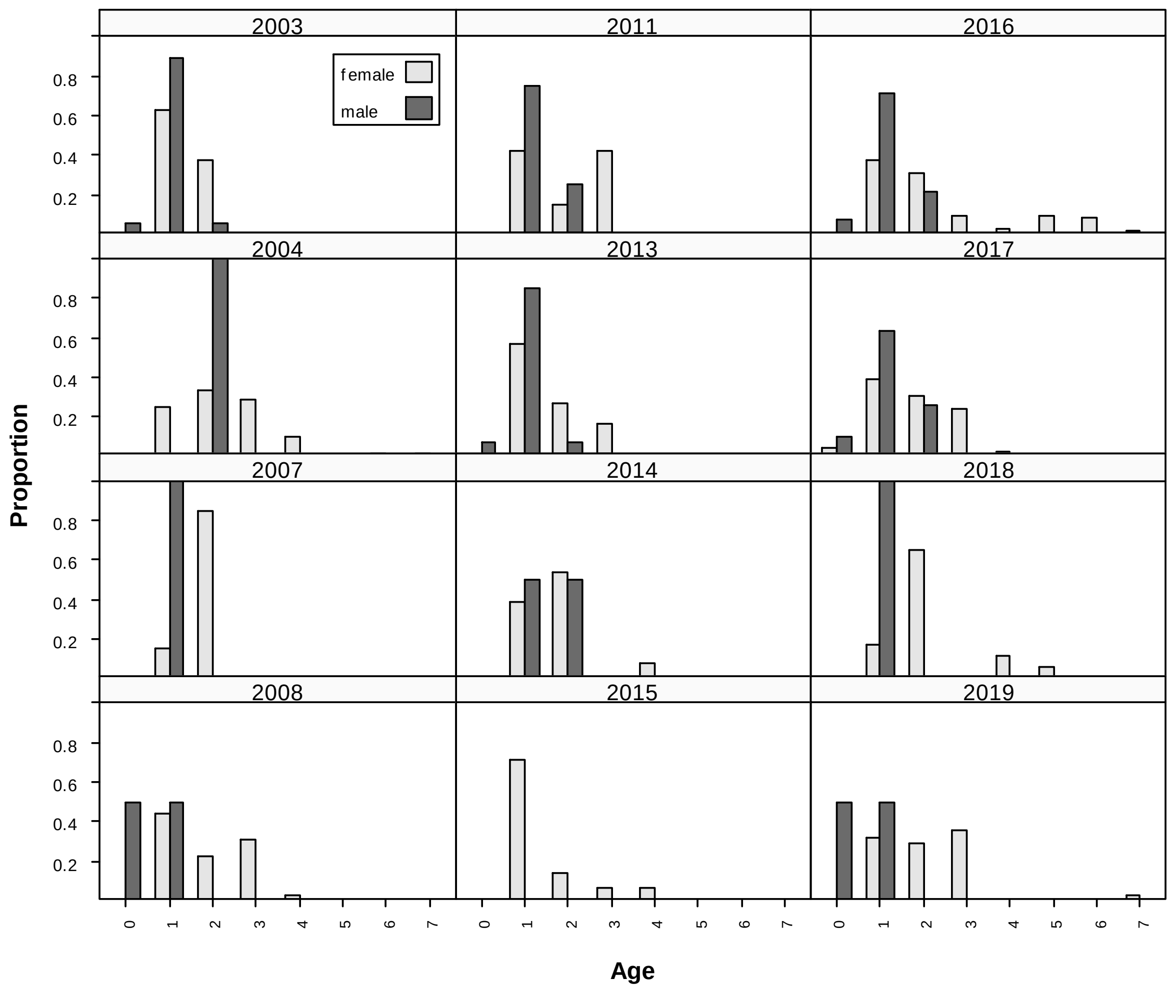


Figure 2.19. Annual age-frequency distributions of adult striped mullet collected in the autumn component of Program 146 by sex, 2003–2019. Note that age 7 represents a plus group.

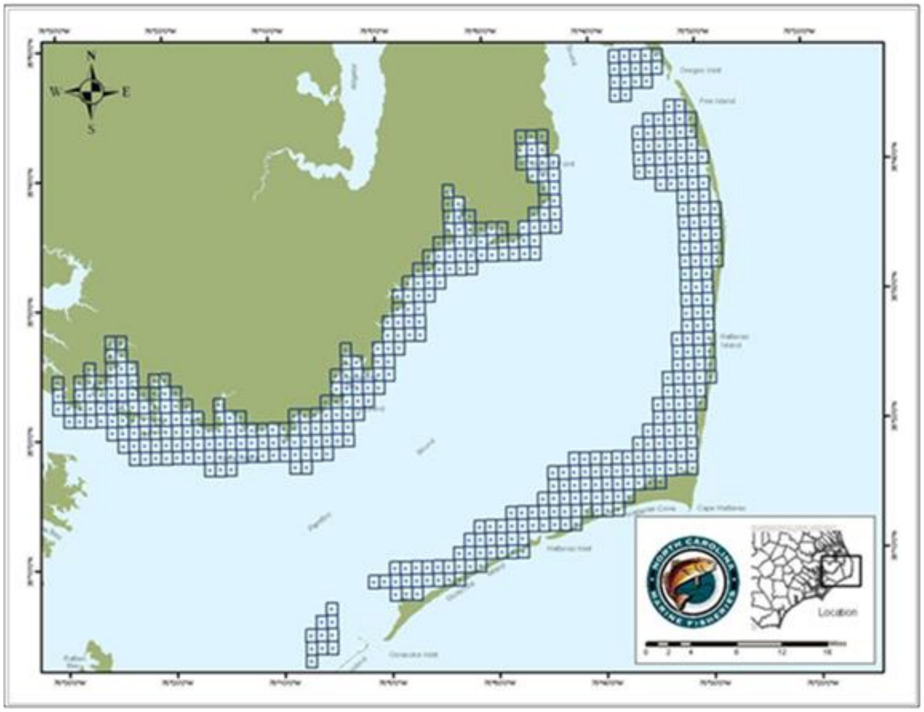


Figure 2.20. The sample regions and grid system for the Pamlico Sound portion of Program 915.

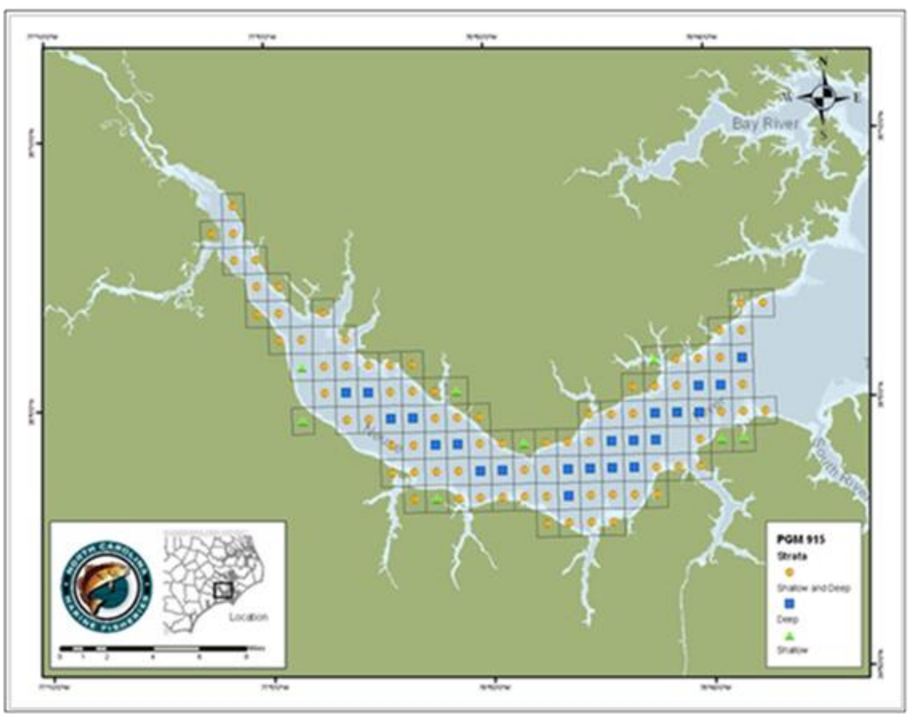


Figure 2.21. The sample regions and grid system for the Neuse River portion of Program 915.

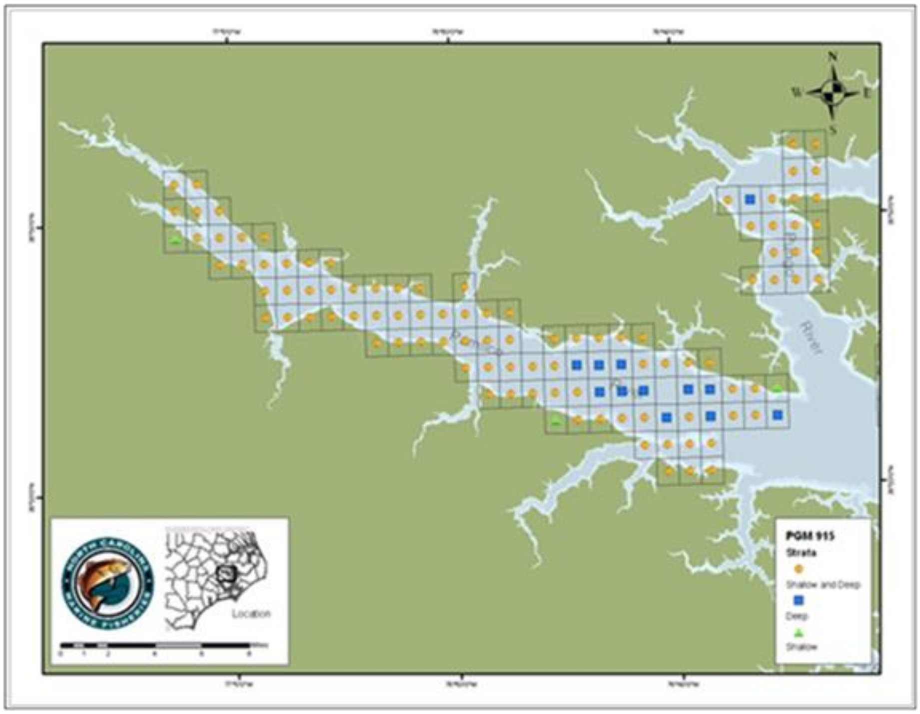


Figure 2.22. The sample regions and grid system for the Pamlico and Pungo river portions of Program 915.

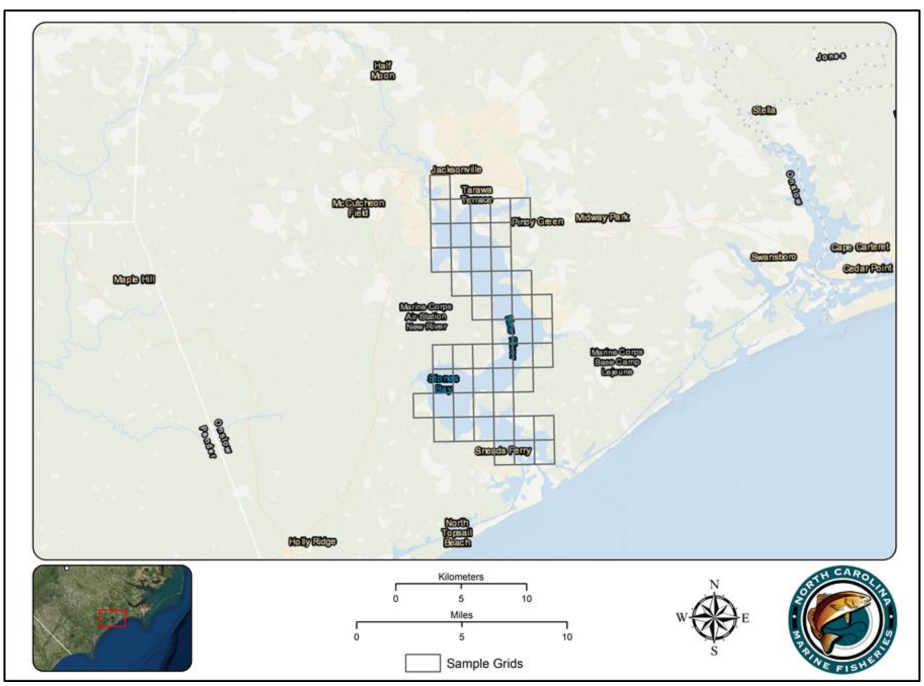


Figure 2.23. Map for Southern District of Program 915.

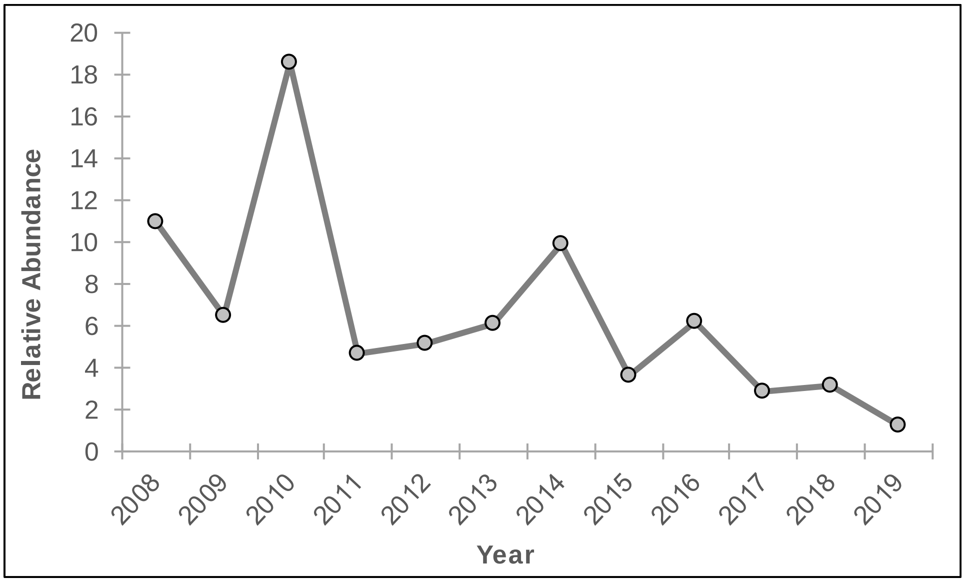


Figure 2.24. GLM-standardized index of relative abundance for adult striped mullet collected in the southern area of Program 915, 2008–2019.

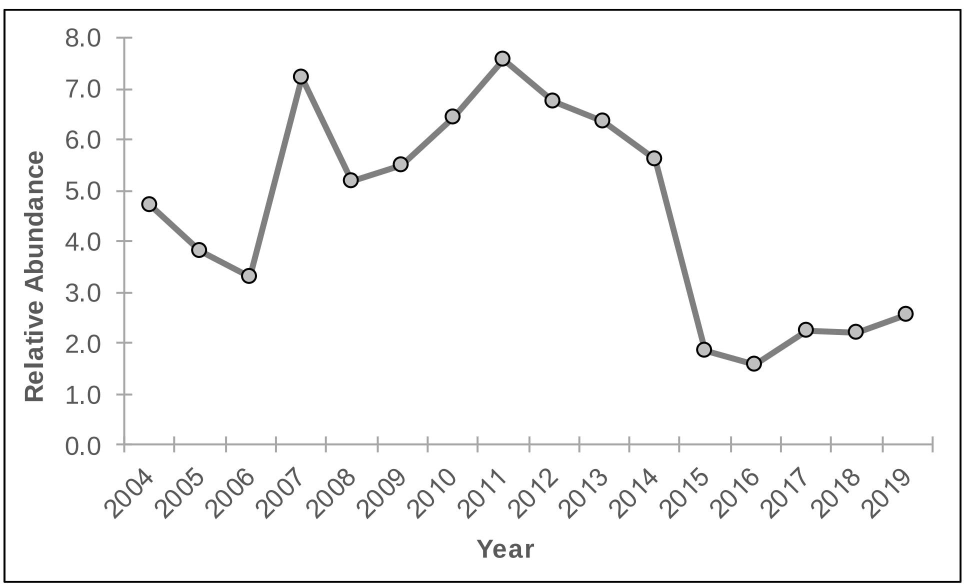


Figure 2.25. GLM-standardized index of relative abundance for adult striped mullet collected in the northern area of Program 915, 2004–2019.

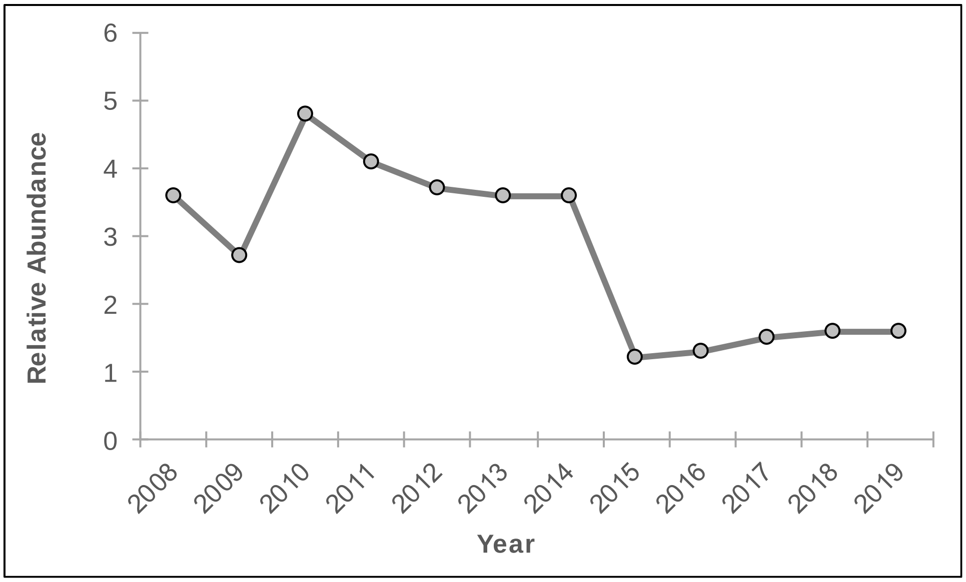


Figure 2.26. GLM-standardized index of relative abundance for adult striped mullet collected in the northern and southern areas combined of Program 915, 2008–2019.

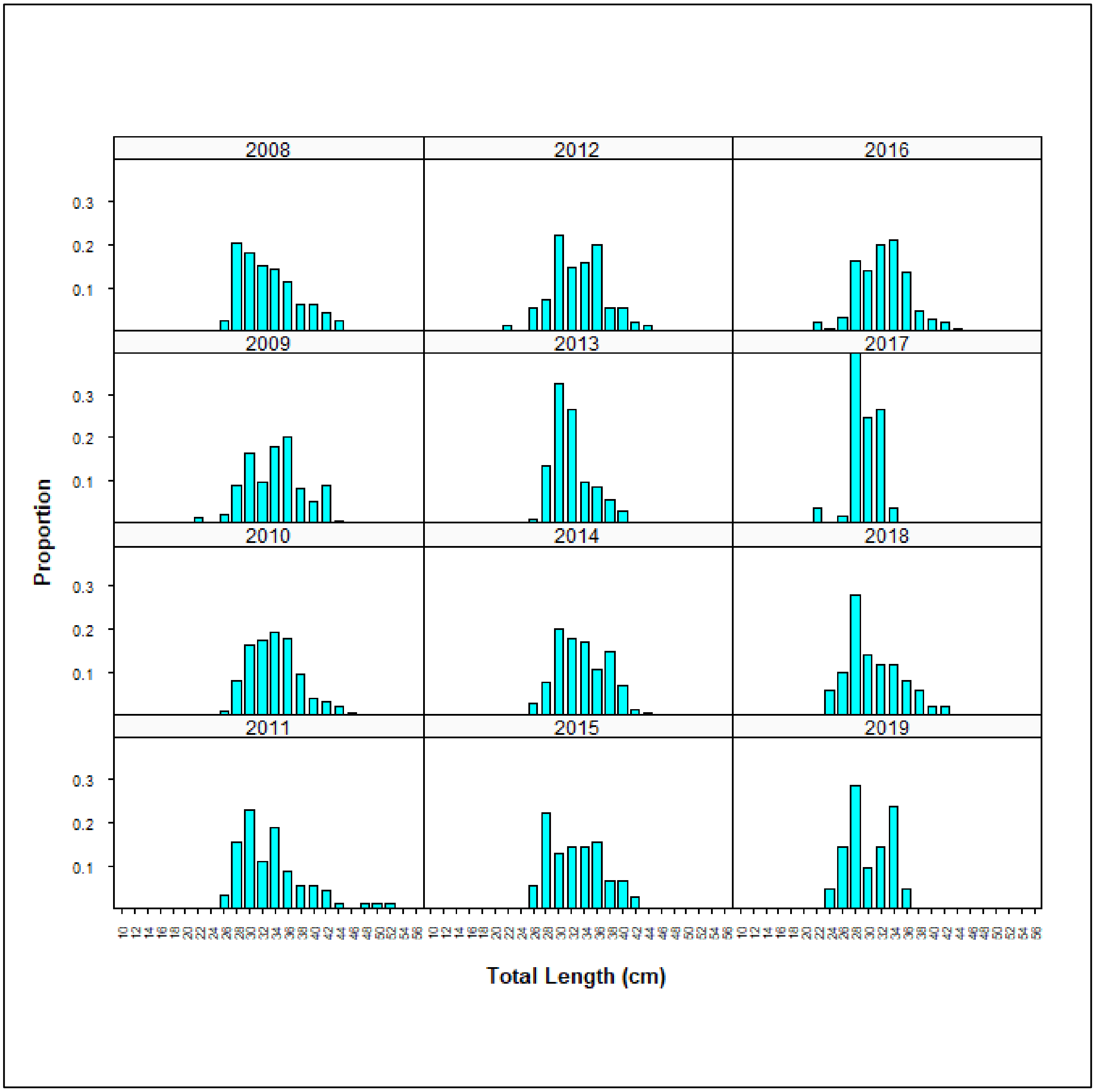


Figure 2.27. Annual length-frequency distributions of adult striped mullet collected in the southern area of Program 915, 2008–2019.

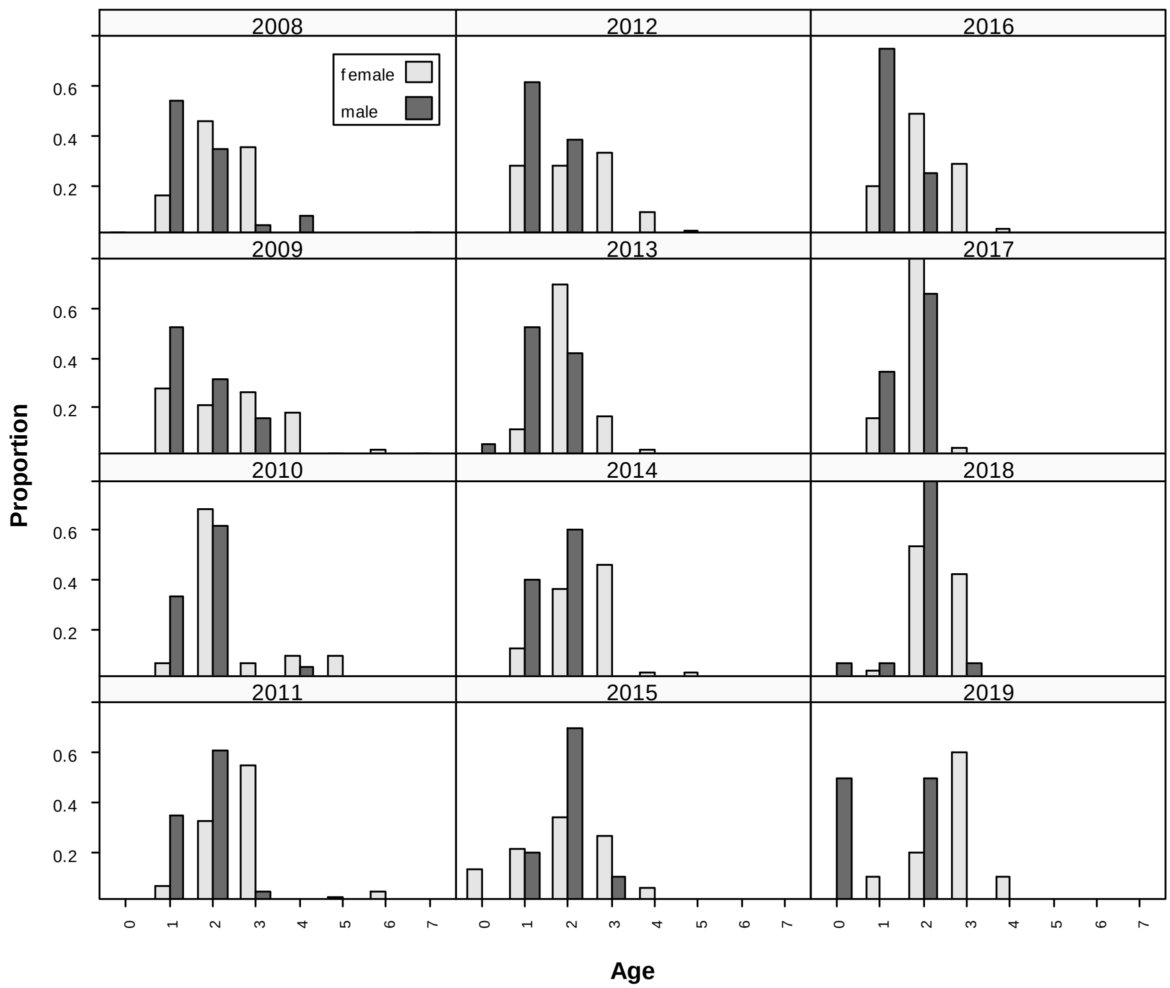


Figure 2.28. Annual age-frequency distributions of adult striped mullet collected in the southern area of Program 915 by sex, 2008–2019. Note that age 7 represents a plus group.

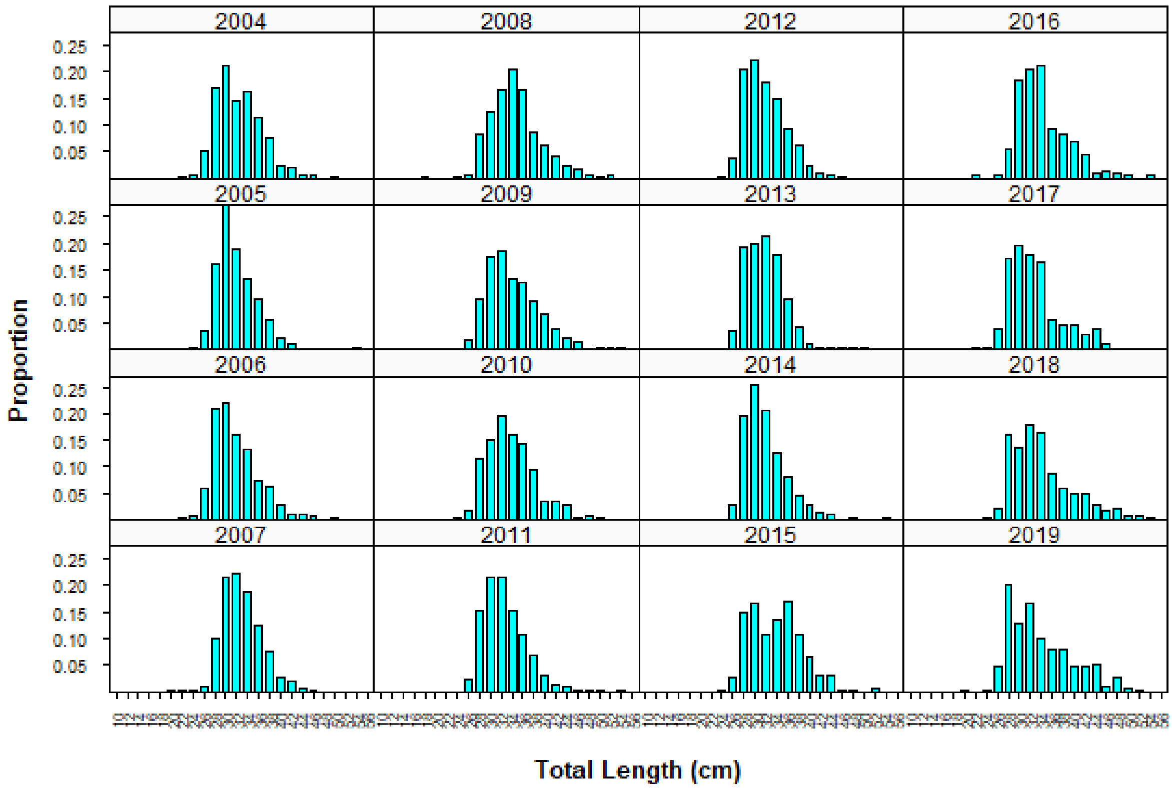


Figure 2.29. Annual length-frequency distributions of adult striped mullet collected in the northern area of Program 915, 2004–2019.

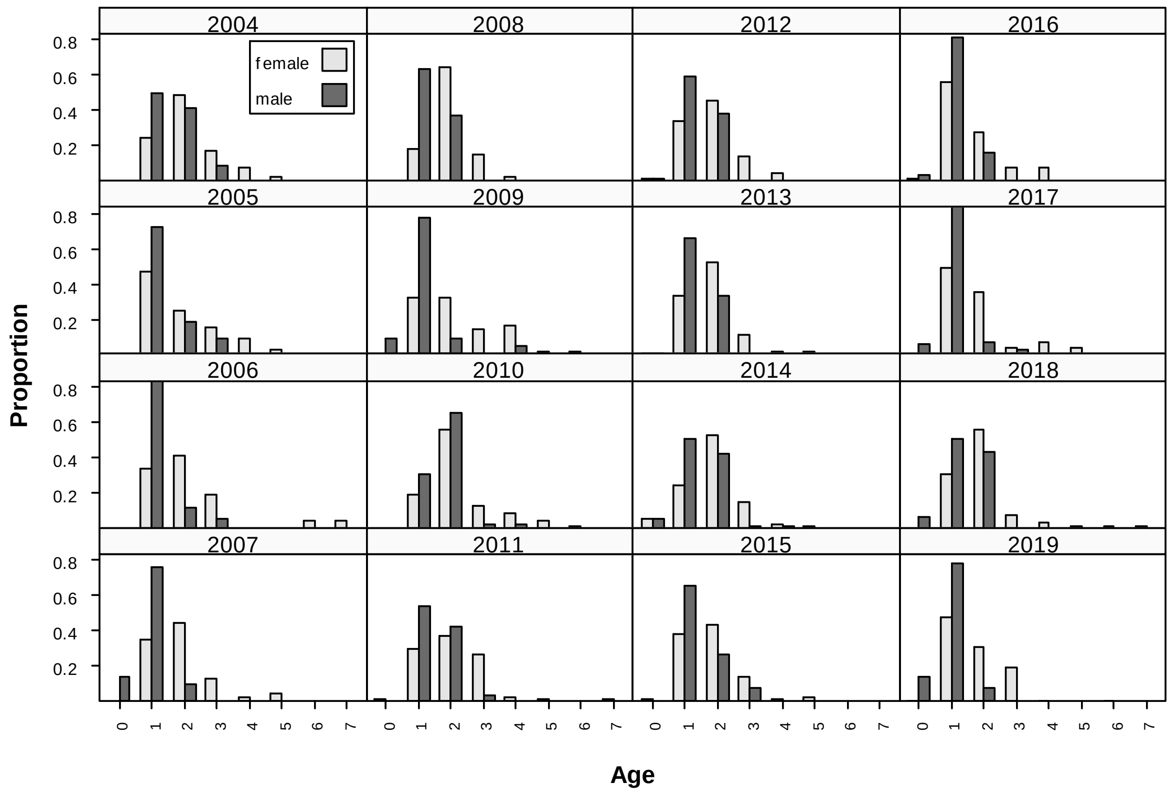


Figure 2.30. Annual age-frequency distributions of adult striped mullet collected in the northern area of Program 915 by sex, 2004–2019. Note that age 7 represents a plus group.

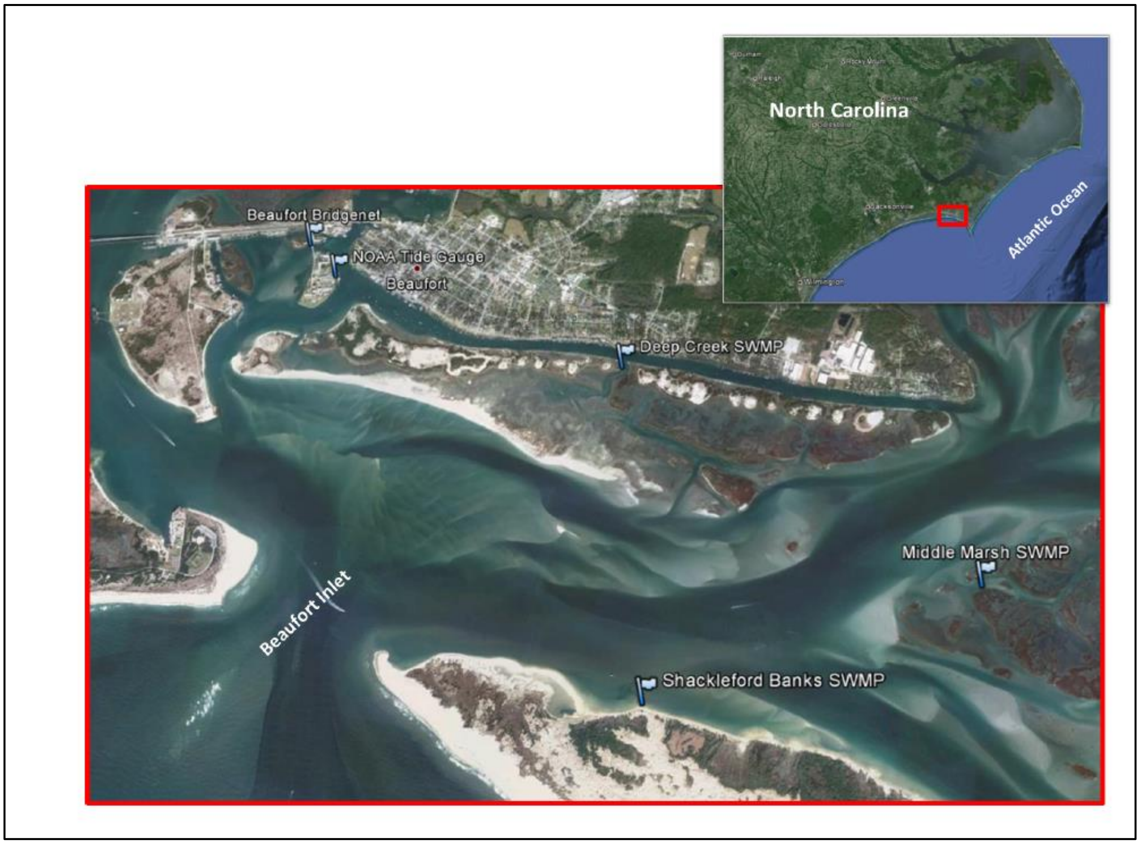


Figure 2.31. Location of the Beaufort Bridgenet Ichthyoplankton Sampling Program (BBISP) station (N 34°43’12.69”, W 76°40’23.90”) on the Pivers Island Bridge in Beaufort, North Carolina, which is 1.5 km upstream from the Beaufort Inlet in the Newport River Estuary.

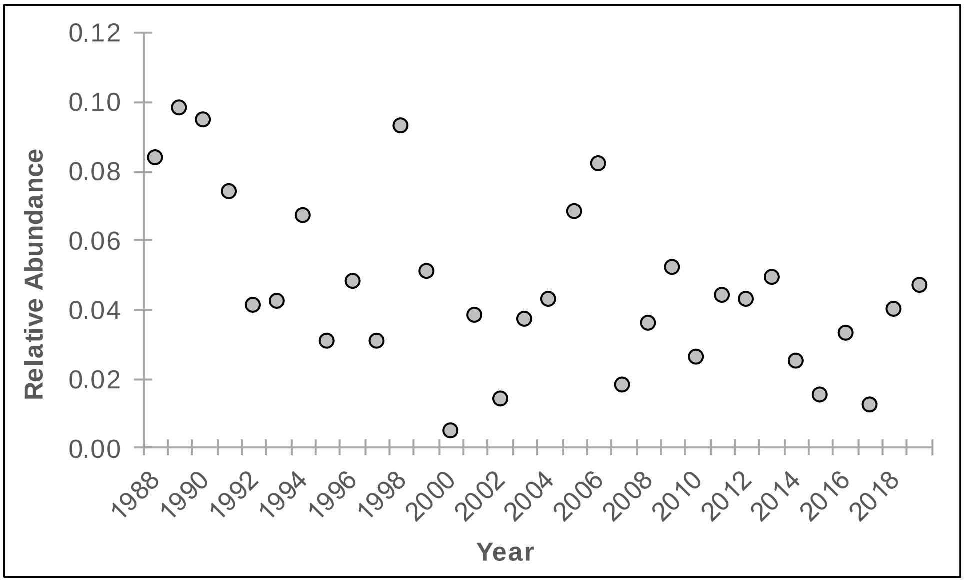


Figure 2.32. Nominal index of relative abundance for age-0 striped mullet collected in the Beaufort Bridgenet Ichthyoplankton Sampling Program, 1988–2019.

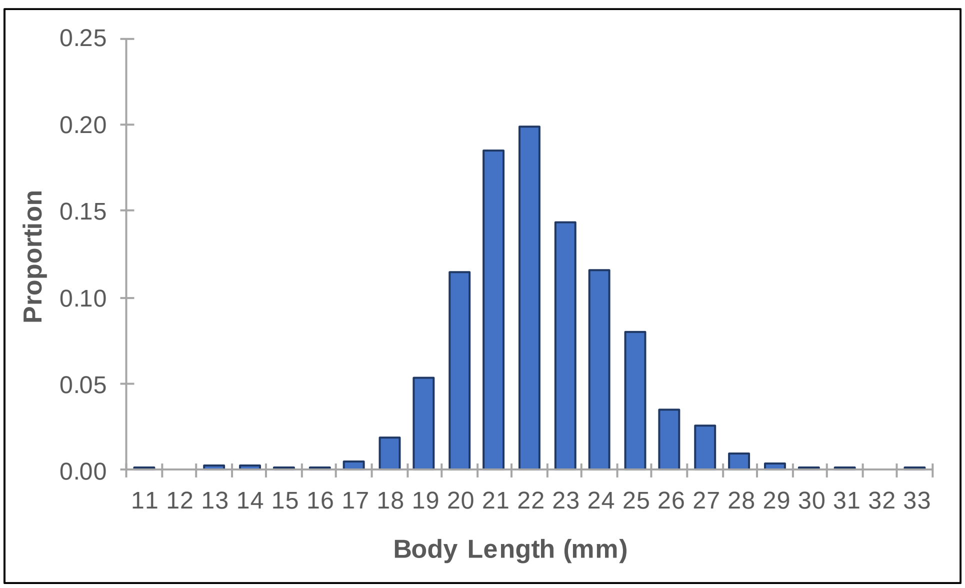


Figure 2.33. Length-frequency distribution of age-0 striped mullet collected in the Beaufort Bridgenet Ichthyoplankton Sampling Program, pooled over 2001 to 2019.

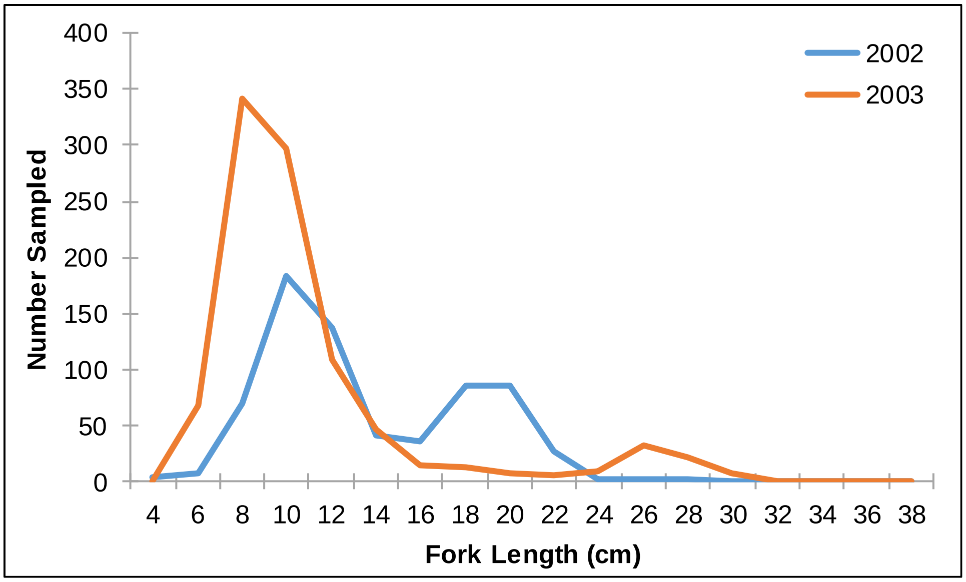


Figure 2.34. Length-frequency distributions of striped mullet collected in the NCDMF fisheries-independent cast net study, 2002 and 2003.

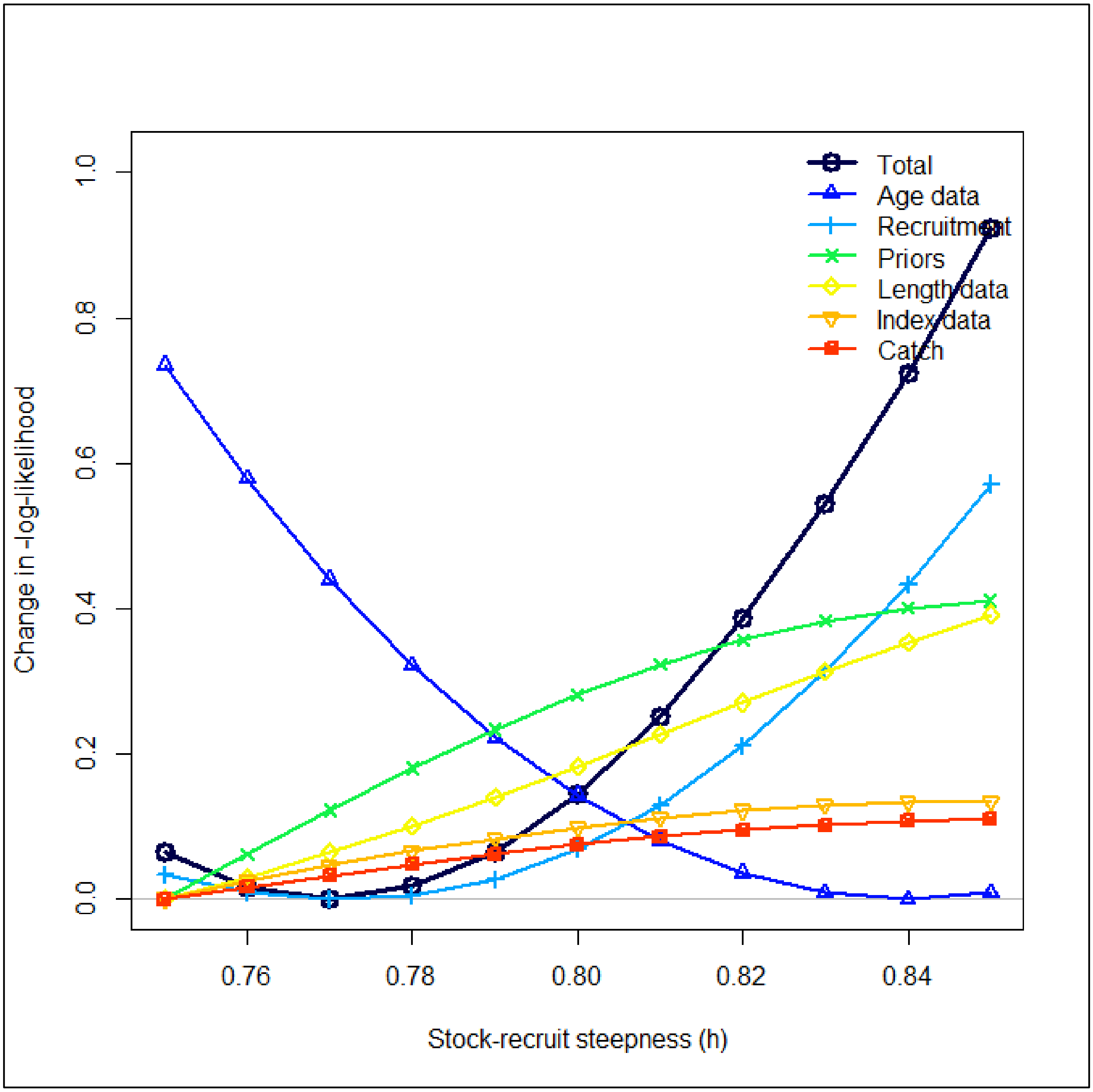


Figure 3.1. Likelihood profile on steepness, *h*, by data component.

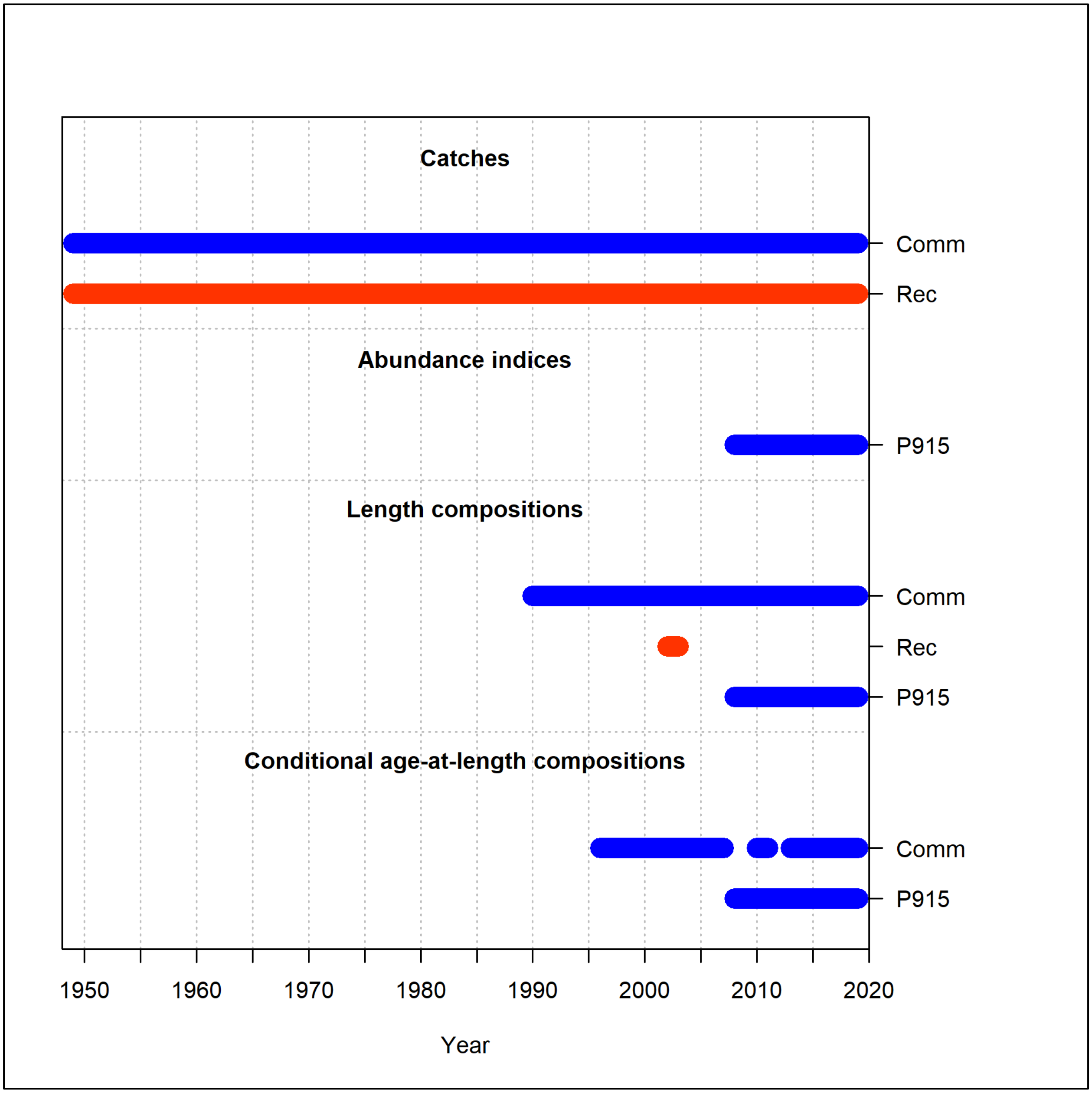


Figure 3.2. Summary of data sources and types used in the base run of the stock assessment model for striped mullet.

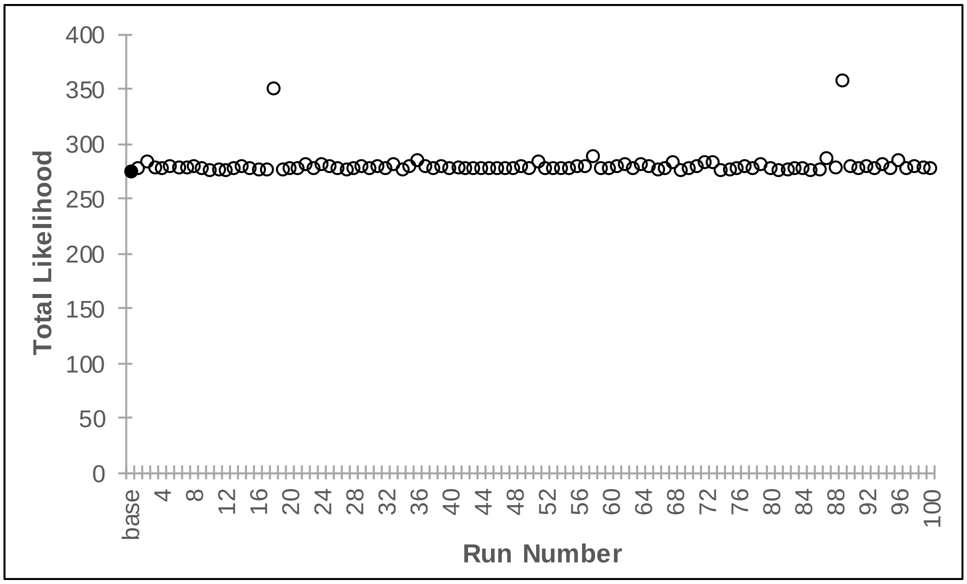


Figure 3.3. Negative log-likelihood values produced from the 100 jitter trials in which initial parameter values were jittered by 10%.

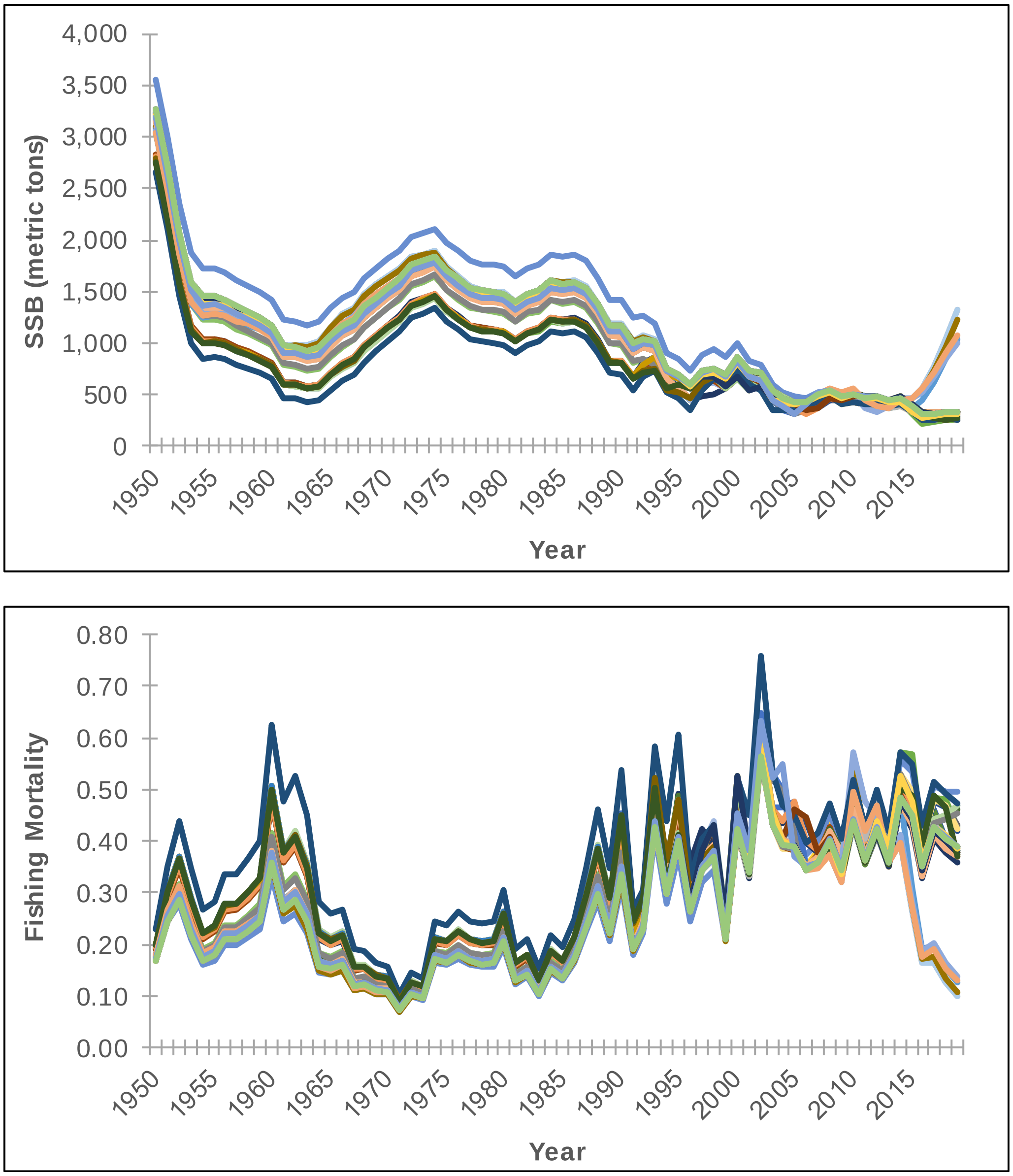


Figure 3.4. Predicted female SSB (top graph) and *F* (numbers-weighted, ages 1–5; bottom graph) from the jitter analysis (10%) applied to the base run of the stock assessment model, 1950–2019.

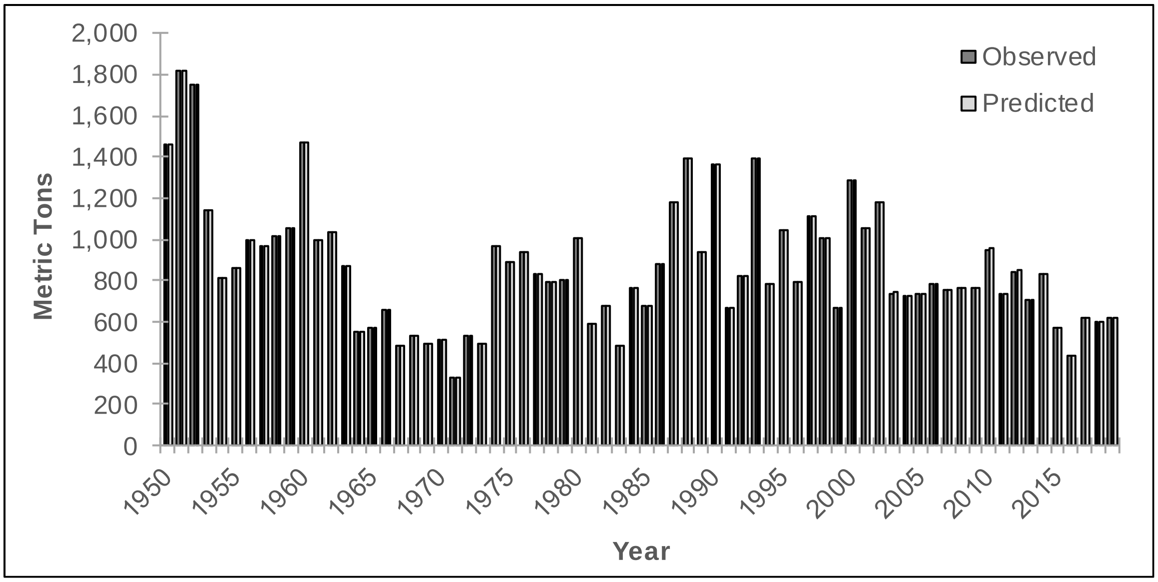


Figure 3.5. Observed and predicted commercial landings from the base run of the stock assessment model, 1950–2019.

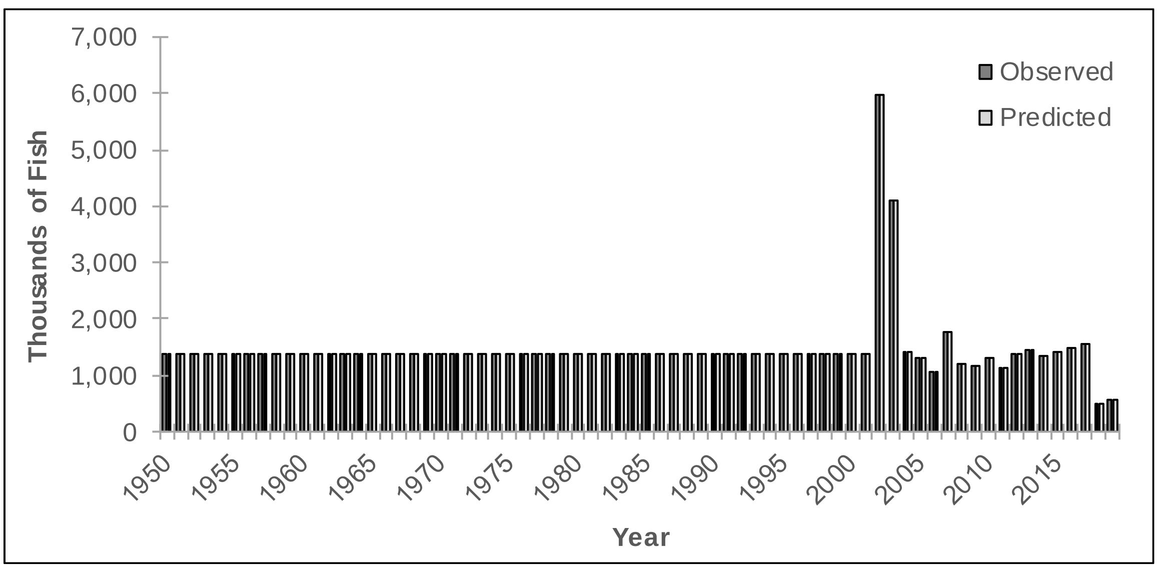


Figure 3.6. Observed and predicted recreational harvest from the base run of the stock assessment model, 1950–2019.

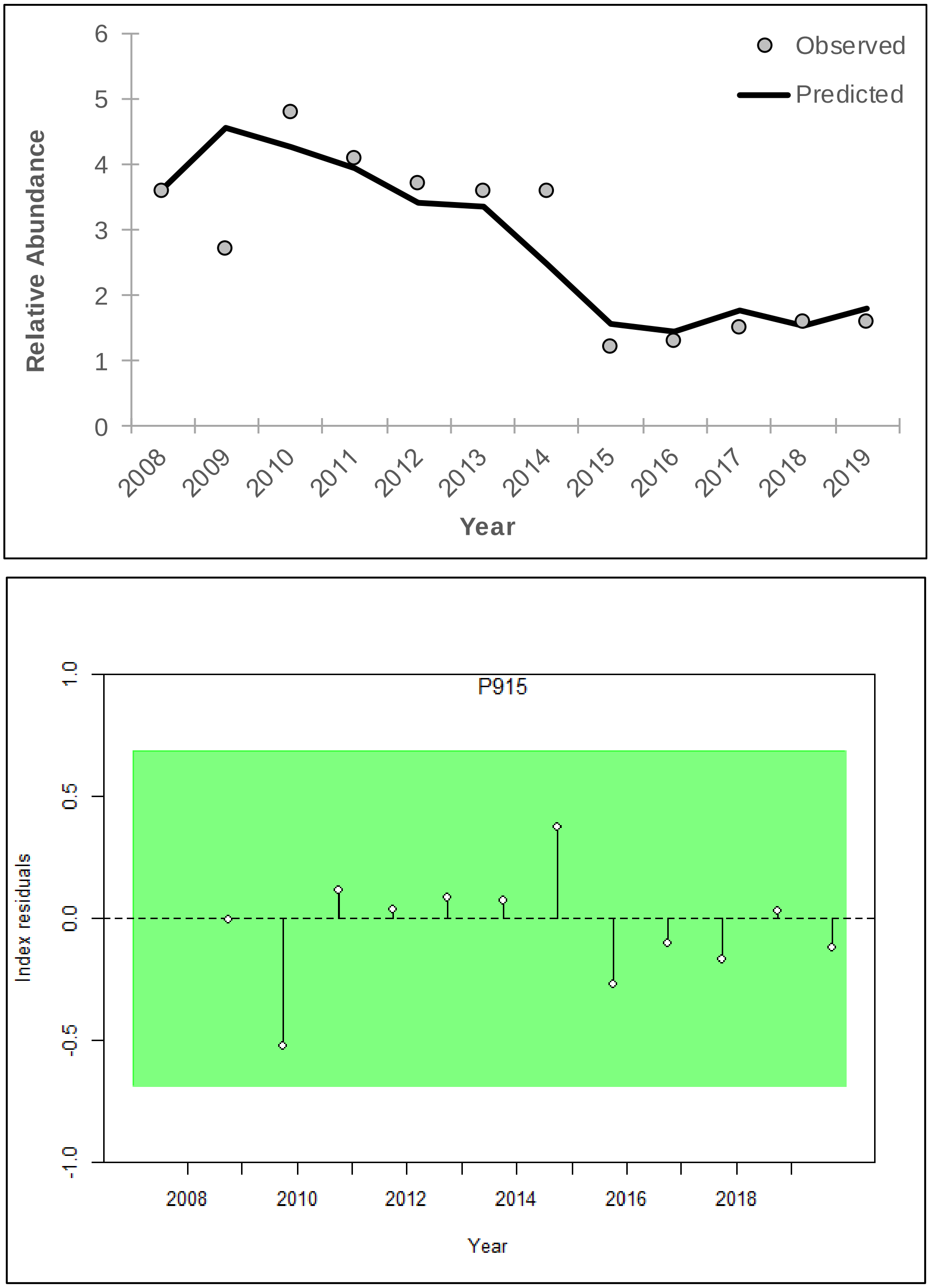


Figure 3.7. Observed and predicted relative abundance (top graph) and associated runs test plot (bottom graph) for the P915 Survey index from the base run of the stock assessment model, 2008–2019. In the runs test plot, green shading indicates no evidence (α = 0.05) and red shading evidence ($p < 0.05$) to reject the hypothesis of a randomly distributed time series of residuals, respectively. The shaded (green/red) area spans three residual standard deviations to either side from zero and the red points outside the shading violate the 'three-sigma limit' for that series.

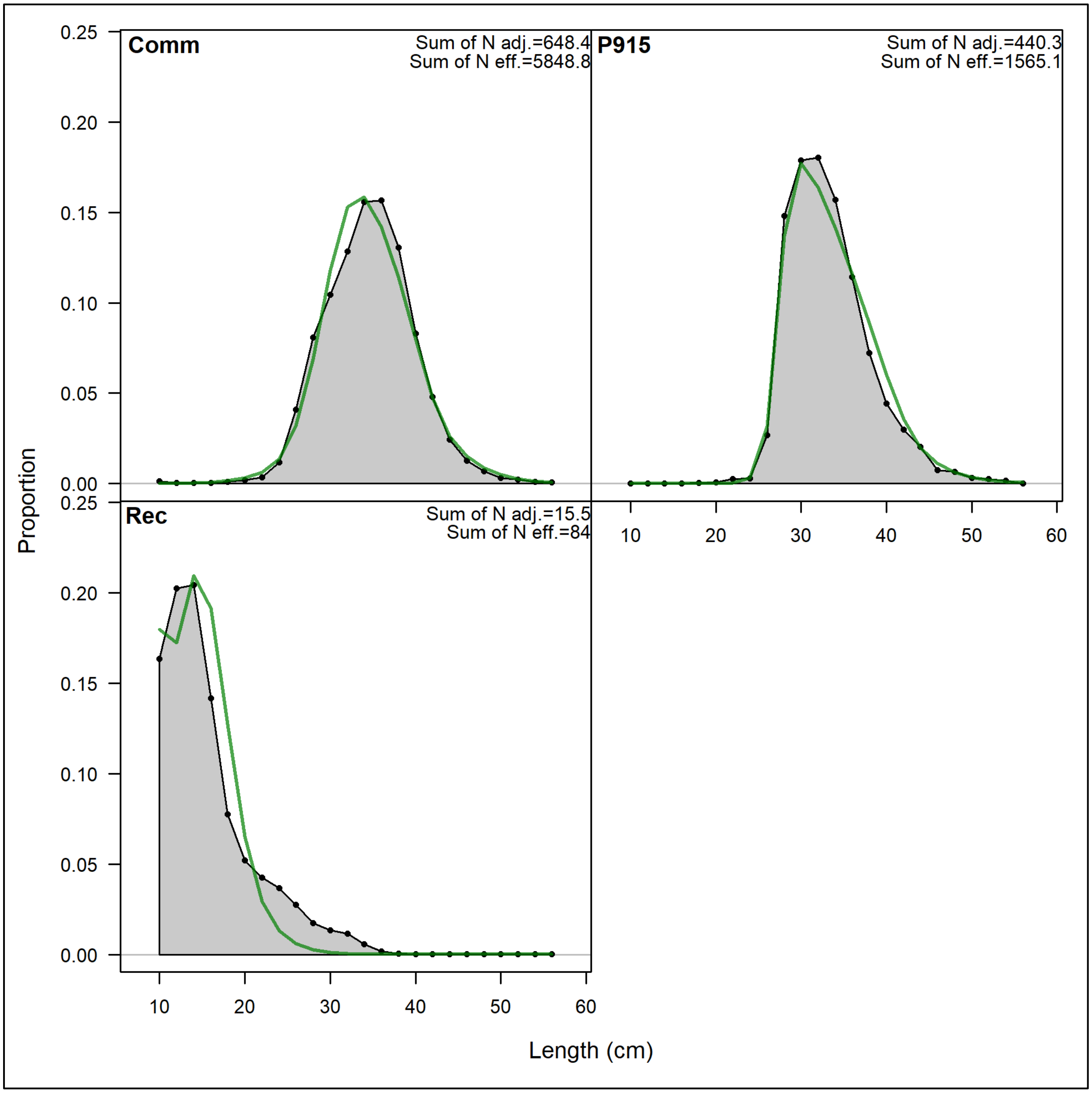


Figure 3.8. Observed and predicted length compositions for each data source from the base run of the stock assessment model aggregated across time. N adj. represents the input effective sample size (number of trips sampled) and N eff. represents the model estimate of effective sample size.

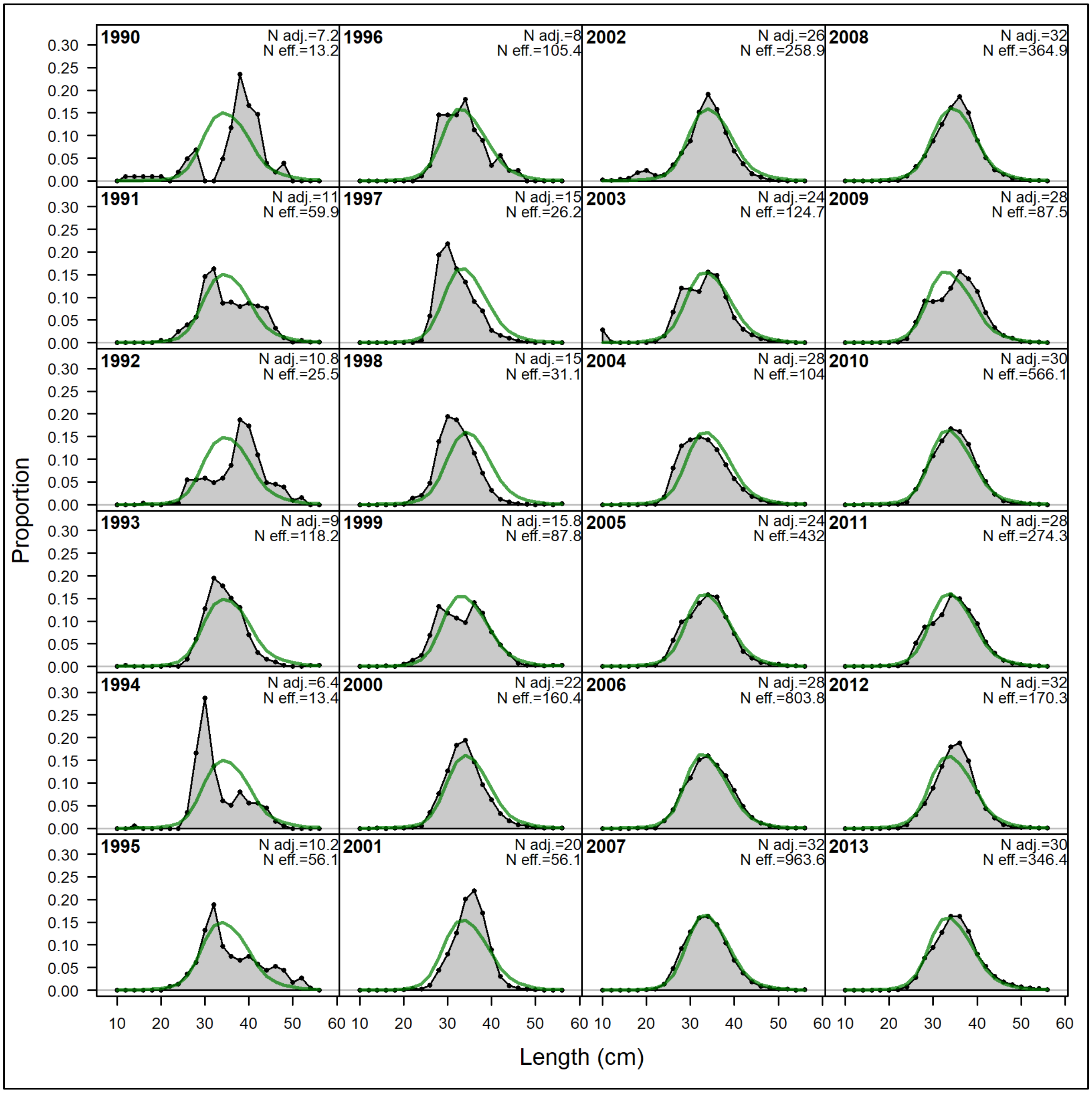


Figure 3.9. Observed and predicted length compositions for the commercial fishery from the base run of the stock assessment model, 1990–2013. N adj. represents the input effective sample size (number of trips sampled) and N eff. represents the model estimate of effective sample size.

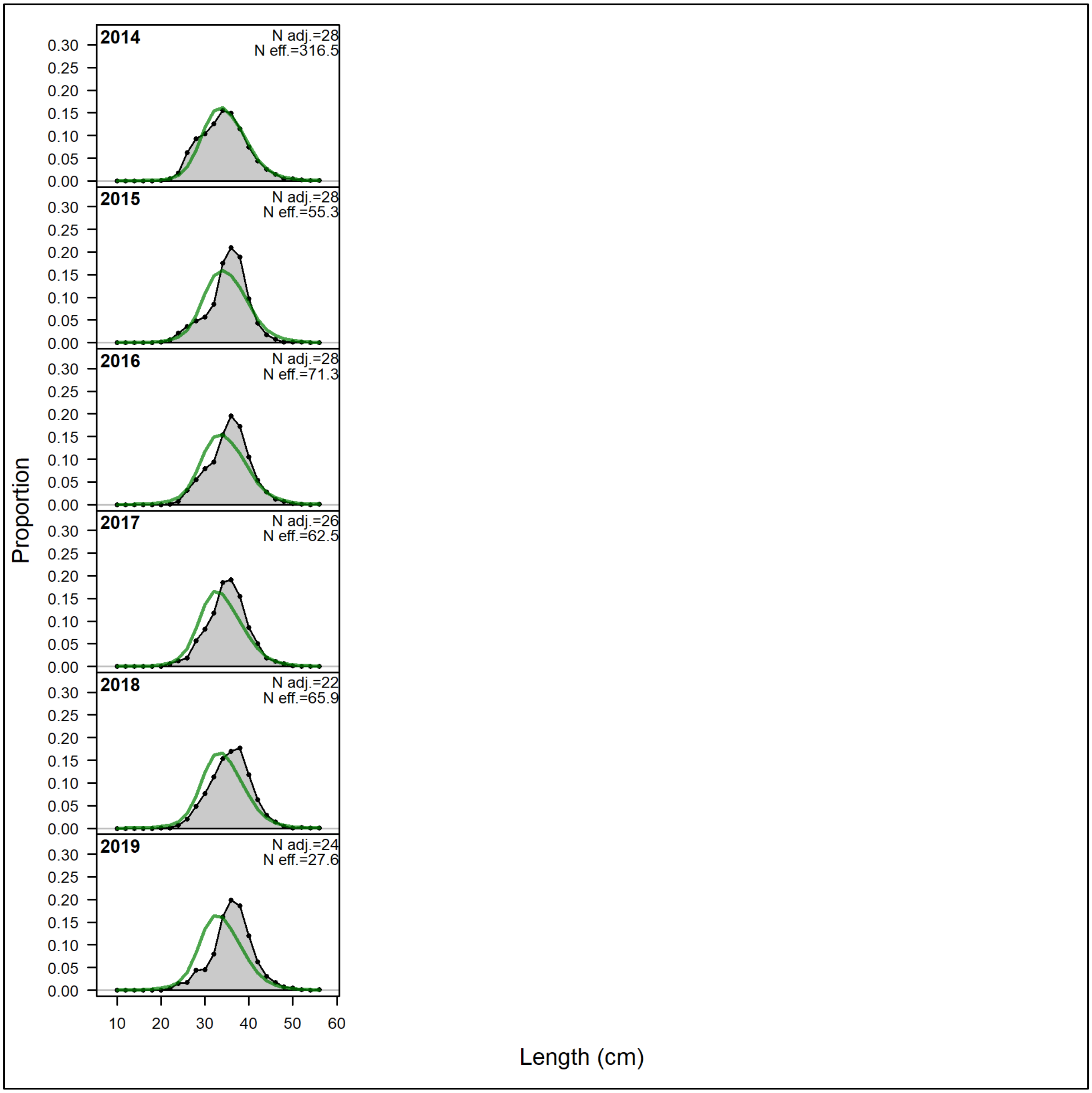


Figure 3.10. Observed and predicted length compositions for the commercial fishery from the base run of the stock assessment model, 2014–2019. N adj. represents the input effective sample size (number of trips sampled) and N eff. represents the model estimate of effective sample size.

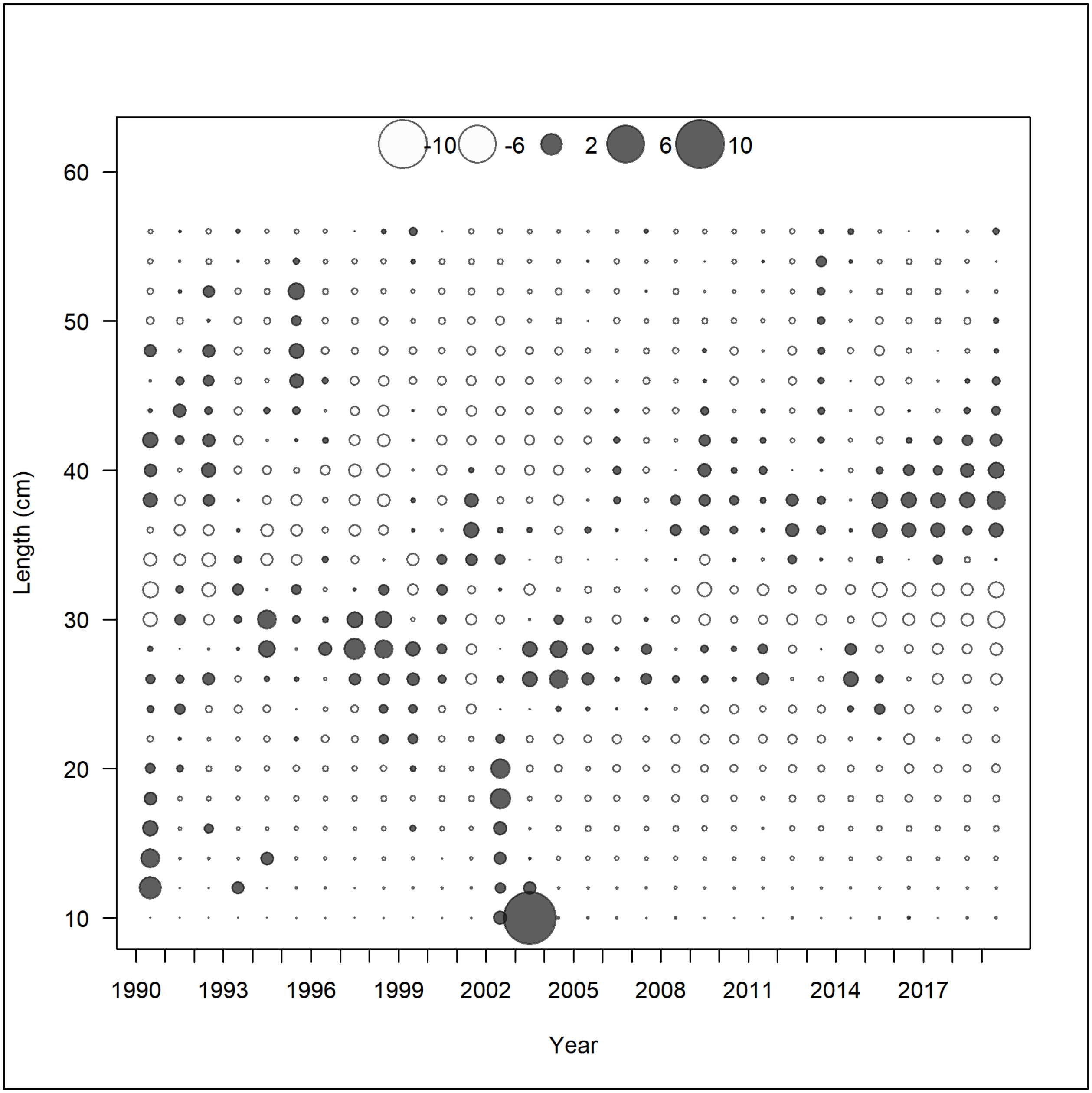
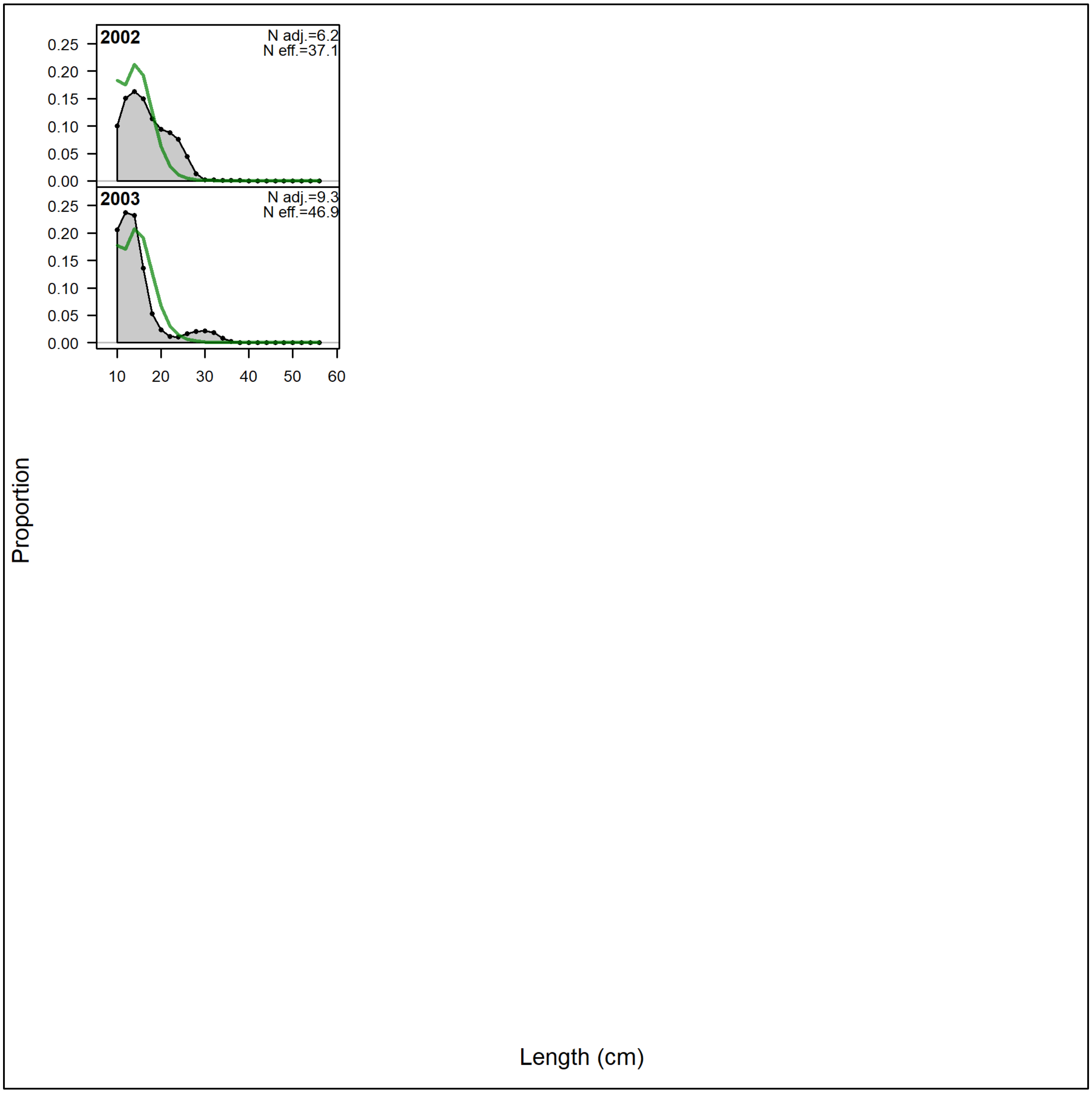


Figure 3.11. Standardized residuals for the commercial fishery length composition data from the base run of the stock assessment model, 1990–2019. Gray circles represent positive residuals (observed > expected) while white circles represent negative residuals (observed < expected). The area of the circles is proportional to the size of the residuals.



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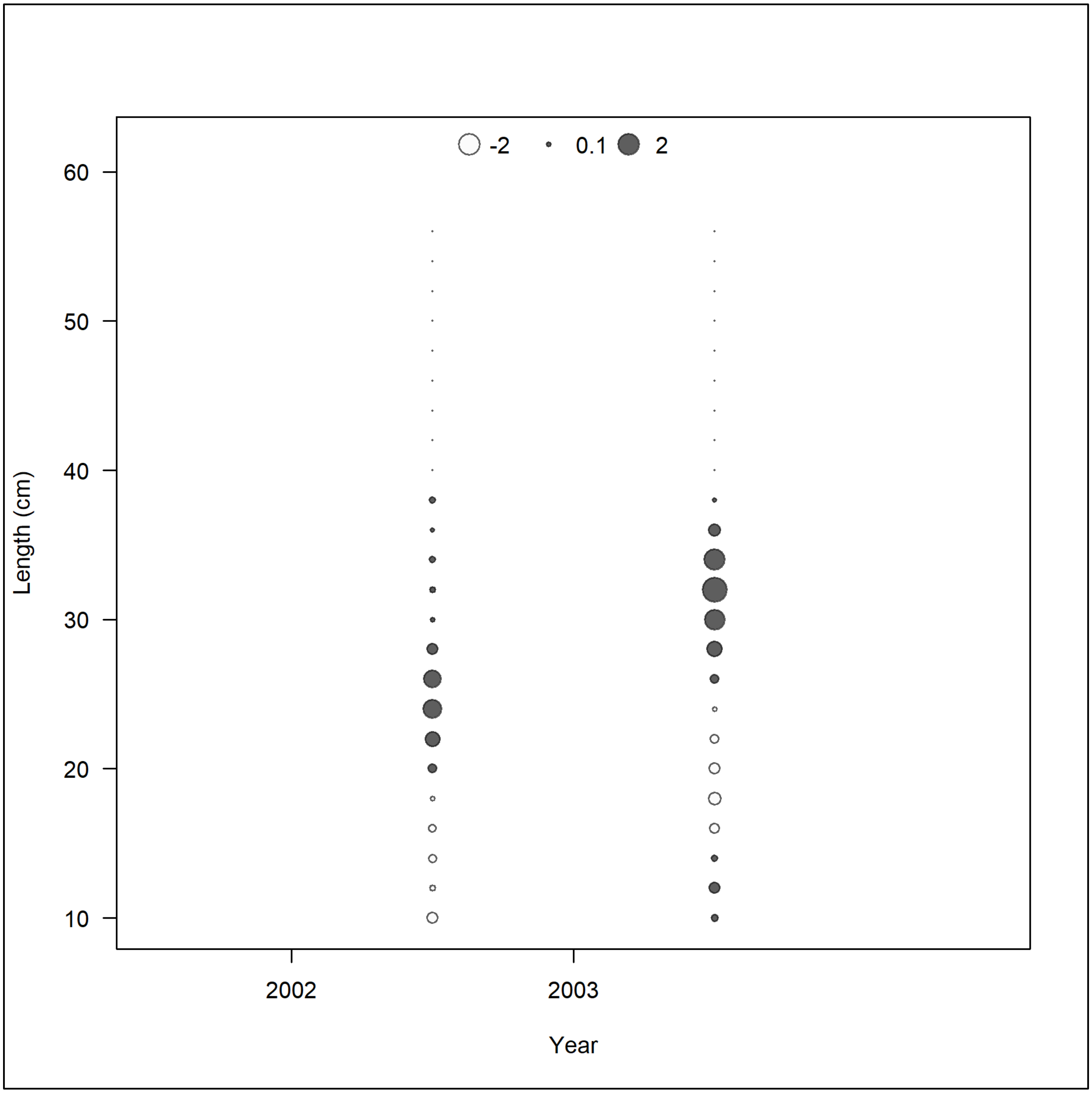

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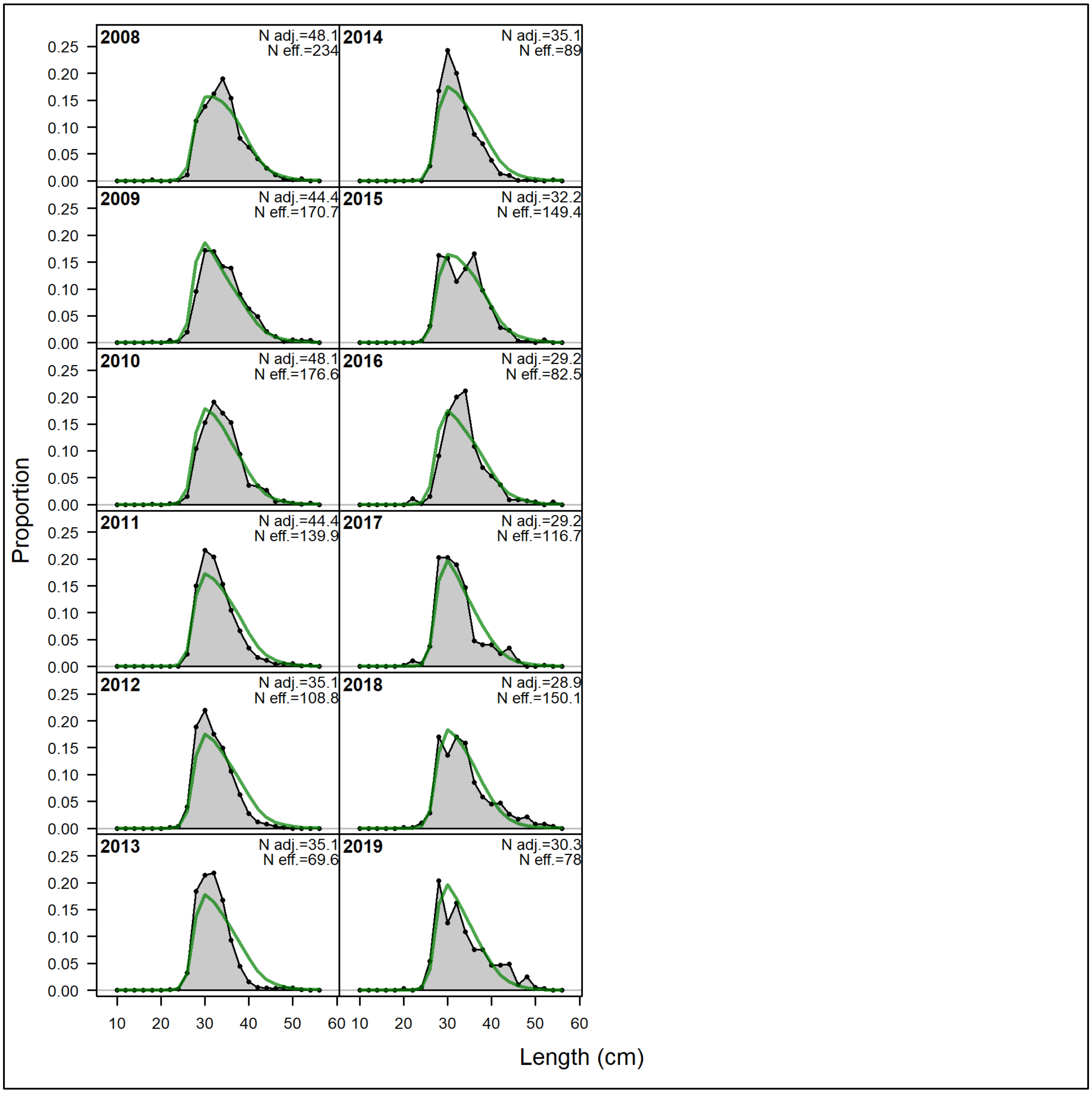
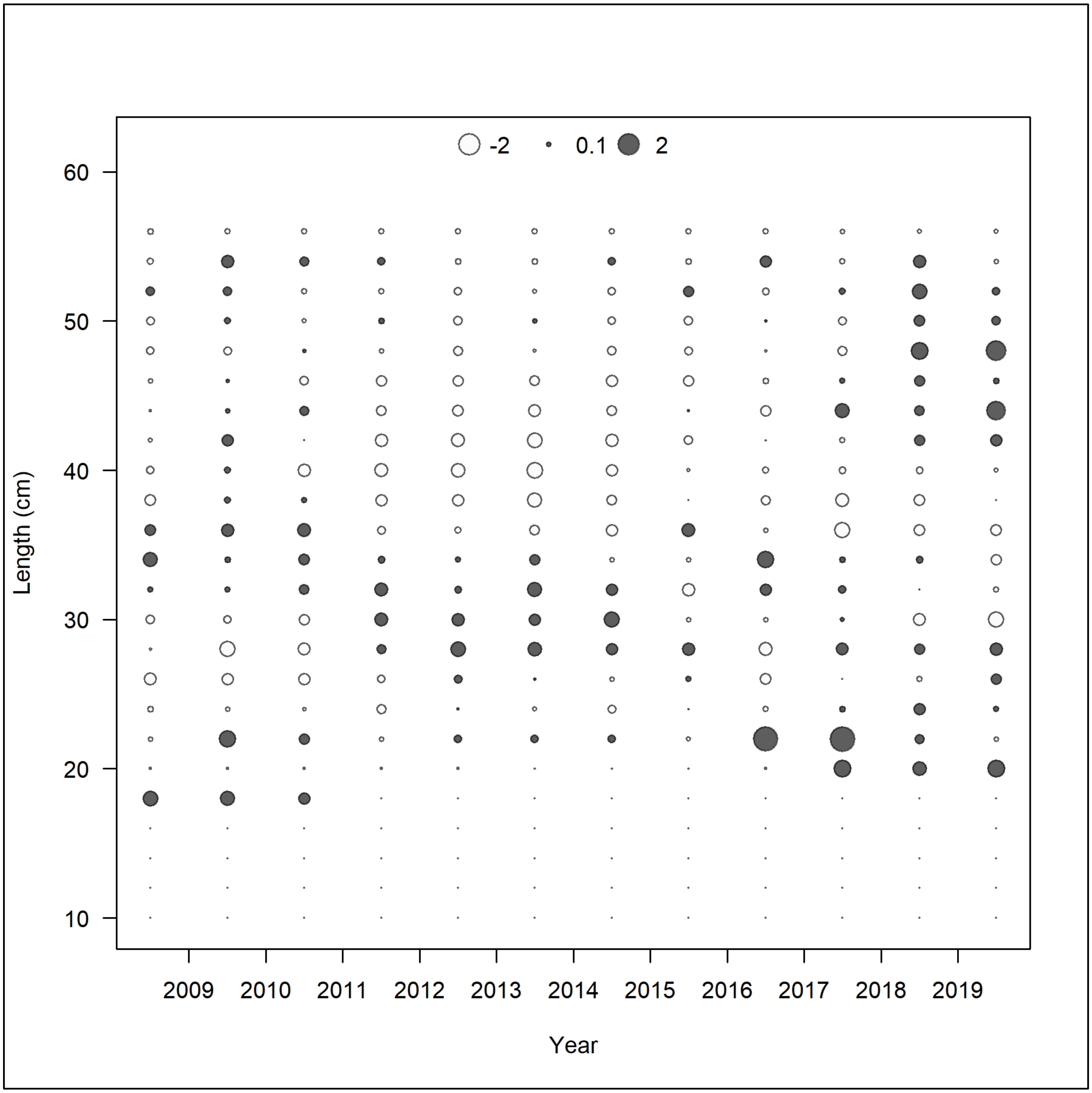


Figure 3.14. Observed and predicted length compositions for the P915 Survey from the base run of the stock assessment model, 2008–2019. N adj. represents the input effective sample size (number of trips sampled) and N eff. represents the model estimate of effective sample size.



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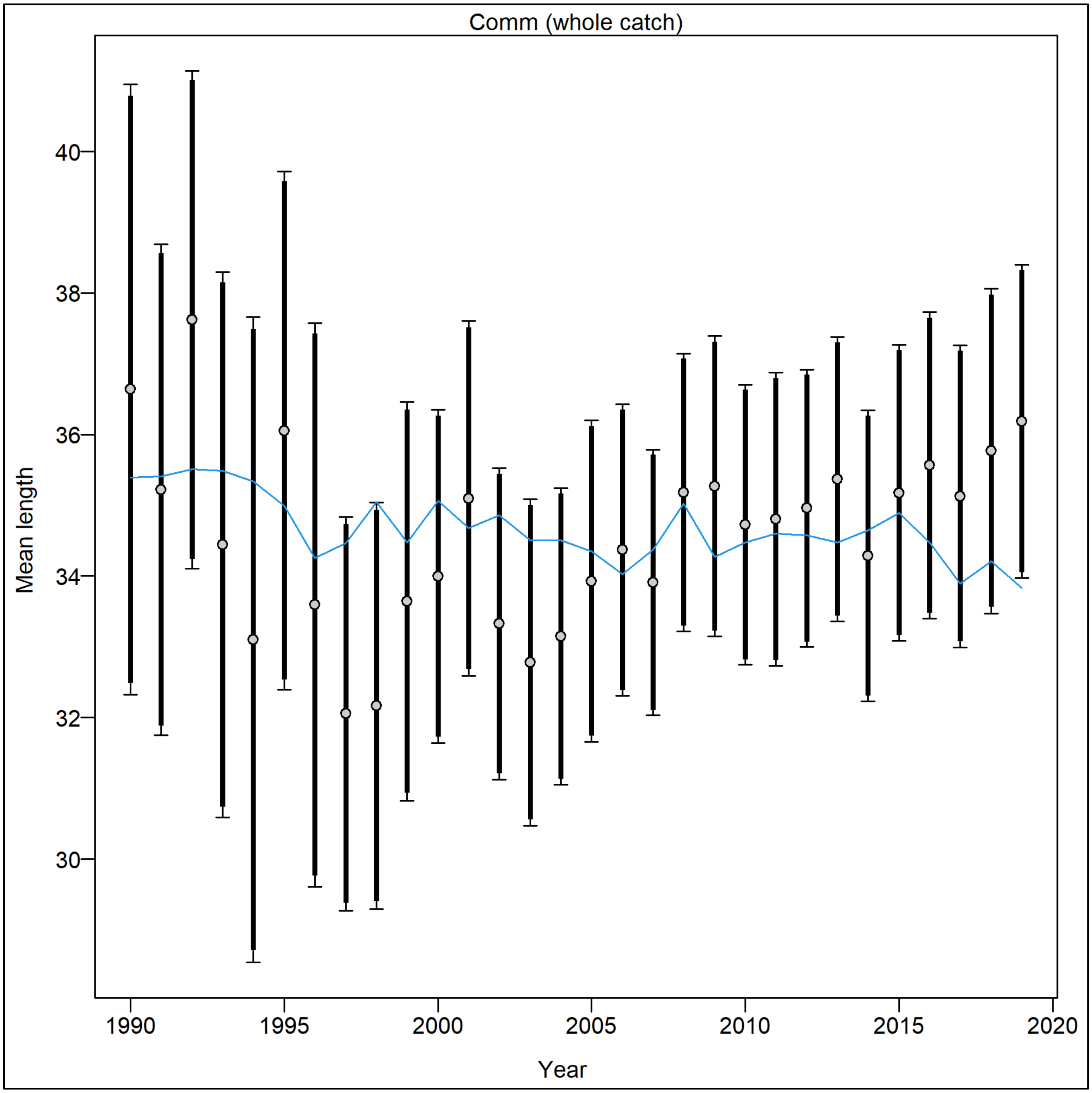

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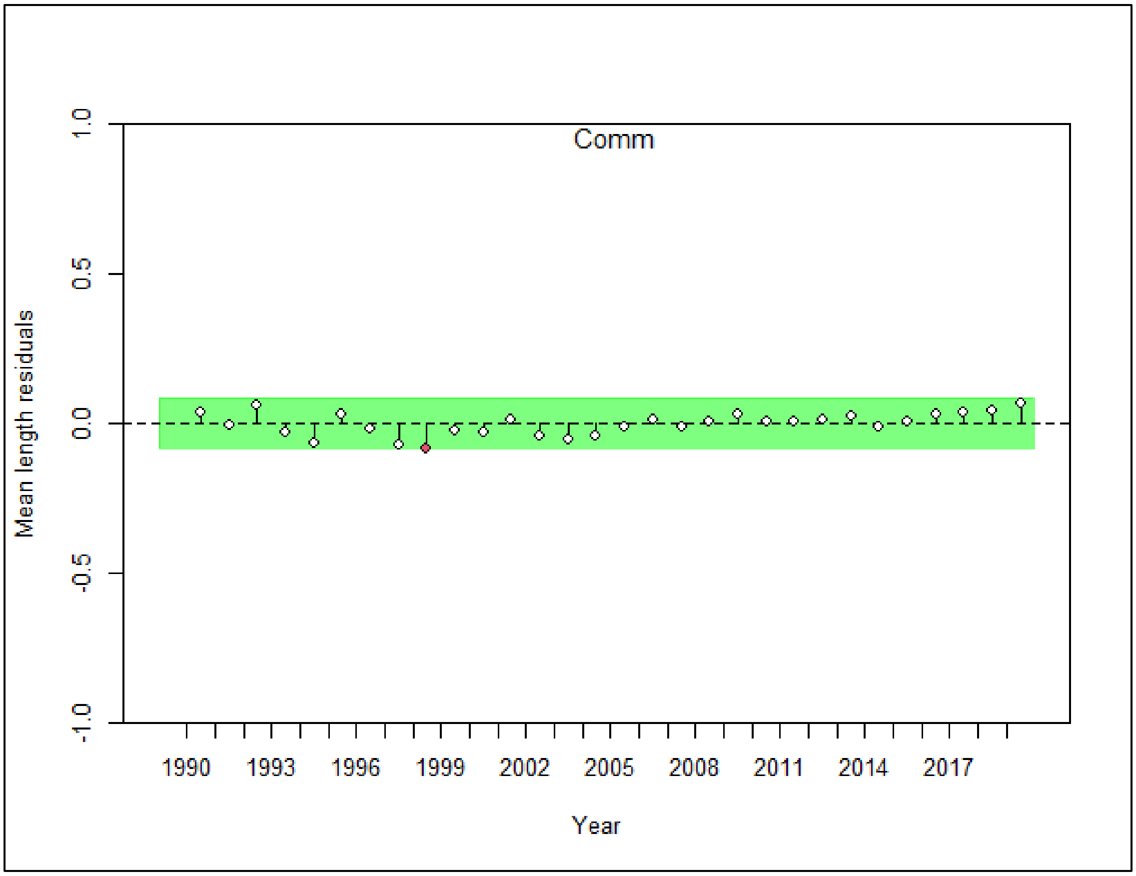


Figure 3.17. Results of the runs test for the commercial fishery mean lengths from the base run of the stock assessment model, 1990–2019. Green shading indicates no evidence (α = 0.05) and red shading evidence ($p < 0.05$) to reject the hypothesis of a randomly distributed time series of residuals, respectively. The shaded (green/red) area spans three residual standard deviations to either side from zero and the red points outside the shading violate the 'three-sigma limit' for that series.

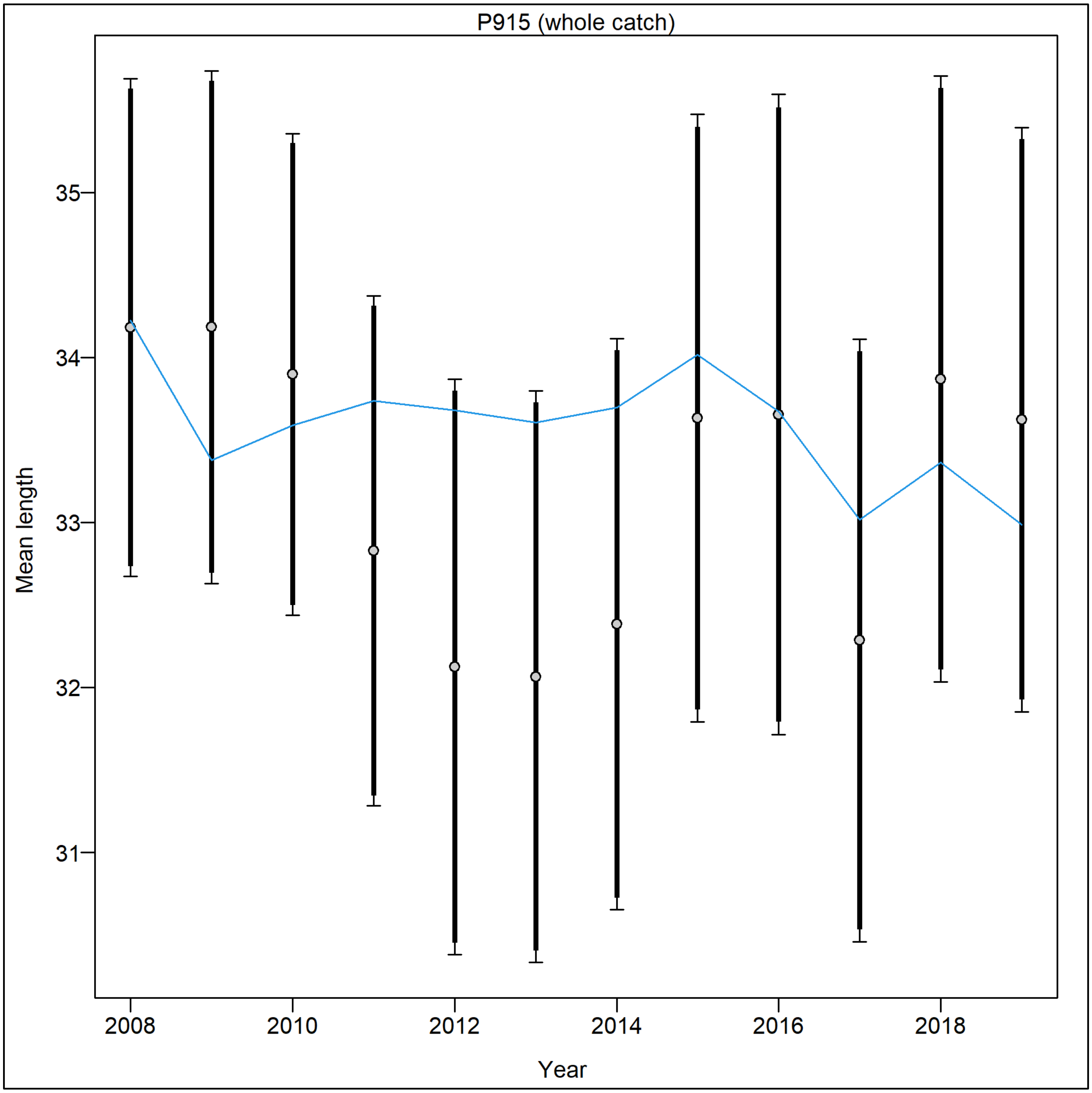


Figure 3.18. Observed mean lengths with 95% confidence intervals (grey dots with error bars) and predicted mean lengths (blue line) for the P915 Survey from the base run of the stock assessment model, 2008–2019.

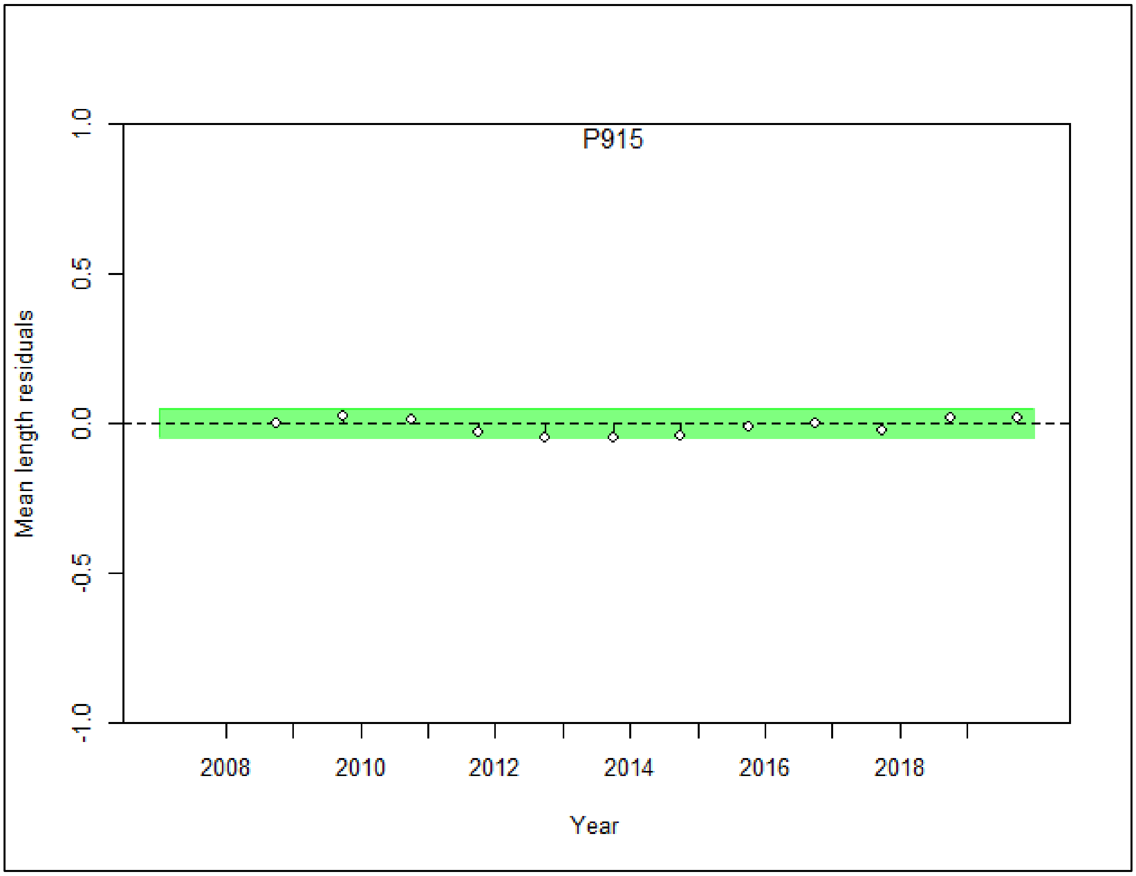
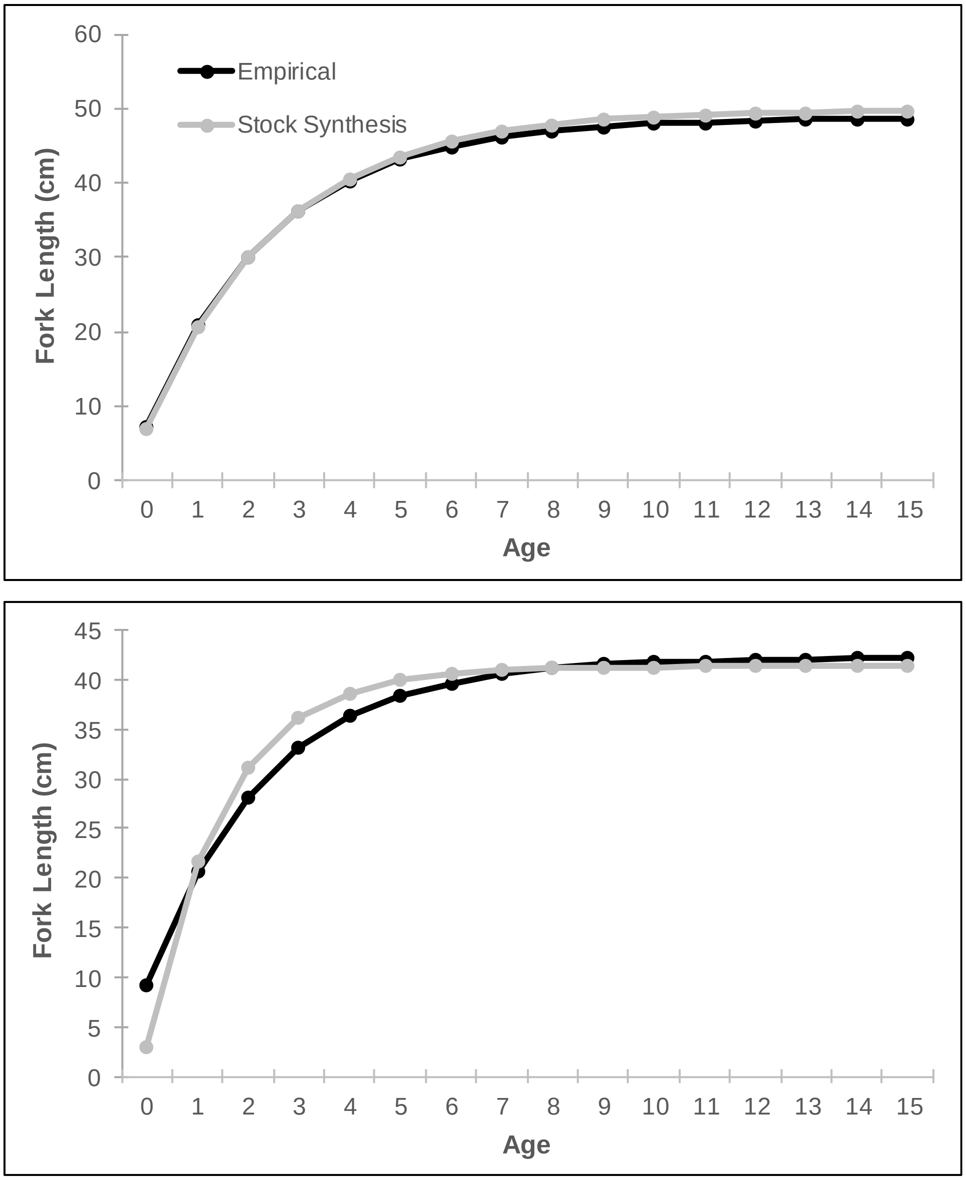


Figure 3.19. Results of the runs test for the P915 Survey mean lengths from the base run of the stock assessment model, 2008–2019. Green shading indicates no evidence ($\alpha = 0.05$) and red shading evidence ($p < 0.05$) to reject the hypothesis of a randomly distributed time series of residuals, respectively. The shaded (green/red) area spans three residual standard deviations to either side from zero and the red points outside the shading violate the 'three-sigma limit' for that series.



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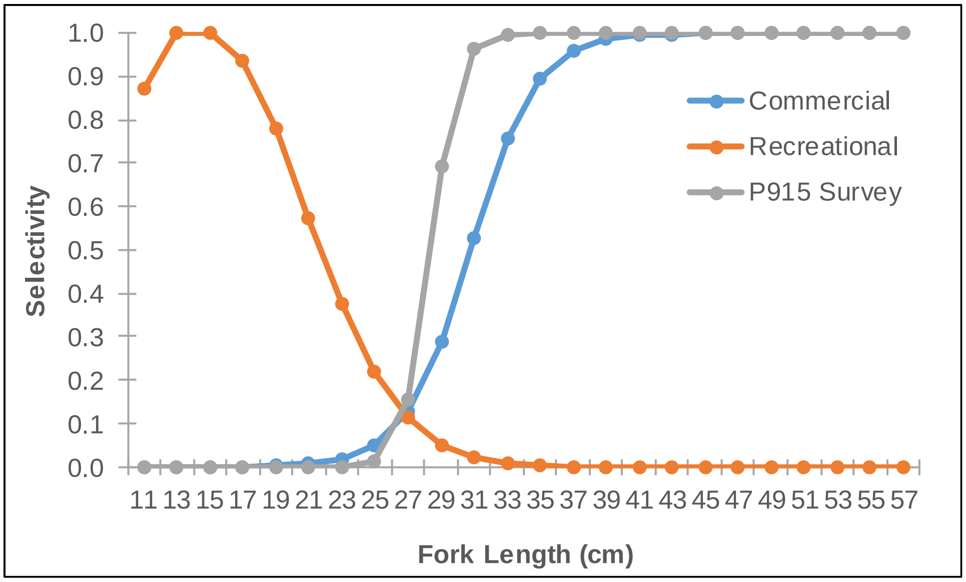

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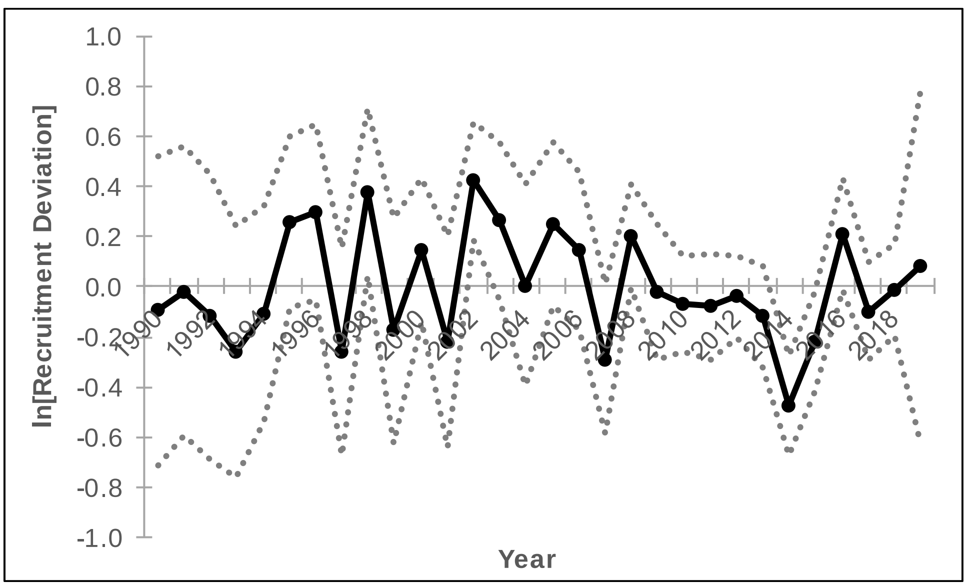

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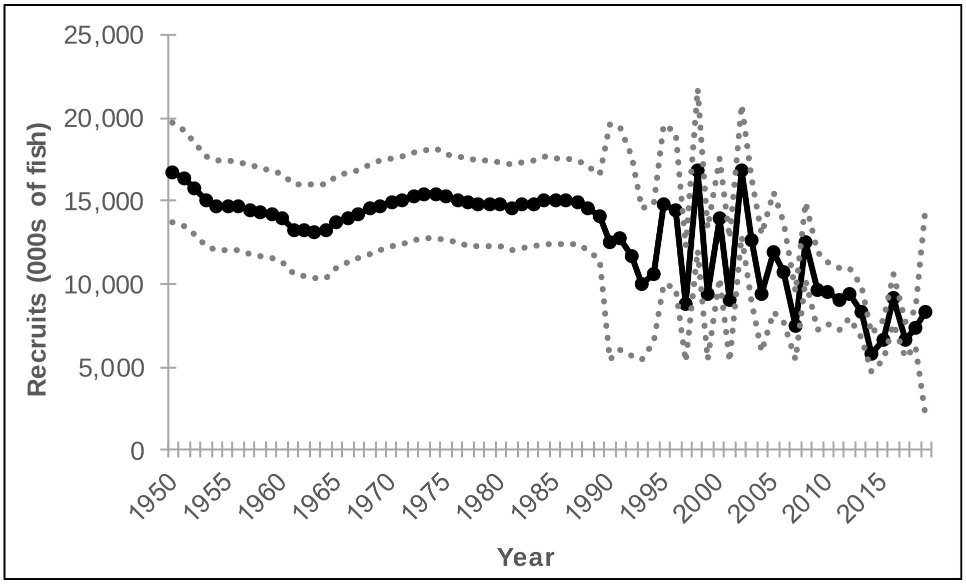

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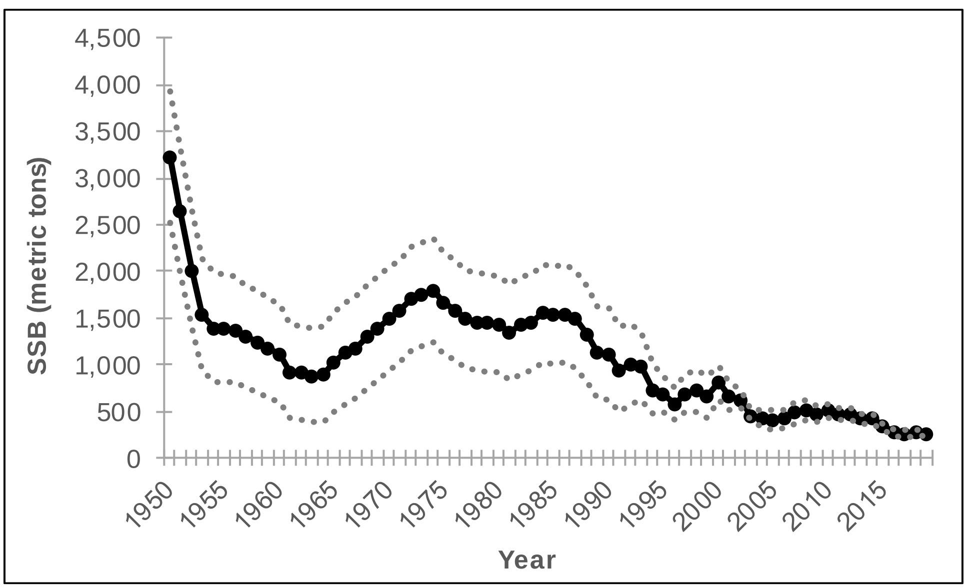
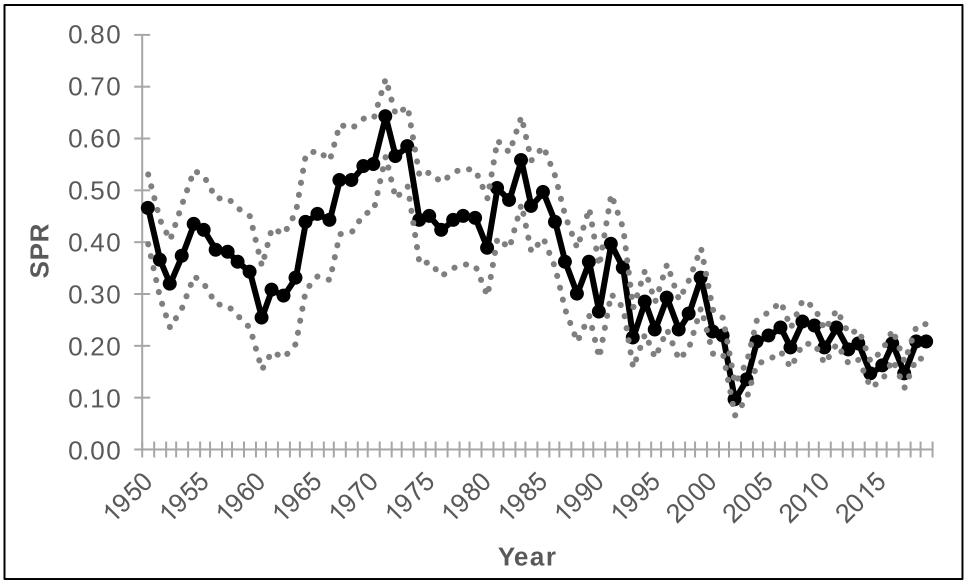


Figure 3.24. Annual predicted female spawning stock biomass from the base run of the stock assessment model, 1950–2019. Dotted lines represent ± 2 standard deviations.



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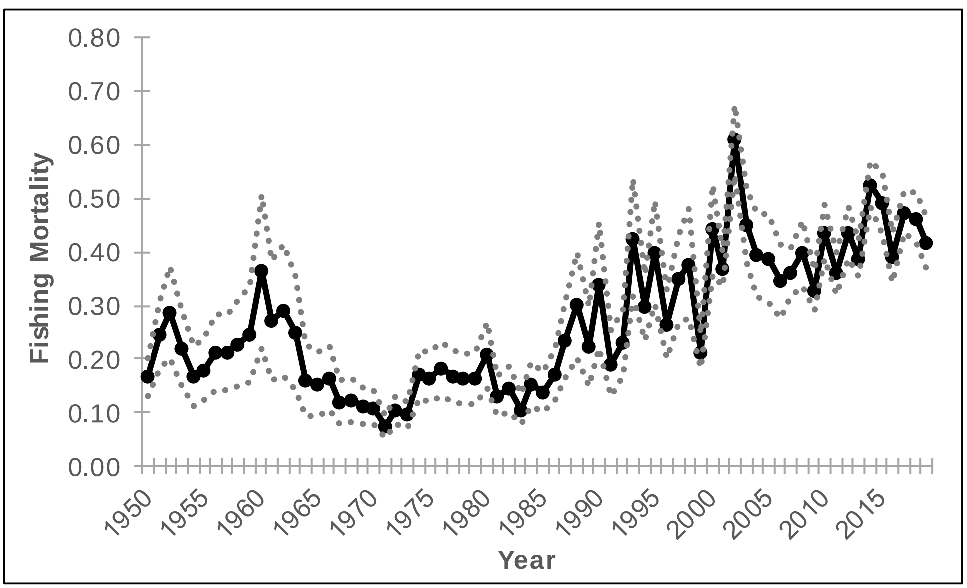

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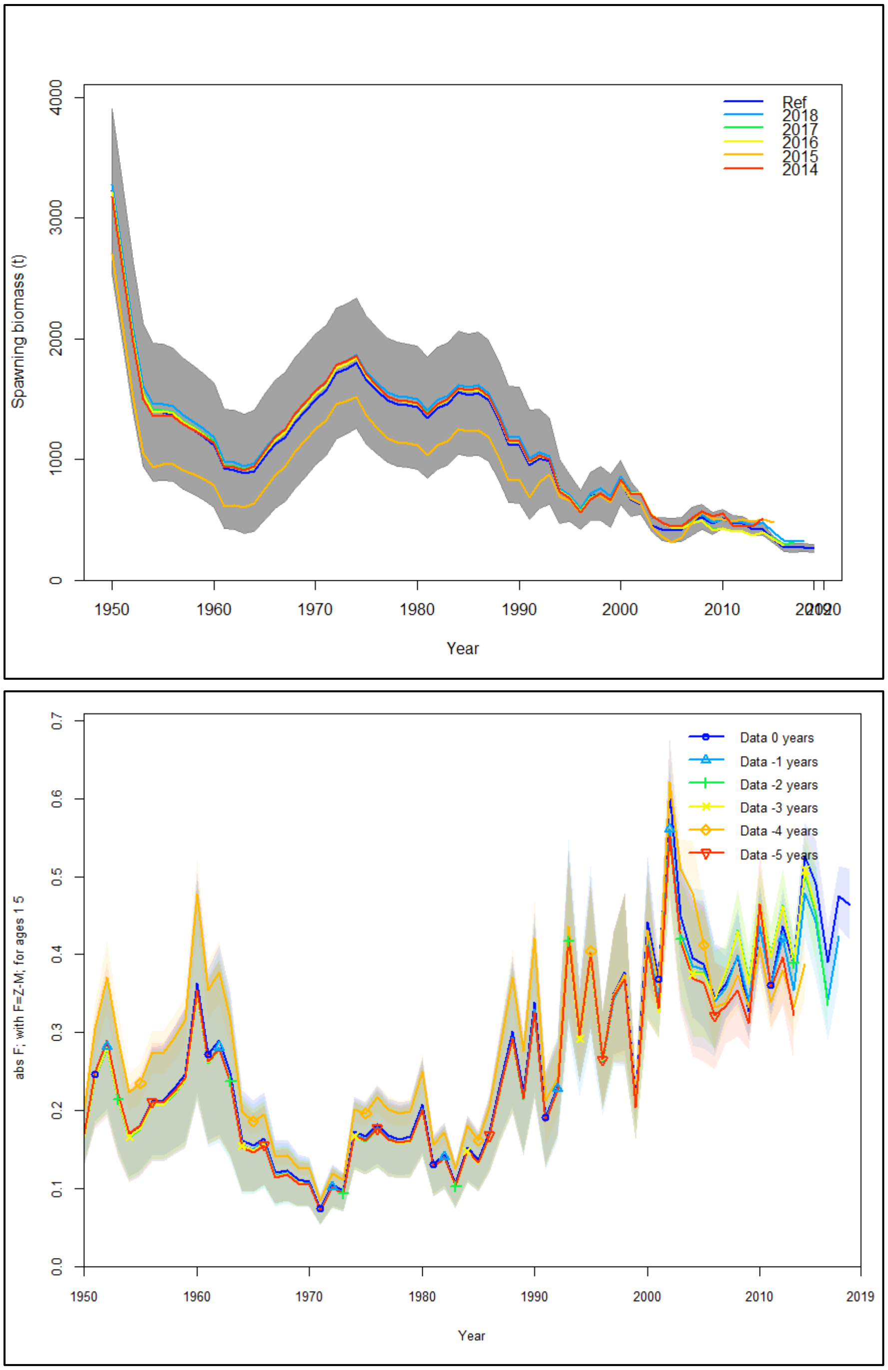

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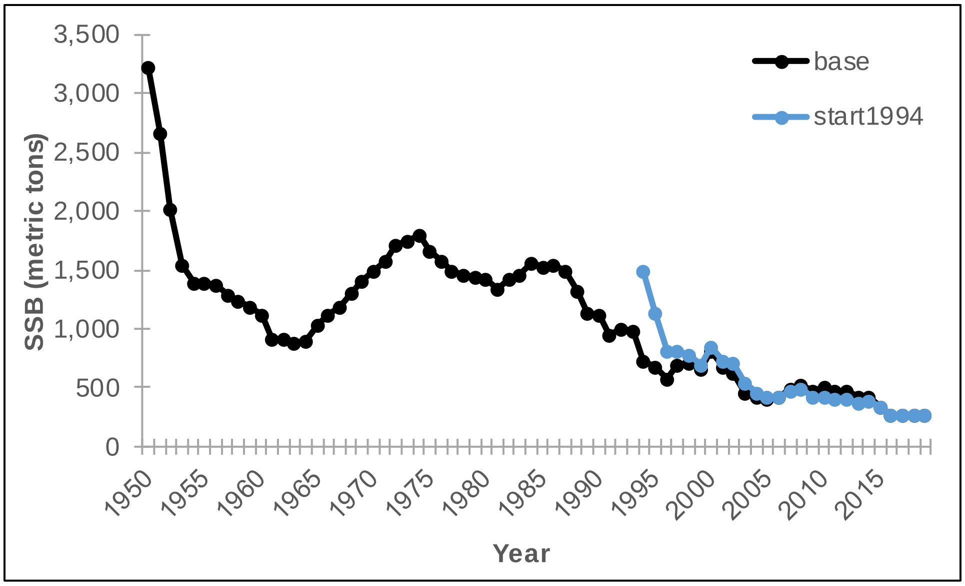

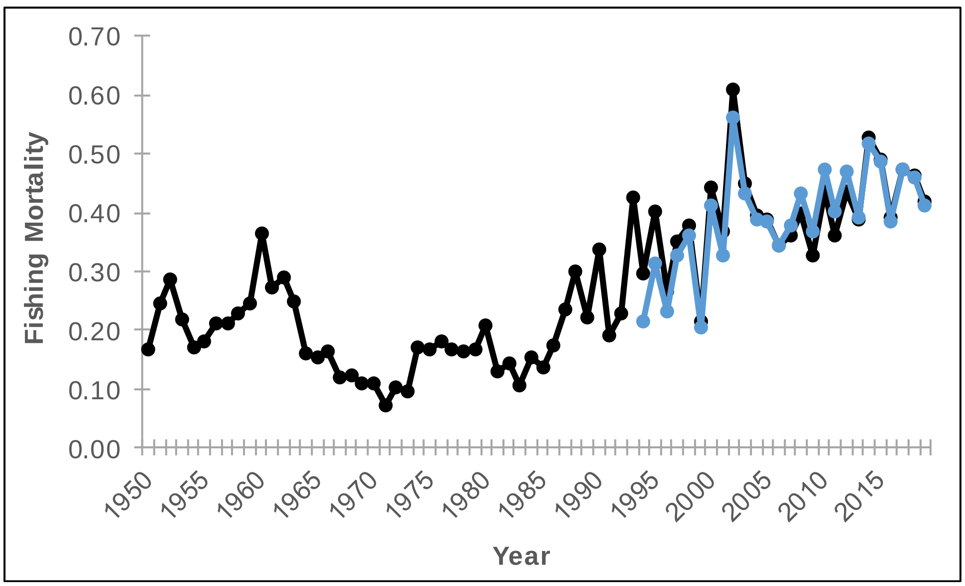

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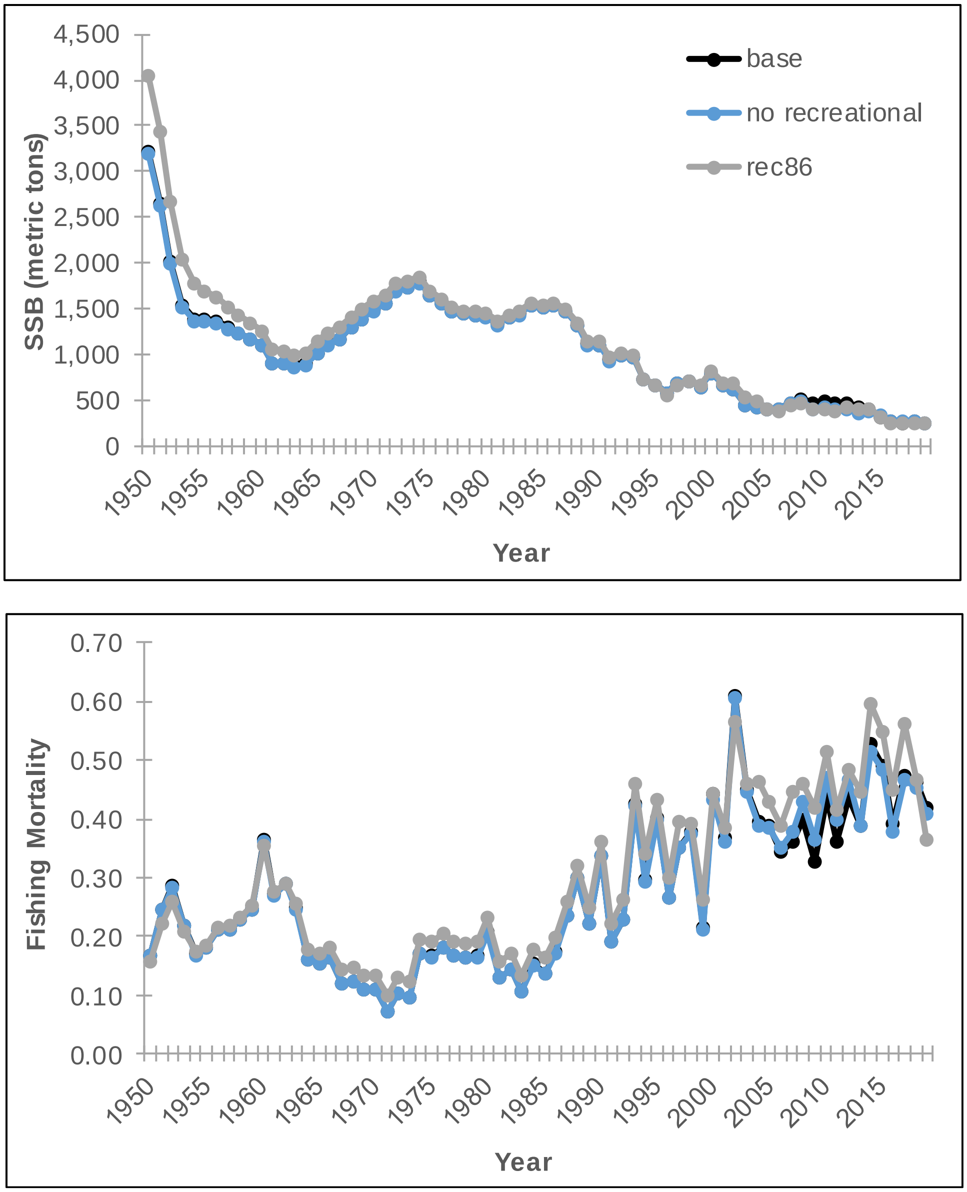

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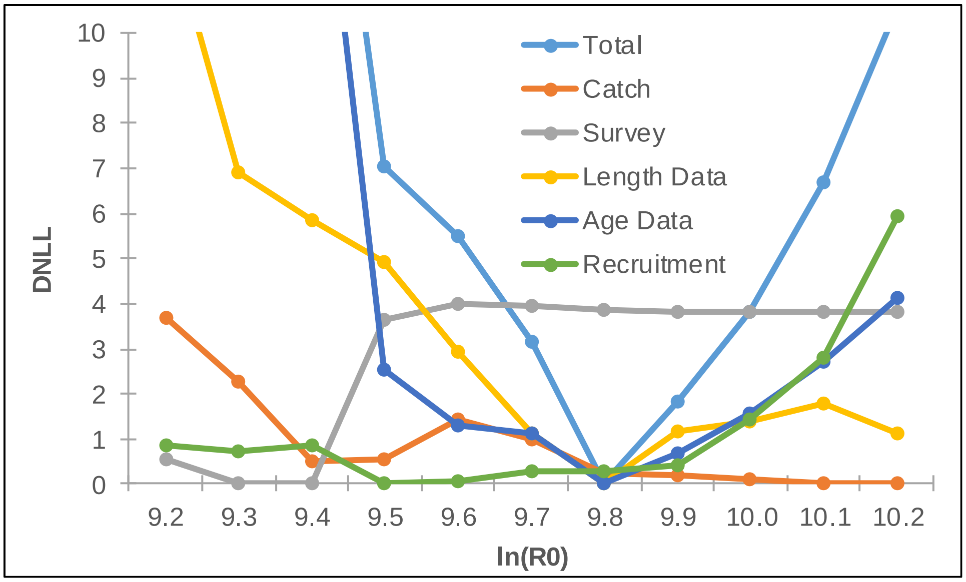

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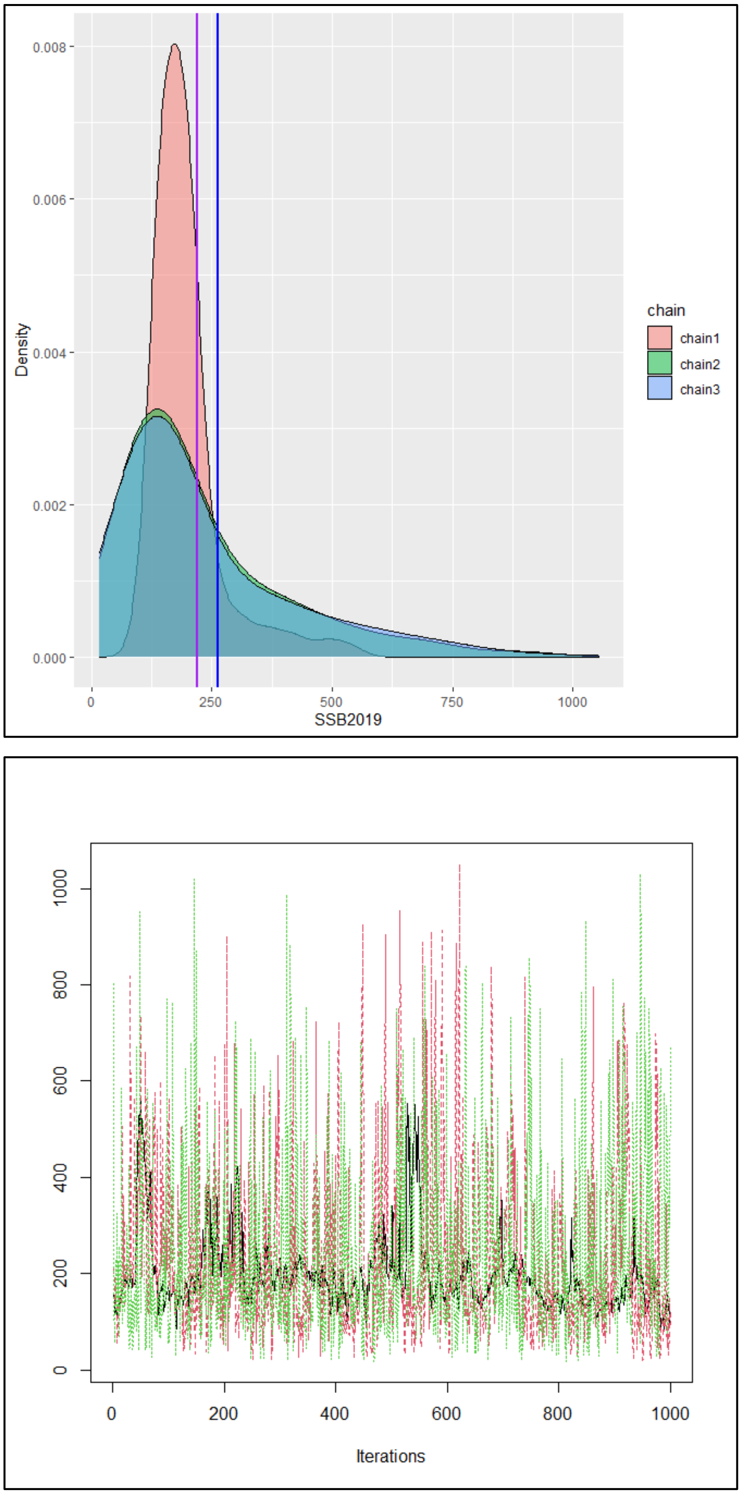

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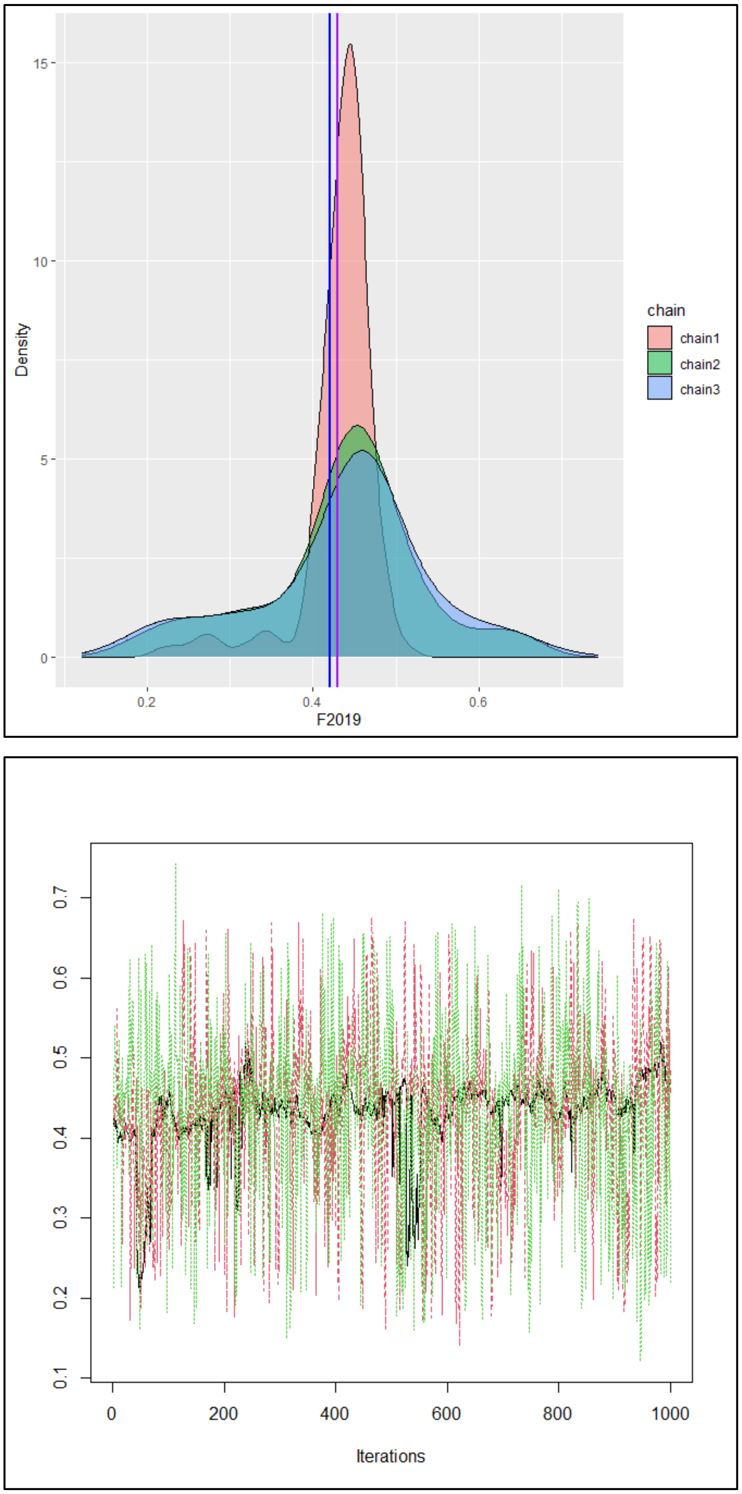

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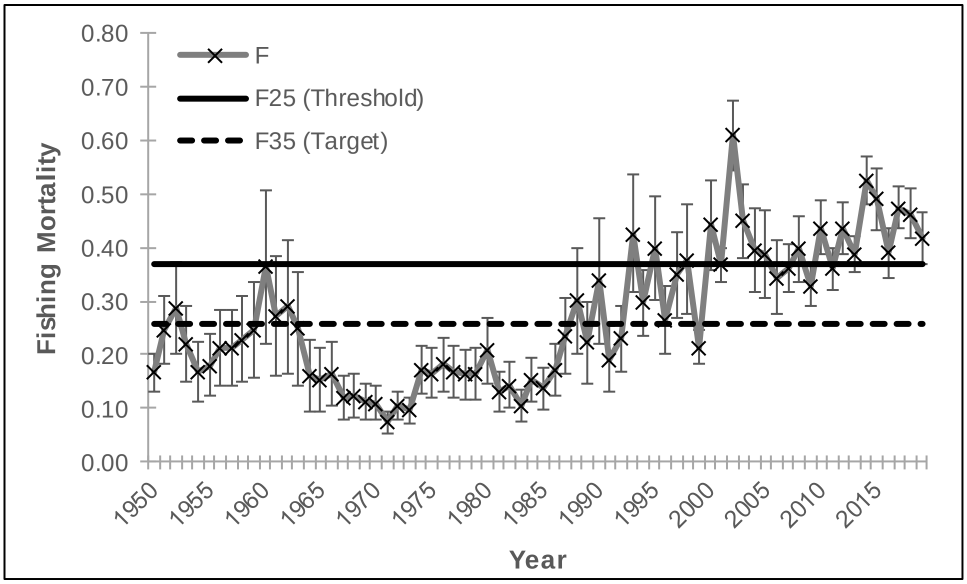

Figure 4.1. Comparison of annual estimates of fishing mortality (numbers weighted, ages 1–5) from the base run to estimates of the fishing mortality target ($F_{35\%}$) and threshold ($F_{25\%}$). Error bars represent ± 2 standard deviations.

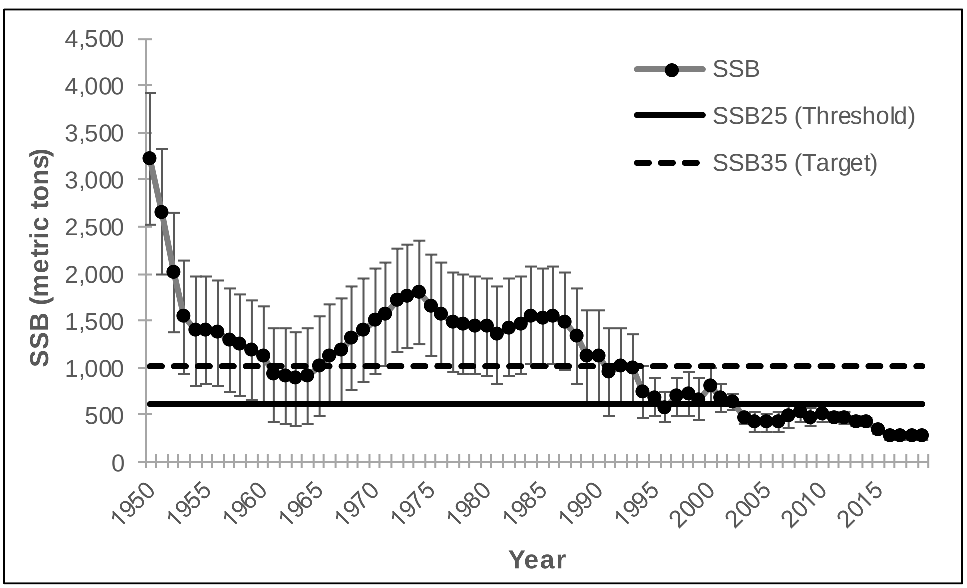

Figure 4.2. Comparison of annual estimates of female spawning stock biomass (SSB) from the base run to estimates of the SSB target ($SSB_{35\%}$) and threshold ($SSB_{25\%}$). Error bars represent ± 2 standard deviations.

External Peer Review Report
for the
2021 Stock Assessment
of
Striped Mullet in North Carolina

External peer review panel

Christopher McDonough (Chair)- Fisheries Management Office, Marine Resources Division, South Carolina Department of Natural Resources. Charleston, SC

Dustin Addis – Marine Fisheries Stock Assessment Group, Florida Fish and Wildlife Research Institute, Florida Fish and Wildlife Commission. Saint Petersburg, FL

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February 2022

EXECUTIVE SUMMARY

The external peer review for North Carolina's Striped Mullet stock assessment, held in webinar workshops from November 8-10, 2021 and from February 8-9, 2022, was aimed to evaluate the stock assessment including input data, stock assessment model configuration, model outputs, model uncertainty, and to make recommendations for the improvement of the stock assessment and future research. As peer reviewers, we're charged with evaluating the North Carolina Striped Mullet stock assessment with respect to the Terms of Reference.

The Peer Review Panel (PRP) commends the Striped Mullet Plan Development Team for their concise and comprehensive presentation of the data inputs used in the stock assessment. The assessment report and summary presentations, as well as subsequent data and analysis requests made for the second workshop meeting, were complete and greatly facilitated evaluation of the assessment model.

The assessment team used fishery-dependent and fishery-independent data and an integrated statistical catch-at-age model (Stock Synthesis; v. 3.30) that was configured and parameterized prior to the review. However, the November 2021 review workshop revealed excluded data sources that were asked to be included by the peer review panel (PRP), existing data conflicts, and possible model misspecifications resulting in biased estimates of parameters and quantities derived from them. The assessment team accommodated all data and exploratory requests from the PRP and prepared a revised stock assessment model for the February 2022 workshop, which in turn was further developed in collaboration with the PRP to produce a base model.

The whole process was very open to alternative approaches and suggestions and allowed for constructive dialogue between the PRP and the assessment team, as conducting stock assessments are an iterative process that allows hypotheses to be tested to establish a stable base model by the reduction of data conflicts, model misspecifications, and uncertainty. We would like to commend the North Carolina Division of Marine Fisheries Striped Mullet Plan Development Team's efforts during the review for providing necessary information on the stock assessment model configuration and parameterization, control files, and input data including life history parameters, landings and discards, and indices of abundance.

Overall, based on the materials presented and additional runs conducted during the review, the PRP agrees the North Carolina Striped Mullet assessment provides stable and consistent results considering various uncertainties in data and model. The PRP agrees that this is the best scientific information available and is suitable for management advice.

Amendment 1 to the NCDMF FMP for Striped Mullet adopted a fishing mortality threshold of $F_{25\%SPR}$ and a fishing mortality target of $F_{35\%SPR}$, with corresponding spawning stock biomass reference points ($SSB_{25\%SPR}$, $SSB_{35\%SPR}$). The base model concludes that the North Carolina Striped Mullet is currently undergoing overfishing ($F_{2019} > F_{25\%SPR}$) and is currently overfished ($SSB_{2019} < SSB_{25\%SPR}$) in the terminal year.

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1 TERMS OF REFERENCE

1.1 Evaluate the adequacy of information used to justify definition of the unit stock.

The stock unit for NC was adequately defined with information from tagging studies, fishery dependent data and fishery independent surveys as all striped mullet inhabiting North Carolina coastal and inland waters. However, there are no recognized sub-populations or distinct genetic stocks of striped mullet in the Atlantic basin and the unit stock for NC is considered solely for the purpose of management in state jurisdictional waters. It is appropriate to consider the state management units as distinct due to the limited movement patterns between states observed in both juveniles and adults. The stock unit is adequately defined for management purposes. But given that the species spawns offshore and is continuously distributed along the Atlantic Coast, it is probably not reproductively isolated and not a completely closed population.

1.2 Evaluate the thoroughness of data evaluation and presentation including:

1.2.1 Justification for inclusion or elimination of available data sources

The 2021 NCDMF Striped Mullet assessment included several broad categories of data used to fit the model and characterize population dynamics: catch time series, indices of relative abundance time series, age compositions and length compositions. The review panel found that the data sets included in the final version of the model were all useful and provided valuable information to the model. However, the data sets included in the original version of the model described in the 2021 Striped Mullet Stock Assessment Report (SAR; NCDMF, 2021) were not all recommended for use, and additional data sources were recommended to be added. We will first focus on data sources included in the final model and then will comment on changes made during the review process.

Removals

The assessment included two sources of removals from the North Carolina Striped Mullet stock: commercial and recreational landings. While commercial landings make up the vast majority of the removals, recreational landings are important to account for, and tend to target smaller fish than the commercial fishery. As in many fisheries, data collection for the commercial fishery is more thorough, and catch is estimated more precisely than the recreational fishery. Due to the nature of the data collection process, the recreational landings are fairly uncertain. This is largely due to limited sampling of catches from anglers harvesting Striped Mullet and species identification issues between Striped Mullet and other mullet species. Recreational landings were not included in the original model run described in the 2021 report, due to the uncertainty in the data. However, substantial sources of removals are important to account for in a stock assessment even if they are uncertain because they characterize absolute losses (i.e. deaths) from the population, rather than providing a relative measure of some aspect of the population like other data sources (i.e. indices and compositions). Furthermore, despite the uncertainty of the recreational landings data, it was judged to be the best available.

Indices of abundance

The NCDMF conducts an annual fishery-independent gillnet survey (Program 915) that samples much of the stock area being assessed and uses gear with a selectivity pattern similar to that of the commercial landings. These attributes make it a relatively ideal source of relative abundance data for the stock. In the 2021 SAR, this survey was used to develop two separate indices. A north index included large areas of the Pamlico Sound in Hyde and Dare Counties, as well as the Neuse, Pamlico, and Pungo Rivers. A south index included the lower portion of the New River. Reviewers recommended combining these indices since the fish being encountered by these surveys are likely mixing substantially over the course of the year and their selectivity was already being described by the same function. Essentially, they were already indexing the same portion of the population despite small spatial differences, and it was judged to be preferable to combine them outside of the model than to include them both in the model and have to make some subjective decision about their relative weights in the model.

The SAR model also included indices from two other data sources which we did not recommend for use in this assessment: NCDMF electrofishing survey (Program 146) and the NOAA Beaufort Bridgenet Survey. Both surveys were excluded largely because they are conducted in areas that are very geographically limited. When included in the model both indices tended to conflict with the NCDMF gillnet survey. Indices from the electrofishing survey even conflicted with each other, even though they index the same location in different seasons. The Bridgenet Survey had the advantage of providing a recruitment index, but because the survey operates at only a single point in the dynamic estuarine waters of NC, we judged that it was not likely representative of the entire stock area.

Age and length compositions

The assessment included age composition data associated with the commercial catch and the gillnet survey. Length compositions were available for the commercial catch, recreational catch, and the gillnet survey. The annual sample sizes for the commercial catch and gillnet survey compositions were adequate, but were limited for the recreational fishery. Age and length composition data corresponding to the NCDMF electrofishing survey were included in the original model, but were not needed in the final model, since this survey index was also excluded.

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

Based on the description in the SAR, the NCDMF gillnet survey seems to be pretty ideal for tracking abundance of this stock. First and foremost, it is a fishery independent index and using consistent sampling methods. It covers a broad spatial distribution over much of the stock area. It is executed with a gear type that is similar to that used by commercial fisheries that gather much of the harvest. The CVs associated with the index were sufficiently precise (<0.2) and quite consistent across years. Selectivity is estimated to be similar between the survey and the commercial fishery. Although it’s preferrable to have longer time series, this index is available for 12 years and exhibits only limited interannual variability between consecutive years while apparently tracking longer term trends.

A lot was made of the decrease in the index between 2014 and 2015, but the absolute change is only slightly larger than the increase in the index between 2009 and 2010. Considering the index standardized to a mean of 1 (I.e. dividing the index by its mean; see table below), a value of 1 in a year indicates the average population size and a value of 2 would suggest that the population was twice as large in that year. In fact, the range 0.43 - 1.73 is not much larger than one. According to the index, the size of the Striped Mullet population between 2008 and 2019 is not very variable but shows a clear decline in recent years.

Year	Program 915 index	Program 915 index standardized
2008	3.6	1.30
2009	2.7	0.97
2010	4.8	1.73
2011	4.1	1.48
2012	3.7	1.33
2013	3.6	1.3
2014	3.6	1.3
2015	1.2	0.43
2016	1.3	0.47
2017	1.5	0.54
2018	1.6	0.58
2019	1.6	0.58

1.2.3 Calculation and standardization of indices and other statistics (Nikolai)

The NCDMF gillnet survey index was standardized with generalized linear model (GLM) approach, that considered 13 environmental or temporal covariates, and ultimately retained six. Presentation of the method is relatively brief but the approach appears to be sound. A more detailed presentation of the methods would be preferable.

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

The data and modeling framework selected by the analytic team were appropriate given the life history of the species and the history of data collection within the region. Pragmatically for this assessment and management, the decision was made to focus the assessment data collected on the unit stock within North Carolina waters. The approach in applying the data within the assessment is typical; which was to explore this through weighting likelihood components and by inclusion/rejection of individual data components in sensitivity analyses. However, this is not always the best approach by letting the model “decide” the base model. A better approach would be to understand the underlying data processes to allow for informed choices to be made prior to model construction.

The following data sources were applied within the model. Life history and biology parameters included growth, length-weight relationship, maturity and natural mortality. Growth was based on available otolith-based age data that were fit with a von Bertalanffy age-length model to estimate growth parameters by sex. The length-weight relationship used the relation of fork length in centimeters to weight in kilograms was modeled by sex using non-linear least squares. Maturity estimation utilized a logistic regression applied to the maturity samples from female striped mullet 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 adequately. Natural mortality was estimated using the Lorenzen (1996) approach to produce estimates of *M* at age by sex.

Fishery dependent data utilized in the model include commercial landings and recreational harvest. Commercial landings in weight along with length and age compositions (NCDMF Trip Ticket Program) were considered. The commercial landings started in 1950, with length and age composition data available for 1990-2019. Recreational landings from the Marine Recreational Information Program (MRIP) included annual recreational observed (Type A) and reported (Type B1) harvest estimates for the mullet genus in North Carolina as estimated by the MRIP in units of numbers of fish, 1981-2019. Length composition data was available for 2002-2003. Fishery independent used in the model was the NCDMF Fisheries-Independent Gill-Net Survey (Program 915 survey) index, with length and age composition data available for 2008-2019.

The peer review panel asserted that long-term recreational landings are an important source of removals and should be included in the assessment model. The analytic team obliged and produced a fisheries-dependent reporting working paper. The recommendation from working paper stated for the base run of the stock assessment that the sum of recreational harvest for striped mullet and a proportion of the recreational harvest for mullet genus be used for removals by the recreational fleet. The proportion of mullet genus recreational harvest that was recommended was 29%, a value derived from a study by the NCDMF of cast net recreational harvest for striped mullet. Estimates of recreational harvest for mullet prior to 2002 were considered unreliable and estimates prior to 2002 (back to 1950) were assumed equal to the median of the 2002 to 2019 time series.

The Program 915 gill-net survey was deemed to be an adequate long-term fishery independent index of abundance that reflected a similar selectivity to that of the commercial fishery and had sufficient spatial coverage of North Carolina inshore waters (Pamlico Sound, Neuse River, Pamlico River, Pungo river, New River, Cape Fear River). Data uncertainties and potential biases were acknowledged and reported adequately within the assessment report.

Data limitations in this assessment exist both in terms of data quality and quantity. The assessment team were transparent and candid about problems with the data and with the model fitting process. After discussion, the review panel agreed that sensible and pragmatic decisions were made on how the data should be used in the final version of the assessment. There was a high amount of uncertainty from estimated MRIP recreational landings due to high annual coefficients of variation (CVs). Nonetheless, as a significant source of removals, recreational landings need to be accounted for in the model. Note that this was not the case with other data sources like indices of abundance which usually should not be used if they are very uncertain. The model uses these data sources in fundamentally different ways. There is also evidence of two distinct recreational fisheries in North Carolina, a live bait fishery and a fishery that targets adults for consumption or to be saved for use as cut bait. MRIP landings and length composition data may not adequately represent both of these fisheries, as those fishermen that catch mullet for live bait typically release them before visual inspection by creel clerks. Therefore, MRIP length composition predominately reflect retained adult lengths. Ideally, the assessment model would account for both recreational fisheries as separate fleets with associated length/age composition data and differing selectivities. However, there was a lack of sufficient data collection to support such a configuration.

Landings data (Commerical landings, NCDMF RCGL recreational survey landings) also did not differentiate between striped mullet and white mullet. Recreational angler misidentification between the two species can also be common, and bait mullet are usually released by anglers before visual inspection by creel clerks and therefore not identified to the species level in the MRIP data (Type B catch). Beginning in 2002, MRIP APAIS (Access Point Angler Intercept Survey) began deferring to mullet genus to classify unobserved type B1 and B2 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.

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

The base model for the assessment was developed in Stock Synthesis (SS). Stock Synthesis is an age- and size-structured assessment model in the integrated analysis class of models. It's widely used, well documented, and further descriptions of SS options, equations, and algorithms can be found in the SS user's manual (Methot et al. 2019), the NOAA Fisheries Toolbox website (http://nft.nefsc.noaa.gov/), and Methot and Wetzel (2013). SS has 1) a population sub-model that simulates growth, maturity, fecundity, recruitment, movement, and mortality processes, 2) an observation sub-model which predicts values for the input data, 3) a statistical sub-model which characterizes goodness of fit and obtains best-fitting parameters and their associated variance, and 4) a forecast sub-model which projects various user-determined management quantities (Methot et al. 2019). The r4ss software (www.cran.r-project.org/web/packages/r4ss/index.html) was utilized extensively to develop various graphics for model outputs and summaries and was used to perform several diagnostic runs.

The methods were appropriate for the available data. SS is a very flexible model that can run in data poor or data rich situations. The differences in model outcomes are dependent on assumptions in implementing those data.

Specific notes on model configuration included the following. Variability in recruitment (SigmaR) was fixed at a value of 0.38. This value was estimated using the FishLife: Fisheries life-history database (http://github.com/james-thorson/FishLife/) which contains predictions of life history parameters for all marine fish and was estimated using a multivariate random-walk process. Recreational fleet selectivity (double normal pattern) was appropriately fixed in order for the model to fit the associated length composition data. Fixing selectivity can be helpful in cases where the fishery data were limited temporally, which was the case in this assessment with only two years of length composition data. However, fixing selectivity can also affect model fits and potentially compromise estimates of stock parameters (e.g. growth, natural mortality, and recruitment). All likelihood components, with the exception of the age data were assigned a lambda weight equal to 1.0 in the base run. The lambda for the age data was reduced to 0.25. This was a personal recommendation from Rick Methot (NOAA Fisheries), the model developer of Stock Synthesis. Despite being down-weighted, the fit to the age compositions was adequate. Francis reweighting was incorporated to improve model fits to the composition data by adjusting effective sample sizes of length and conditional age-at-length data so that variability of model inputs was consistent with the model fits to mean length or mean age (Francis 2011).

Model diagnostics used to assess model convergence, stability, and uncertainty in results:

- Hessian matrix inversion
- Model convergence level using the default criterion of 0.0001
- Presence of estimated parameters at a bound
- Examination of the correlation matrix identifying highly correlated parameter pairs
- Parameters examined for excessively high variance
- Jitter analysis (10% for a series of 100 trails)
- Evaluation of fits to commercial landings, survey indices, length compositions
- Evaluation of estimated growth vs empirical growth comparisons.
- Evaluation of residual fits to various data components
- Retrospective analysis (5-year peel)
- Jack-knife analysis
- Likelihood profile of R0
- Age Structured Production Model
- MCMC Analysis (3 chains, 7,500,000 iterations total, 1,000 posterior samples)
- Sensitivity runs of the base model included a start year of 1994 which corresponded to the data rich period (Base model start year is 1950) and characterizing 86% of recreational landings of mullet species to Striped Mullet (Base model characterizes 29% to Striped Mullet).

The base model was determined to be properly configured, and consistent with standard practices. Model diagnostics demonstrated that the base model converged successfully, reached a global solution, gave stable and consistent results, displayed minimal data conflicts, and showed little indication of model misspecification. Sensitivity runs showed that a differing start year and an alternative proportion of recreational landings of mullet species to Striped Mullet had very little effect on model outputs and stock status. After consideration of all sensitivity analyses, the PRP concluded that none of the cases considered made sufficient difference to the conclusions drawn from the analyses to warrant changing from the base case.

1.5 Evaluate the adequacy and appropriateness of recommended stock status determination criteria given available information regarding the ecological role of striped mullet. Evaluate the methods used to estimate values for stock status determination criteria.

Stock status was determined by comparing the estimated spawning stock biomass (SSB) in the terminal year of the assessment with the threshold value ($SSB_{threshold}$). The stock would be considered overfished if SSB< $SSB_{threshold}$. Similarly, fishery status was determined by comparing the estimated fishing mortality (F) in the terminal year of the assessment with the threshold value ($F_{threshold}$). The stock would be considered to be undergoing overfishing if F> $F_{threshold}$. Threshold values are commonly based on equilibrium values of F and SSB associated with the maximum sustainable yield (MSY). Alternatively, threshold reference points can be determined by estimating the F value that would maintain a proportion of the unfished spawning potential (e.g. $SSB_{F=0}$). The ratio of fished to unfished spawning potential is known as spawning potential ratio (SPR) can be used. For example, a value of $F_{40\%}$ represents the level of F that would maintain 40% of the spawning potential that would be present in the absence of fishing. It is commonly recommended that such reference points be set by determining the F that maintains at least 30-40% of the unfished spawning potential. In the current stock assessment, the threshold values are based on an F that is expected to maintain only 25% of the unfished spawner biomass. This criterion is based on Amendment 1 of the NCDMF FMP for striped mullet. While the general approach is appropriate, it should be noted that the use of F that maintains only 25% of the spawner biomass is relatively risky.

1.6 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.

The base model of the striped mullet stock assessment identified as of March 2022 (results contained in STM_SSOutputData_2022_v3.xlsx file sent by Laura Lee to reviewers) should be considered the best scientific information available for management of this stock. The Stock Synthesis modelling software is used extensively throughout the United States and internationally, and has been widely tested. The fixed life history parameters provided to the model were based on high quality data from the NC stock and used sound approaches. The index of abundance and corresponding composition data are based on a fishery independent survey conducted by the NCDMF over much of the stock area using a gear that is very effective at catching Striped Mullet in the size range corresponding to much of the catch. Catch information for the commercial fleet, which harvests most of the removals, is high quality. Catch information for the recreational fleet is considered to be much less precise, but it appears that that fleet makes up a small proportion of the overall removals, and it is a merit of the current assessment that it is accounted for. The model fit the data fairly well, and once the range around parameters being estimated in the model was decreased to a reasonable range, the model proved to be quite stable. Other diagnostics such as jitter analysis, profile plots, sensitivity, and retrospective analysis also support the use of the model. The final model is fairly easy to interpret. The decline in the Program 915 index and age truncation indicated in the composition data show signs of a shrinking population. Recruitment is declining as the population declines, as expected from the stock-recruit relationship, but the good news is the recruitment residuals show no additional signs of recruitment problems (e.g. no decline in recruitment deviations). Though we were not presented with projection analyses, it seems likely that projections that apply an appropriate decrease in F will show that the population should rebound in a modest time frame. This situation can be monitored by observing trends in the Program 915 index and looking for expansion of age compositions between assessments.

It is worth noting that the results from this assessment are very different from the previous (2018) assessment, which found no overfishing and was unable to adequately quantify SSB. But we have reason to believe there may have been issues with the configuration of that model, and therefore the differences between the assessments may be partly due to problems with the 2018 assessment model. Although we did not review that assessment, we were given the impression that the configuration of the 2018 model was similar to the configuration of the version of the stock assessment model originally supplied to the current assessment, detailed in the November

2021 report. The main problem with the November 2021 model was that it contained several additional indices and sets of composition data that conflicted with each other and were not providing helpful information to the model. And by including these data sources, the model was required to estimate several more parameters (e.g. selectivity parameters) with poor information, leading to greater model instability. In addition, that model did not include any source of recreational landings data. If the 2018 model configuration was similar to that model, it may not have provided a reliable impression of the population dynamics of the Striped Mullet population. We consider the current model to be a substantial improvement from the November 2021 model, and likely the 2018 model and represents the best scientific information available.

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

The PRP thoroughly reviewed the research recommendations identified by the striped mullet working group, in addition to noting additional research and data collection needs. After review between the PRP and the assessment chair, the research recommendations were refined and prioritized into a final set of research recommendations, that were adapted from the stock assessment report and provided here as high, medium or low priorities. The order and priority of research recommendations address the needs and short-comings of current monitoring efforts as well as data that would make future assessments better.

The following research recommendations are offered to improve future stock assessments of the North Carolina striped mullet stock:

<u>High</u>

- Increasesampling 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.

<u>Medium</u>

- Consider a tagging program to provide estimates of stock size, *F*, and *M*
- Consider genetic and/or tagging studies to examine the extent of 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 NC striped mullet

Low

- Perform an acoustic tagging study to evaluate spatial and temporal variation in habitat use to more effectively design and conduct fishery-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

1.8 Recommend timing of next stock assessment for the species.

Next assessment should be able to stay on the current schedule used for the species (every ~ 5 years)

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Estuarine Striped Bass Fishery Management Plan Amendment 2 Decision Document

May 2022

N.C. Division of Marine Fisheries
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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

In February 2022, the North Carolina Marine Fisheries Commission (MFC) reviewed draft Amendment 2 of the Estuarine Striped Bass Fishery Management Plan (FMP). At that time a motion was passed to send draft Amendment 2 for public and MFC Advisory Committee review after a requested edit to the plan, removing options associated with gill net use above the ferry lines in the Tar-Pamlico and Neuse rivers.

Amendment 2 was jointly developed by the Division of Marine Fisheries (DMF) and Wildlife Resources Commission (WRC) staff and includes four issue papers, three address sustainable harvest in three areas of the state and one addresses hook and line as a commercial gear. The goal of the plan being to achieve self-sustaining populations unless prevented by biological or environmental factors.

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 for disbursement to legislative bodies for review
August 2022	MFC votes on final adoption of FMP
TBD	DMF and MFC implement management strategies

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

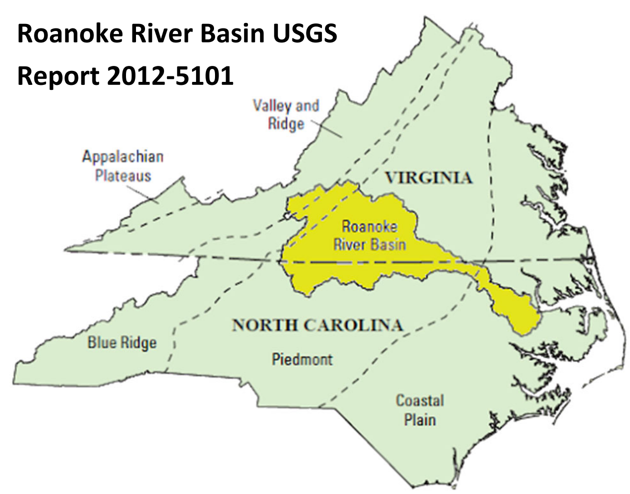
There are two estuarine striped bass management units and four stocks in North Carolina. The Northern management unit includes the Albemarle Sound Management Area (ASMA) and Roanoke River Management Area (RRMA). The striped bass stock in these two harvest management areas is referred to as the Albemarle– 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 6 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.

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 Reform Act and Amendment 6 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 Estuarine 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

Roanoke River Basin USGS Report 2012-5101



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 heavily influenced by 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.

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.

Amendment 2 to the Estuarine Striped Bass FMP

Amendment 2 addresses the management strategies for the A-R stock and the CSMA stocks separately. Appendix 2 focuses on the A-R stock, while Appendix 3 and 4 are focused on the CSMA stocks. Appendix 5 addresses a gear specific issue. Recommendations are indicated in options followed by rationale. **Orange** text with a * indicate DMF recommendations. When WRC recommendations differ, they are indicated in **green** text with ** following.

Appendix 2: Albemarle-Roanoke Sustainable Harvest Issue Paper

The peer reviewed stock assessment indicates the A-R stock is overfished and overfishing is occurring. The state Fisheries Reform Act and the ASMFC FMP require management measures be implemented to address the status of the stock. The November 2020 Revision to Amendment 1 implemented management to end overfishing in one year. This issue paper considers management beyond the revision to achieve sustainable harvest.

Management Options

1. Manage for sustainable harvest through harvest restrictions (page 58)
    A. Status Quo: use of a TAL*
    B. Implement a harvest moratorium

Appendix 2: Albemarle-Roanoke Sustainable Harvest Issue Paper (continued)

Management Options Continued

2. Commercial fishery managed as bycatch fishery (page 60)
   A. Status Quo: bycatch fishery*
   B. End bycatch fishery
3. Accountability measures address TAL overages (example table on p. 7 of this document; FMP page 63) Please note, for all overage options: overages will be deducted from the management area/sectors fishery(ies) TAL, not the TAL plus buffer; if paybacks exceed the next year's TAL, paybacks will be required in subsequent years to meet the full reduction amount; in situations where a TAL has been reduced from a previous year's overage, if the reduced TAL is exceeded, any required paybacks are reduced from the fisheries' original TAL, not from the reduced TAL. .
   A. If landings from all three management area/sectors combined (RRMA recreational, ASMA recreational, and ASMA commercial) exceeds the total TAL by 10% in a single calendar year, then the fishery(ies) contributing to the overage will reduce their TAL by their percent contribution to the overage the next calendar year.
      - Chronic: 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 deduct the annual average overage from their annual TAL for the next five years.
   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 the fishery(ies) contributing to the overage will reduce their TAL by their percent contribution to the overage the next calendar year.
   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 the TAL will be deducted from that fisheries' 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 the TAL will be deducted from that fisheries' allocated TAL the next calendar year. *

   WRC does not support any accountability measures as written. WRC supports the following: 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.**
4. Size limits to expand age structure (page 64)
   A. Status Quo: 18-inch ASMA and 18 – 22-inch harvest slot with 1 fish greater than 27-inch in RRMA
   B. Increase minimum size
   C. In ASMA, implement 18-25-inch harvest slot*
   D. In RRMA, maintain 18-22-inch harvest slot and one fish greater than 40 inches
   E. In RRMA, maintain 18-22-inch harvest slot and no fish greater*

Appendix 2: Albemarle-Roanoke Sustainable Harvest Issue Paper (continued)

5. Gear modifications and area closures to reduce discard mortality (page 68)
    - A. Status Quo: Commercial harvest of striped bass with gill nets and recreational harvest and catch-and-release fishing in the ASMA and RRMA including on the spawning grounds*
    - B. Do not allow harvest of striped bass with gill nets
    - C. Do not allow harvest or catch-and-release fishing for striped bass on the spawning grounds
    - D. Expand the single barbless hook requirement to the entire RRMA during striped bass season
    - E. Require non-offset, barbless circle hooks when fishing live or natural bait in inland waters of the RRMA May 1 through June 30*
6. Adaptive Management* (page 72)
    - Update stock assessment at least once between benchmarks to review Biological Reference Points and TAL
    - If F exceeds the F_{Target}, reduce the TAL
    - Ability to change daily possession limits, open and close seasons, and require gear modifications to keep below the TAL
    - A future harvest moratorium is an option based on stock assessment results

Rationale - Albemarle-Roanoke Sustainable Harvest

- Managing fisheries removals by setting TAL to a sustainable level has proven to be an effective tool in the striped bass fishery, therefore the Division recommends the status quo use of a TAL.
- The DMF recommends pound for pound overage pay backs due to the stock status. Because the A-R stock is overfished the Division believes a more conservative approach of maintaining landings at the TAL , without a buffer, is warranted.
- Implementing a slot limit in the ASMA would increase protections for the spawning stock.
- Expanding the single barbless hook requirement to the entire RRMA would negatively impact fishers targeting many sport fish species, instead continued angler education on best fishing practices is recommended.
- Adaptive management allows managers to quickly address overfishing while allowing for and monitoring fishing.

Appendix 3: Tar-Pamlico and Neuse Rivers Sustainable Harvest

This issue paper considers management measures in the Tar-Pamlico and Neuse rivers to promote self-sustaining populations. A no-possession measure was implemented in 2019 to protect important year classes in order to increase the age structure and abundance of Tar-Pamlico and Neuse river striped bass. Options 2 and 3 are dependent on continuing the no-possession measure for CSMA striped bass.

Management Options

1. Striped bass harvest (page 88)
    A. Continue no-possession measure*
    B. End no-possession measure if 2025 data review indicates self-sustaining populations
2. Gear restrictions or limits (page 90)
3. Adaptive management* (page 94)
    - In 2025, review data through 2024 to evaluate management*

Rationale - Tar-Pamlico and Neuse Rivers Sustainable Harvest

- Maintaining no-possession will continue to protect important age classes which is expected to lead to increases in the age structure and abundance moving towards sustainable stocks.
- Adaptive management allows management to be adjusted to respond to data between full FMP reviews.

MFC Action

At its February 2022 business meeting, the MFC passed a motion to remove options 2.B. and 2.C. from draft Appendix 3. These options, if selected, provided access above the ferry lines to commercial gill net operations during shad season. Gear, season, and area limitations were included in those options as well as observer monitoring. These options were removed from the draft plan prior to public and advisory committees review, thus the DMF has not provided a recommendation for these options. The WRC recommendation did include a recommendation for 2.C.

Appendix 4: Cape Fear River Sustainable Harvest

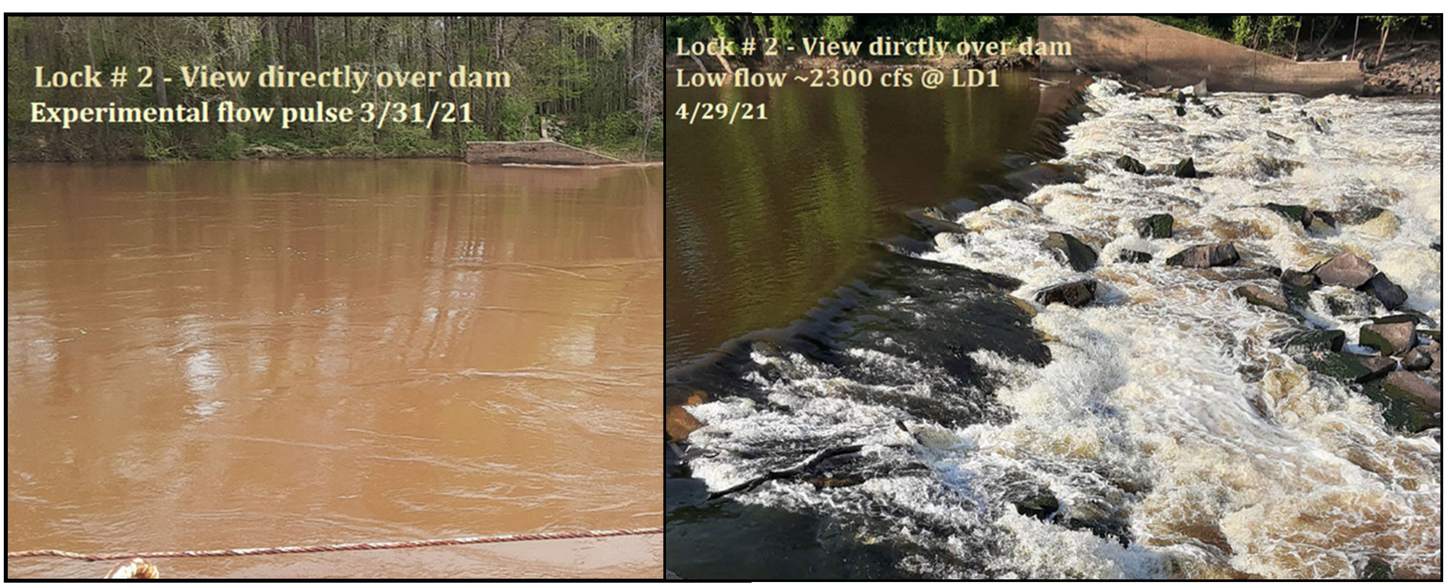
This issue paper considers management measures in the Cape Fear River to promote sustainable harvest. A no-possession measure was implemented in 2008 to increase the age structure and abundance of Cape Fear River striped bass.

Management Options

1. Striped Bass Harvest
    - A. Maintain no possession provision* (page 109)
    - B. Allow seasonal harvest in the Cape Fear** (page 110)
    - C. Allow seasonal harvest in Joint and Inland Fishing Waters above the 140 Bridge (page 111)
    - D. Allow harvest in Inland Fishing Waters on the mainstem of the Cape Fear River (page 112)
2. Adaptive management* (page 113)
    - Continue YOY surveys and genetic PBT analysis (page 113)
    - Management measures which may be adjusted include means and methods, harvest area, season, size, and creel limit.
    - Must be evaluated by staff with the MFC Finfish AC consultation.

Rationale - Cape Fear River Sustainable Harvest

- The DMF recommends maintaining no-possession to evaluate passage at the newly renovated Lock and Dam 1 and further assess indications of wild spawning occurring in the system (See figure below). Allowing harvest during spawning season may impact fish making successful passage to spawn.
- The WRC recommends allowing harvest in the Cape Fear to provide opportunities for harvest of a hatchery-supported stock. Despite 13-years of no-harvest, the population remains stocked fish with limited spawning and access to spawning grounds is unlikely before the next plan review. Options 3 and 4 provide access should conditions improve. Adaptive management may be used to limit area and season.
- Adaptive management allows management to be adjusted to respond to data between full FMP reviews. It should be noted that WRC has limited proclamation authority and temporary rules require 30-days to be implemented.



Appendix 5: Hook and Line as a Commercial Gear

Amendment 1 management did not approve use of hook-and-line at that time. However, a rule change was made to allow this as an adaptive management tool. This issue paper further considers the appropriate time for approval of hook-and-line as a commercial gear.

Management Options

1. Hook and Line as a Commercial Gear (page 117)
    - A. Do not allow hook and line as a commercial gear for estuarine striped bass*
    - B. Allow hook and line as a commercial gear for estuarine striped bass
2. Adaptive management* (page 122)
    - If TAL will be quickly exceeded or unable to be harvested, management will be reevaluated.
    - If enforcement activity or License and Statistics data suggests significant unreported catch, additional tagging or reporting requirements may be implemented.
    - Management measures that may be adjusted include means and methods, harvest area, season, size, and limit.
    - Must be evaluated by staff and MFC

Rationale - Hook and Line as a Commercial Gear

- Due to the stock status and limited TAL, status quo is the appropriate management. Implementing a hook and line fishery could lead to changes in fishing effort. Because of the current stock status, it is unclear how this change might impact recovery. Therefore, the DMF recommends continuing management with the bycatch provision in the commercial fishery.
- Adaptive management allows management flexibility to respond to data between full FMP reviews. If there are changes within the fishery or stock which indicate management changes are appropriate, DMF and the MFC may evaluate at that 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

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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

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EXECUTIVE SUMMARY

This section to be completed after final adoption of the plan.

INTRODUCTION

This is Amendment 2 to the North Carolina Estuarine Striped Bass Fishery Management Plan (FMP). By law, each FMP must be reviewed at least once every five years (G.S. 113-182.1). The NC Division of Marine Fisheries (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 North Carolina striped bass (*Morone saxatilis*) stocks are managed within four distinct areas: (1) Albemarle Sound Management Area (ASMA), (2) Roanoke River Management Area, (3) Central Southern Management Area (CSMA), and (4) Atlantic Ocean. The MFC adopts rules and policies and implements management measures for the estuarine striped bass fishery in Coastal Fishing Waters in accordance with 113-182.1. The Estuarine Striped Bass FMP is jointly developed by the DMF and the North Carolina Wildlife Resources Commission (WRC). The migratory Atlantic Ocean stock is managed by the Atlantic States Marine Fisheries Commission (ASMFC). The ASMA and RRMA are also subject to compliance requirements of the ASMFC Interstate FMP for Atlantic Striped Bass. Until Amendment 2 is approved for management, estuarine striped bass are managed under Amendment 1, the November 2014 and November 2020 Revisions to Amendment 1, and the February 2019 Supplement A (NCDMF 2013, 2014, 2019, 2020).

FISHERY MANAGEMENT PLAN HISTORY

Original FMP Adoption:	January 1994 May 2004
Amendments:	Amendment 1 – May 2013
Revisions:	November 2014 November 2020
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 estuarine management units in North Carolina (Figure 1). The northern management unit is comprised of two harvest management areas: the Roanoke River Management Area (RRMA) and the Albemarle Sound Management Area (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 North Carolina Fishery Management Plan for Interjurisdictional Fisheries.

The southern geographic management unit is the Central Southern Management Area (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 North Carolina through the MFC and the WRC.

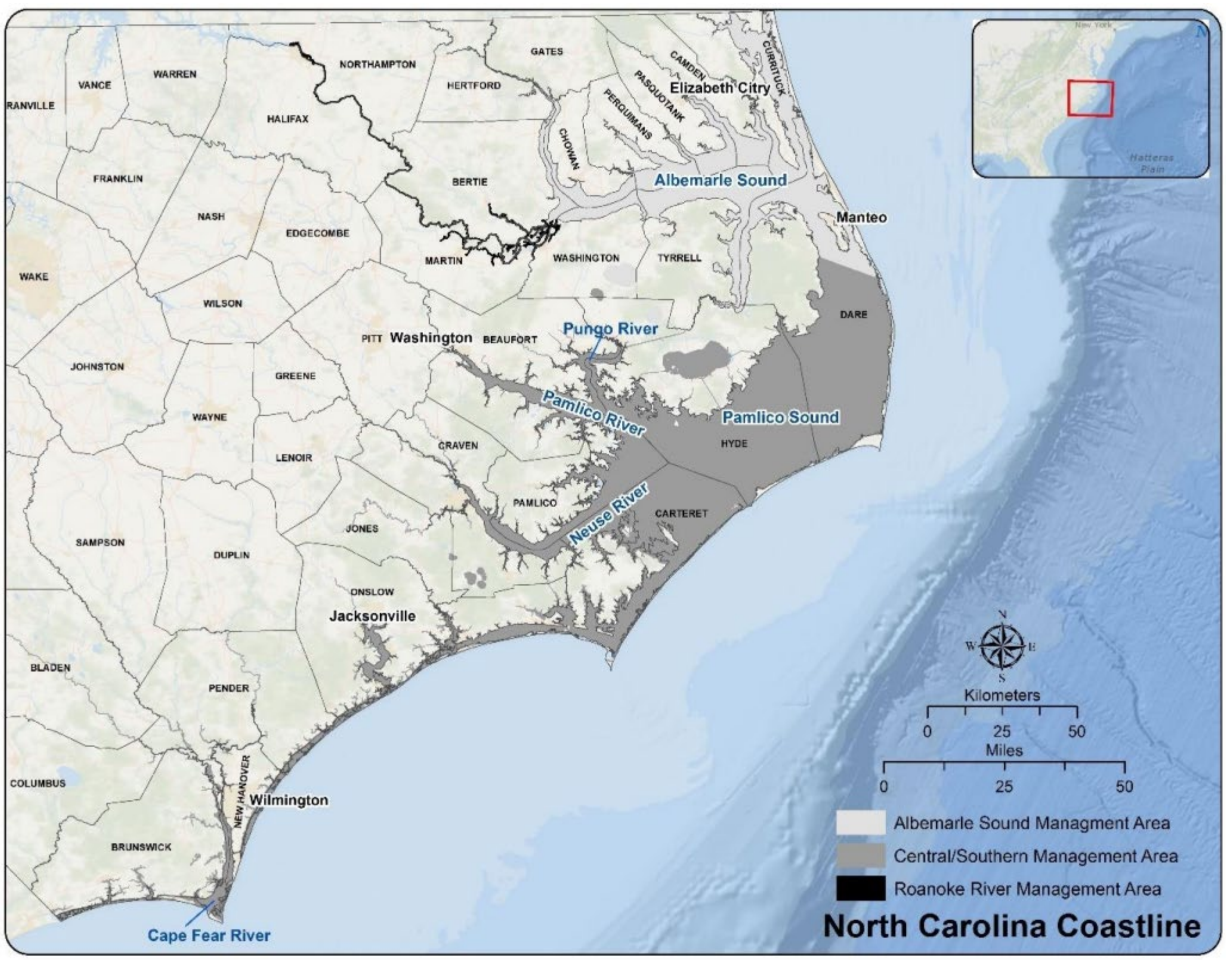

Figure 1. Boundary lines defining the Albemarle Sound Management Area, Central/Southern Management Area, and the Roanoke River Management Area.

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 North Carolina, the species is also known as striper, rockfish, or rock. Stocks from Maine to the A-R in North Carolina are migratory, spending most of their adult life in the estuaries and ocean before moving into fresh water to spawn in the spring. The A-R stock large 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 North Carolina, 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 large distances to spawning grounds located in freshwater portions of coastal rivers. Spawning grounds for the A-R stock are concentrated at the fall line, 130 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 (ability to produce offspring) 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 North Carolina 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 North Carolina: 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 from 1991 through 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 estimating 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.

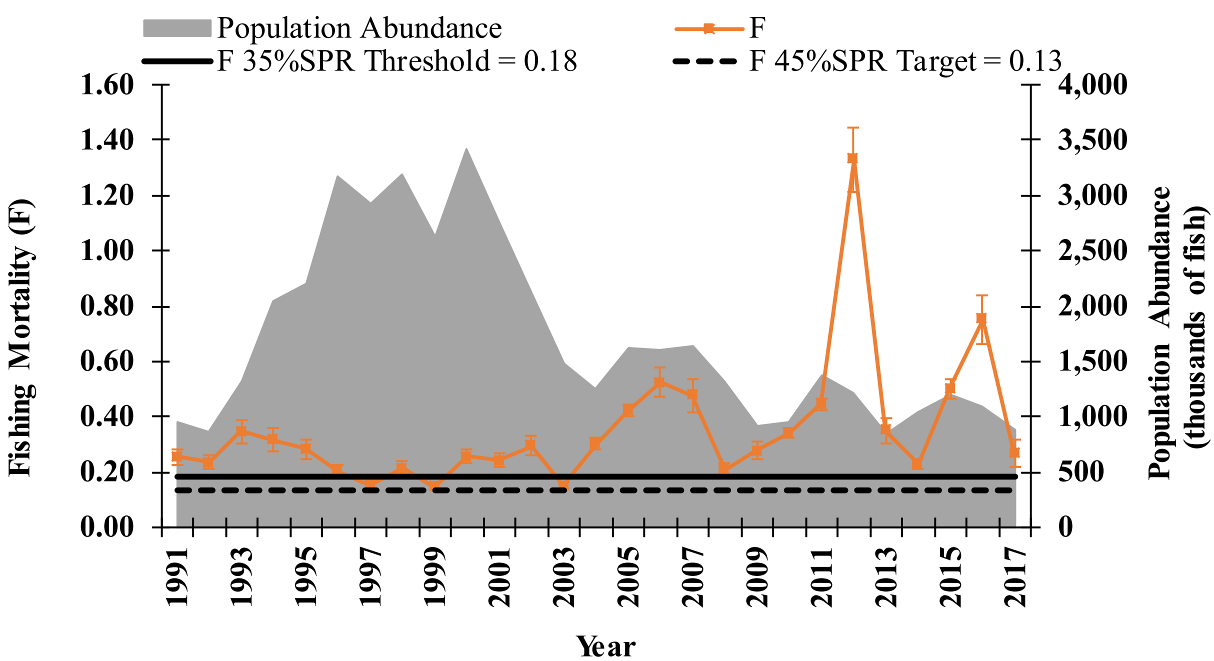

Figure 2. Estimates of fishing mortality (*F*) and population abundance for the Albemarle-Roanoke striped bass stock, 1991–2017. Error bars represent ± two standard errors. Source: Lee et al. 2020.

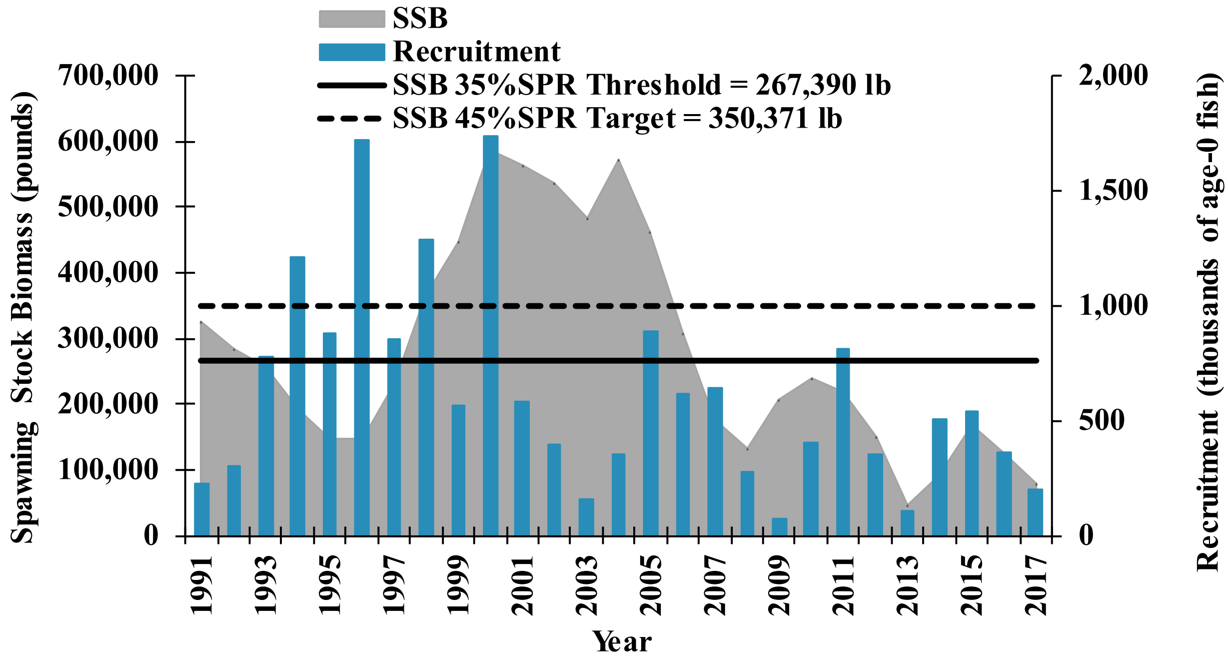

Figure 3. Estimates of spawning stock biomass (SSB) and recruitment of age-0 fish coming into the population each year for the Albemarle-Roanoke striped bass stock, 1991–2017. Source: Lee et al. 2020

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 North Carolina'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

All commercial harvest on the A-R stock occurs in the ASMA. Under Amendment 1, the ASMA commercial striped bass fishery is a bycatch fishery, meaning 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 gill 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 annual total allowable landings (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. From 1990 through 1997 the 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 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 (Figure 4).

The decline in landings during 2005–2009 was due to poor year classes produced from 2001 to 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 (NCDMF 2020).

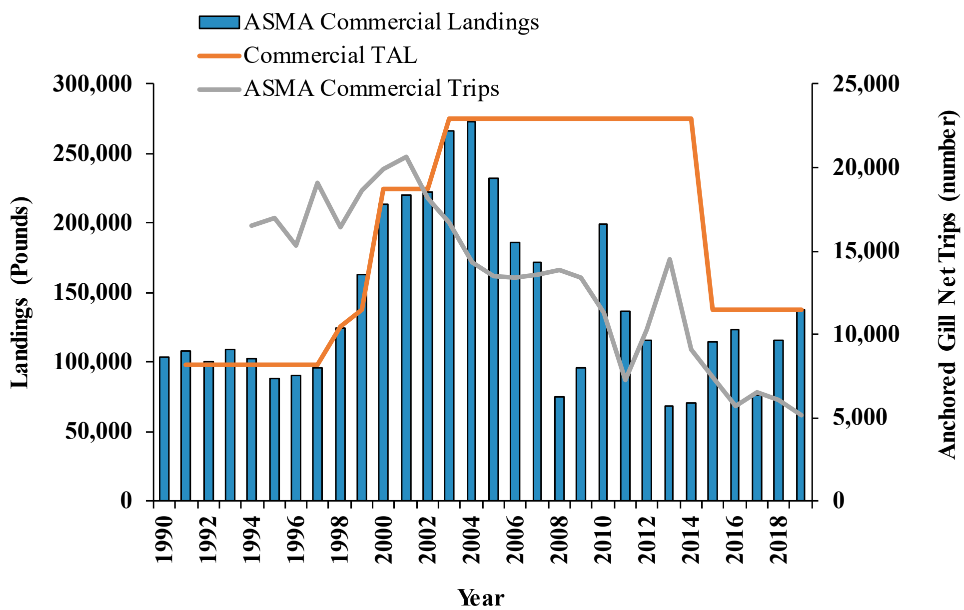

Figure 4. Commercial striped bass landings and the number of all anchored gill net trips in the Albemarle Sound Management Area (ASMA) 1991–2019.

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.

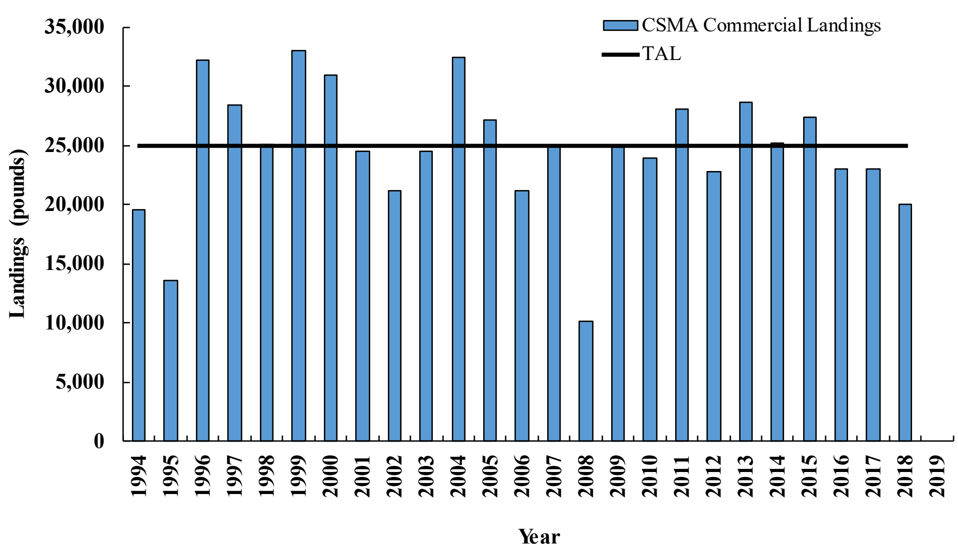

Figure 5. Annual commercial CSMA striped bass harvest and TAL in pounds, 1994–2019. Since 2019 the commercial season has been closed.

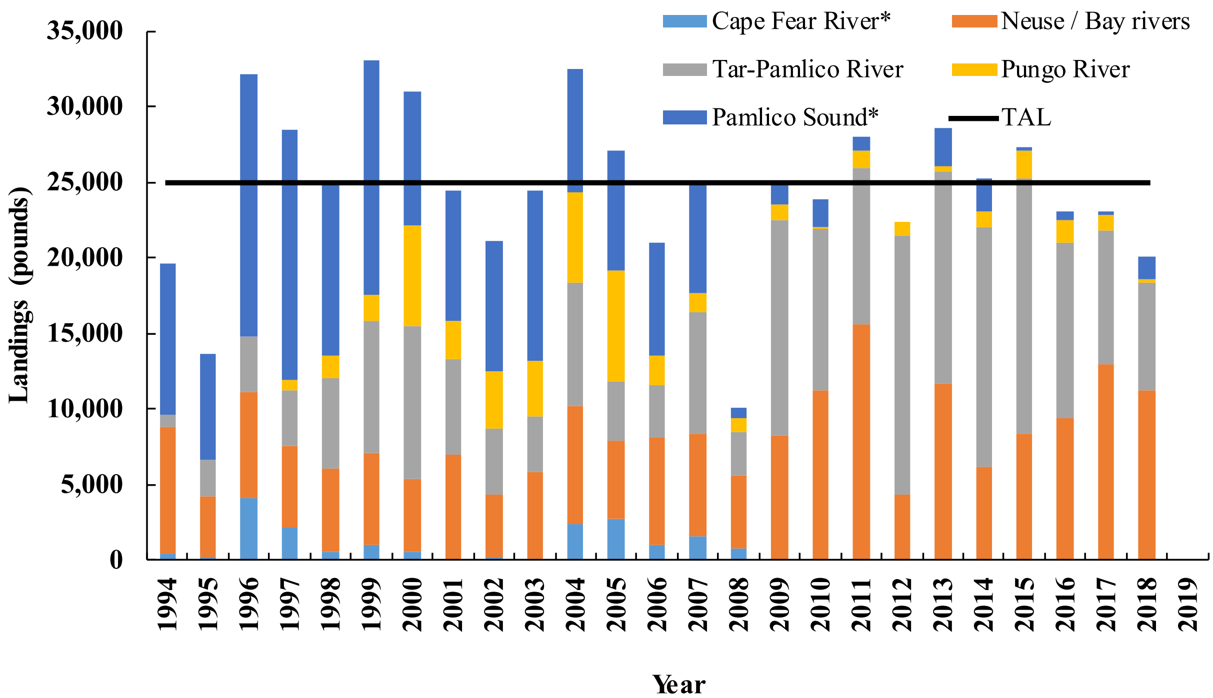

Figure 6. Commercial striped bass harvest by system, and the TAL in the CSMA, 2004–2019. There has been a harvest moratorium in the Cape Fear River since 2008, and a closed season in the CSMA since 2019. *Landings data for the Cape Fear River in 2001 and the Pamlico Sound in 2012 are confidential.

RECREATIONAL FISHERIES

ASMA

In the initial 1994 FMP the MFC and WRC approved management to split the TAL evenly between the commercial and recreational sector fisheries when the stock recovered (Citation). 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 age-3 to age-5 fish.

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 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).

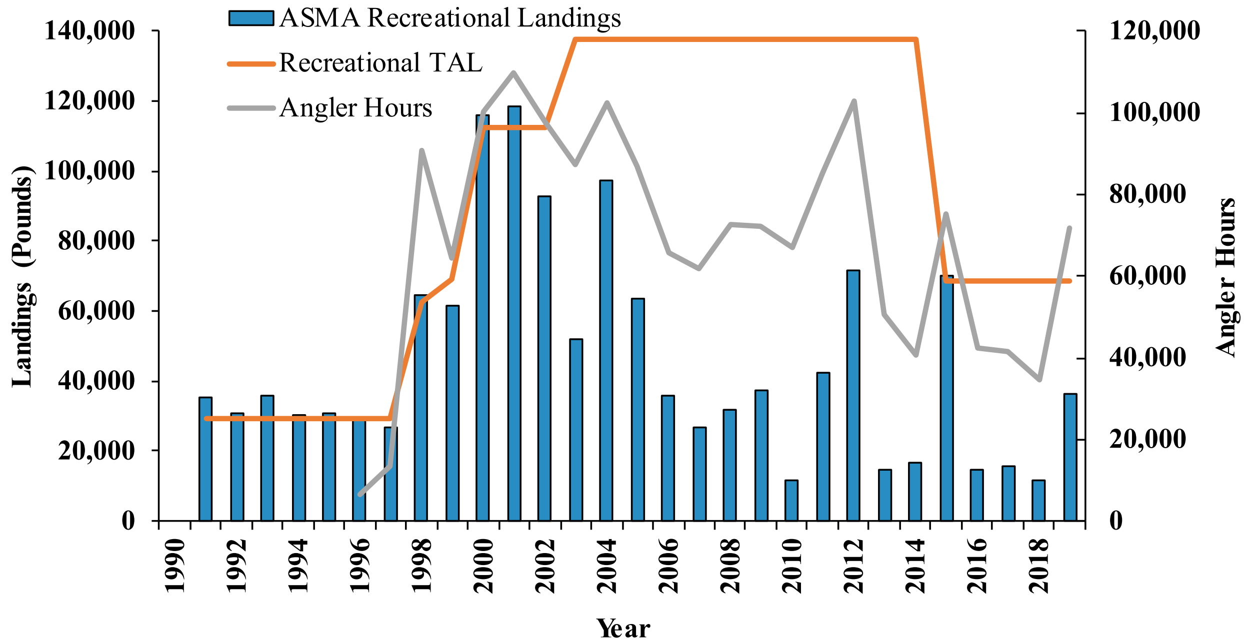

Figure 7. Recreational striped bass landings and the hours of striped bass fishing effort in the Albemarle Sound Management Area (ASMA) 1991–2019.

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	Number of fish caught per trip
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	0.67
2006	10,707	65,757	10,711	35,985	2,490	6,339	626	9,455	0.44
2007	9,629	61,679	7,143	26,633	1,148	12,259	192	13,599	0.81
2008	11,793	72,673	10,048	31,628	391	36,324	260	36,975	1.69
2009	11,326	72,021	12,069	37,313	20	38,683	1,860	40,563	1.73
2010	9,660	66,893	3,504	11,470	569	15,398	233	16,200	1.23
2011	13,114	85,325	13,341	42,536	317	20,114	1,141	21,572	0.82
2012	14,490	102,787	22,345	71,456	1,024	19,977	3,970	24,971	0.68
2013	7,053	50,643	4,299	14,897	31	16,034	316	16,381	1.44
2014	7,264	40,478	5,529	16,867	18	22,558	510	23,086	1.80
2015	11,132	75,009	23,240	70,008	1,573	45,559	2,402	49,534	1.44
2016	7,023	42,276	4,794	14,486	252	8,822	1,278	10,352	0.88
2017	7,658	41,371	4,215	15,480	56	24,004	600	24,660	2.08
2018	9,057	34,764	3,465	11,762	281	21,337	3,970	25,588	2.04
2019	18,833	71,800	10,723	36,351	52	32,020	2,896	34,968	1.18

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**	**Weight (lb)**	**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

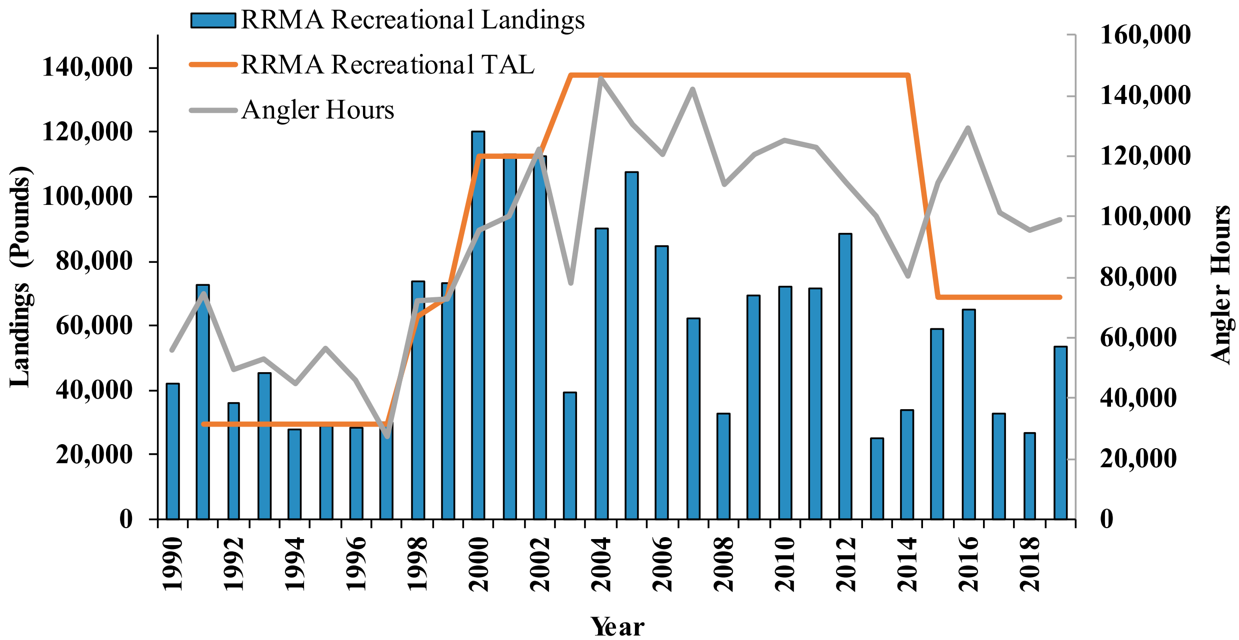

Figure 8. Recreational striped bass landings and the hours of striped bass fishing effort in the Roanoke River Management Area (RRMA) 1991–2019.

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

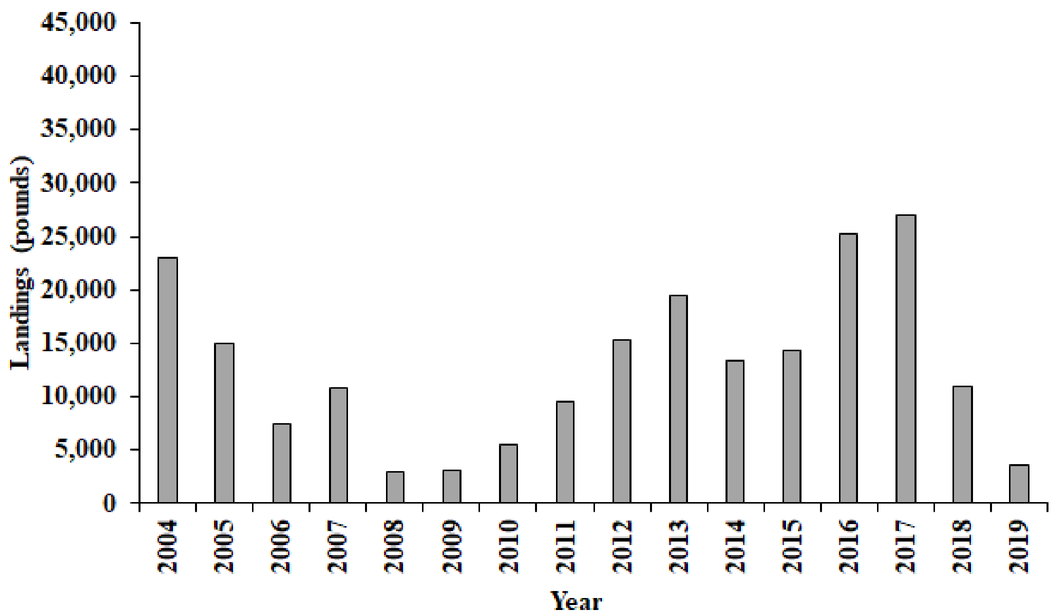

Figure 9. Annual recreational CSMA striped bass landings in pounds, 2004–2019. The 2019 season was January 1–March 19, 2019.

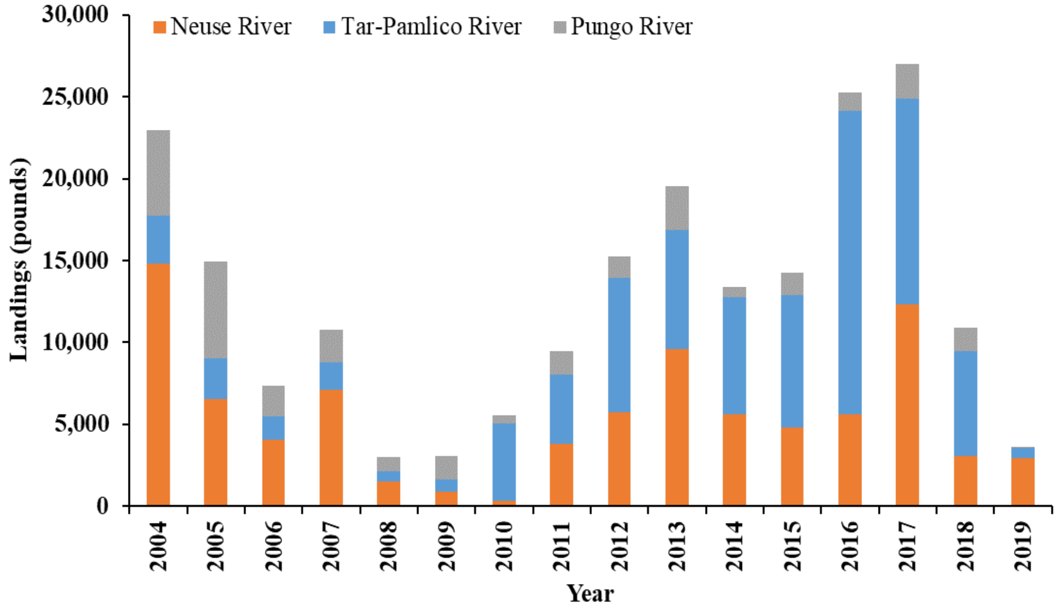

Figure 10. Recreational striped bass harvest in the Tar-Pamlico, Pungo, and Neuse rivers, 2004–2019. The 2019 season was January 1–March 19, 2019.

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.

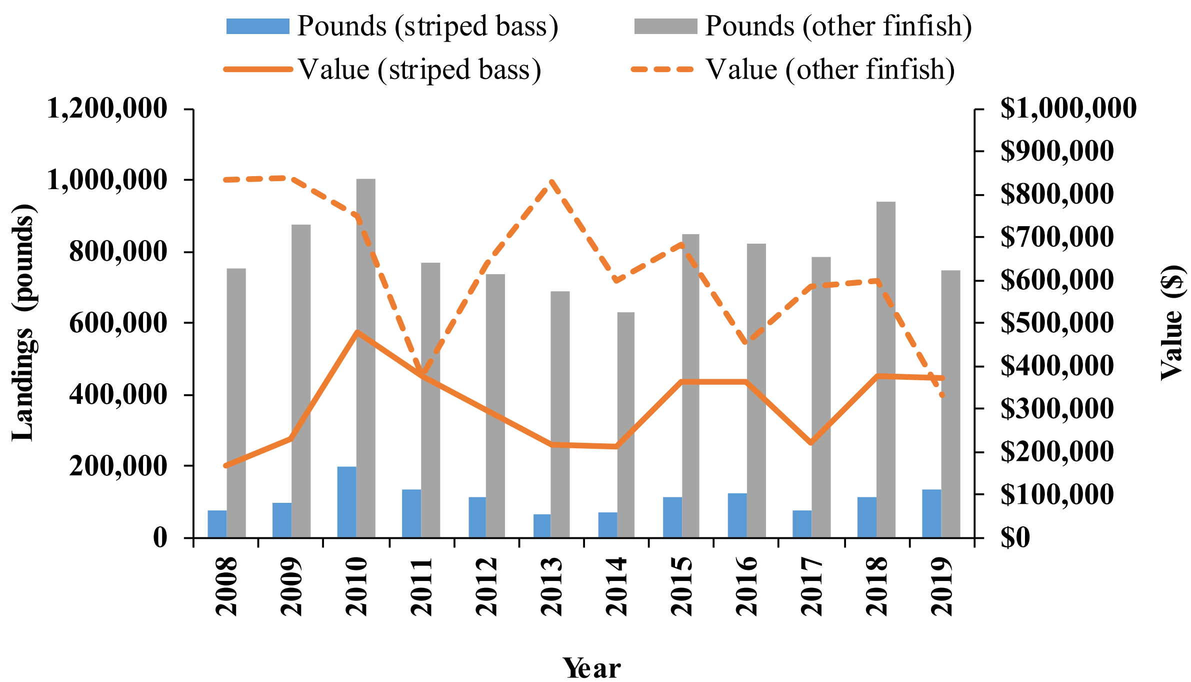

Figure 11. Annual commercial striped bass effort and ex-vessel value data for the ASMA, 2008–2019.

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

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 unique structure, in which striped bass cannot be harvested unless it is in tandem 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.

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).

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

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

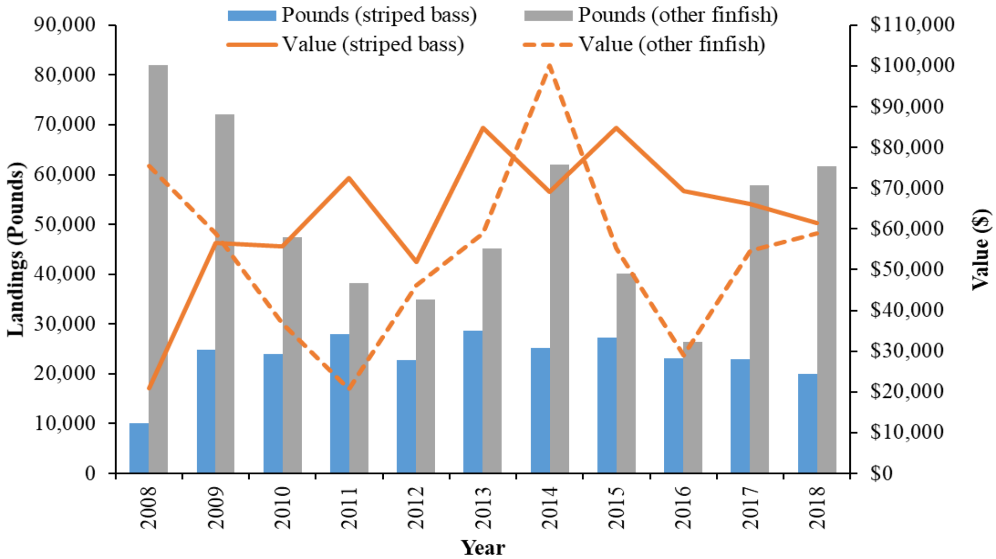

Figure 12. Annual Striped Bass effort and ex-vessel value data for the CSMA, 2008–2019.

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	18,833	71,800	$1,528,169	$532,055	$873,914	12.63	$3,475,633
Average	10,700	63,003	$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. A number of 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.

Across management areas, each operates under different recreational harvest limits, including both season length and size restrictions. For example, while the ASMA is open for harvest from October to April with an 18-inch minimum TL size limit, the RRMA only allows harvest from March to April, and includes an 18-inch minimum TL size limit and a 22–27-inch TL 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 North Carolina 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, North Carolina Environmental Management Commission (EMC), and North Carolina Coastal Resources Commission (CRC) for the protection and enhancement of fishery habitats of North Carolina. 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 North Carolina, 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 is undergoing a mandated five-year review, with adoption planned in 2021. The review 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 North Carolina. 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 North

Carolina. 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 Sounds 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 postulated 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). 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 North Carolina can be found in the APNEP Aquatic Nuisance Species Management Plan.

Manmade barriers also act as impediments to spawning for striped bass stocks in North Carolina. 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 suspended 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, Gaston Dam and Roanoke Rapids Dam, owned and operated by Dominion Energy, 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 multiple years of environmental studies and collaboration with numerous resource agencies and other 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 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.

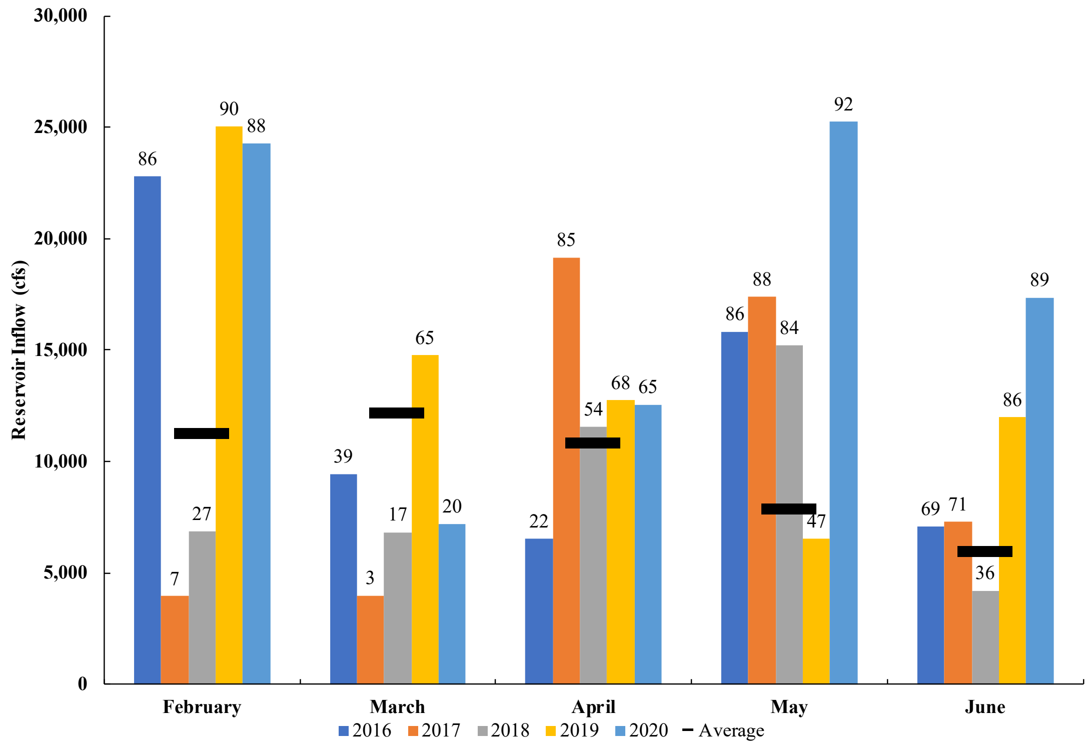

Figure 13. Monthly inflow data for John H. Kerr Reservoir on the Roanoke River during February – June of 2016–2020. Data were provided by USACE staff. Numbers of the columns provide the rank for 91–92 years of data. A rank of 1 is driest and rank of 92 is wettest.

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 North Carolina 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 (in no particular order) 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 more comprehensive list of research recommendations is provided in the FMP Update and Research Priorities documents (reviewed annually) and can be found at 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

This section to be completed when the MFC selects their preferred management strategies that are taken out to review by the DEQ secretary and appropriate legislative committees.

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 U.S. Fish and Wildlife Service (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%

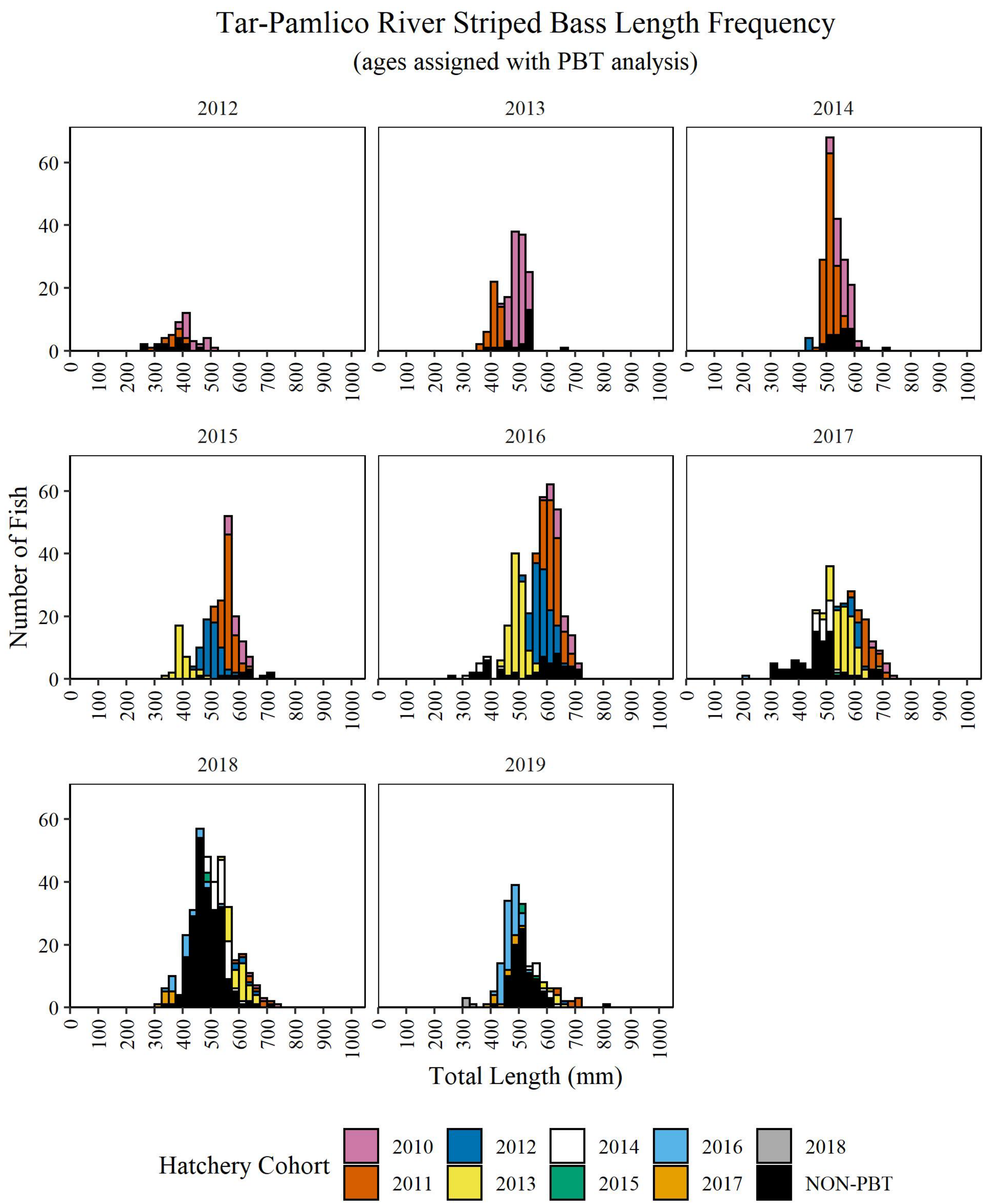

Figure 1.1. Length-frequency histograms for at-large striped bass collected in the Tar-Pamlico River by WRC and DMF, 2012–2019. Hatchery cohorts identified by parentage-based tagging analysis (PBT) are plotted within each 25-mm length group. Fish identified as non-PBT were not assigned to a hatchery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

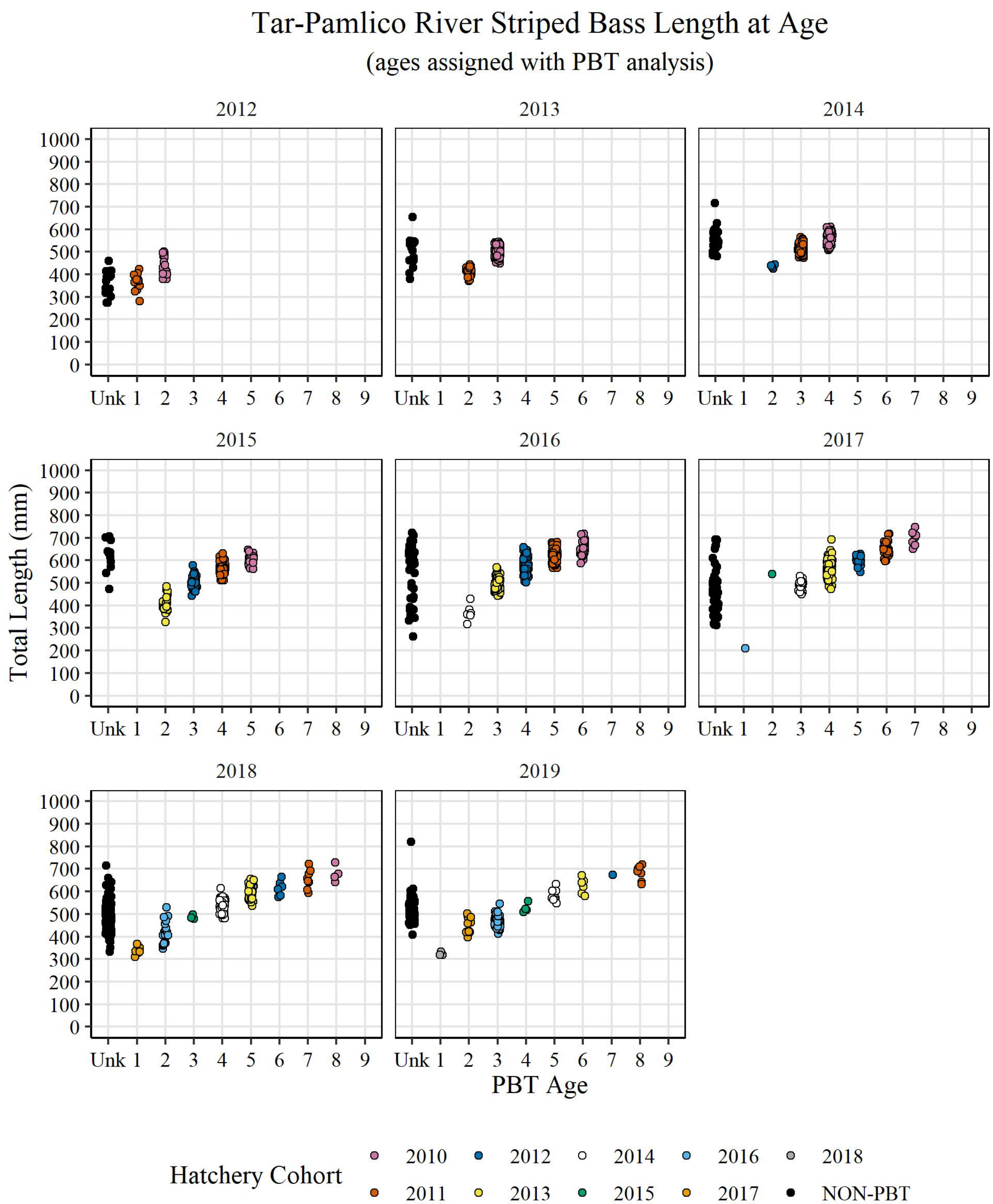

Figure 1.2. Length at age for at-large Tar-Pamlico River striped bass collected by WRC and DMF, 2012–2019. Ages were identified using parentage-based tagging (PBT) analysis. Those fish with an unknown age (Unk) each year were not identified as hatchery cohorts by PBT analysis and could not be assigned 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%

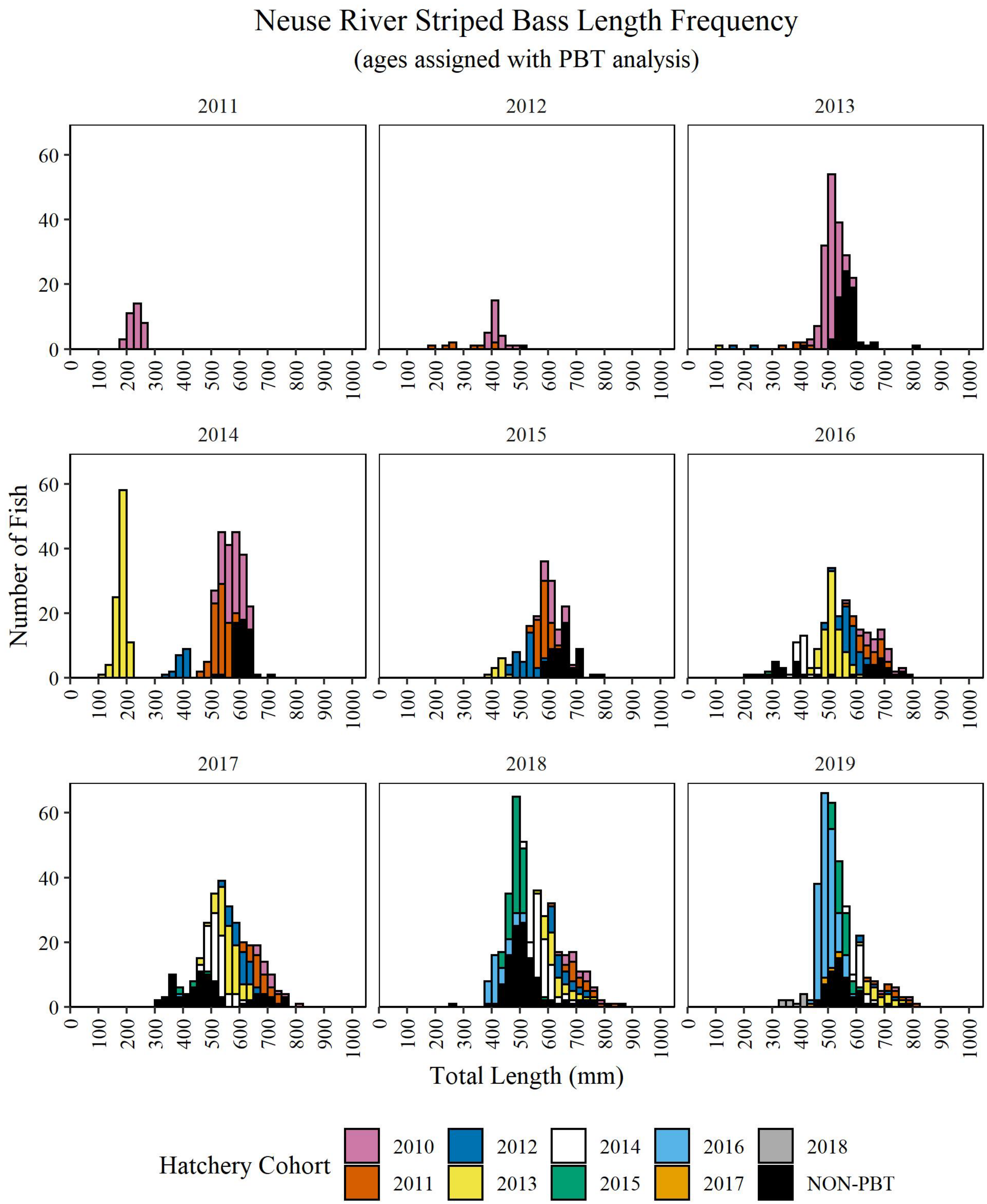

Figure 1.3. Length-frequency histograms for at-large striped bass collected in the Neuse River basin by WRC and DMF, 2011–2019. Hatchery cohorts identified by parentage-based tagging analysis (PBT) are plotted within each 25-mm length group. Fish identified as non-PBT were not assigned to a hatchery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

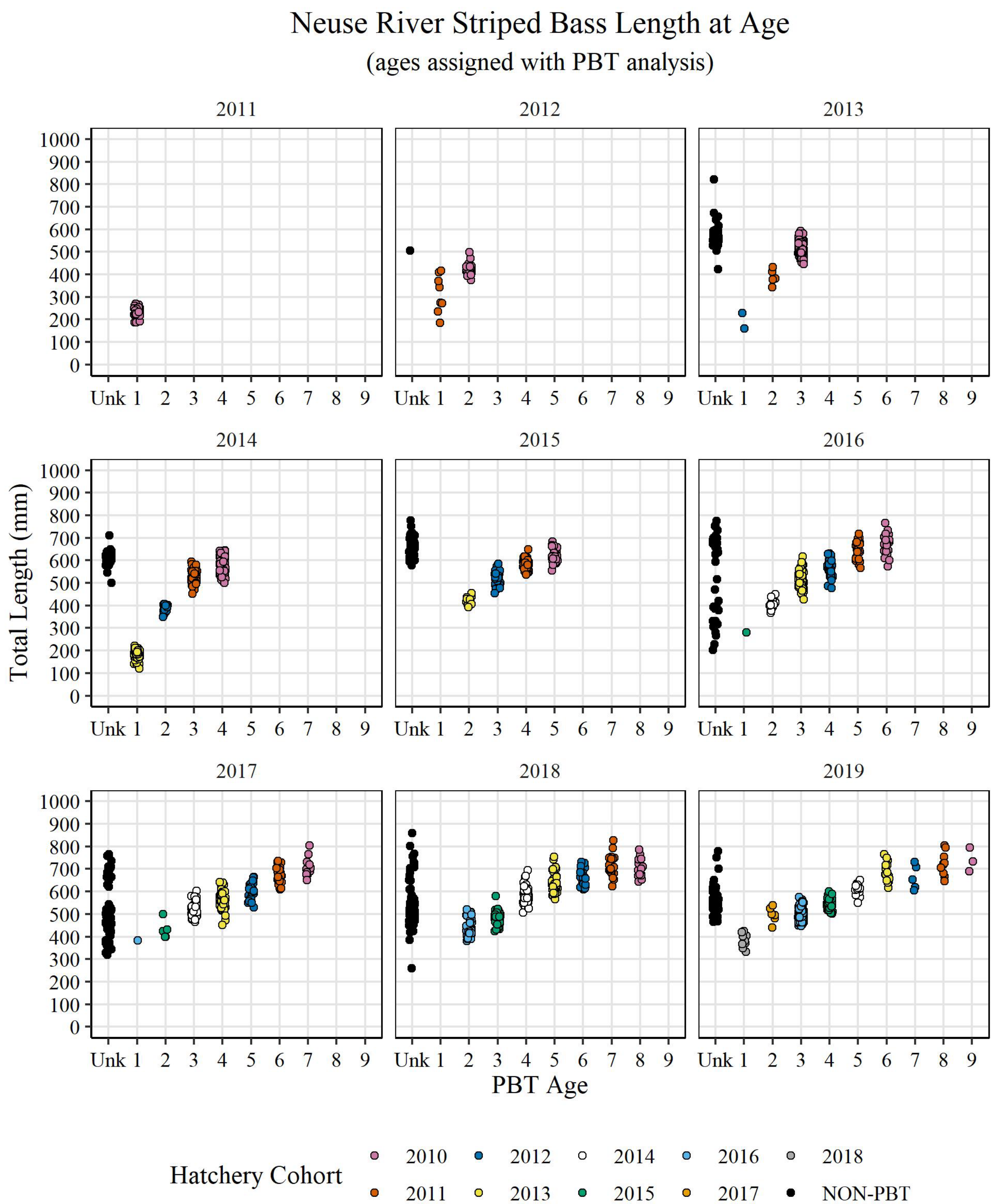

Figure 1.4. Length at age for at-large Neuse River striped bass collected by WRC and DMF, 2011–2019. Ages were identified using parentage-based tagging (PBT) analysis. Those fish with an unknown age (Unk) each year were not identified as hatchery cohorts by PBT analysis and could not be assigned an age. 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.

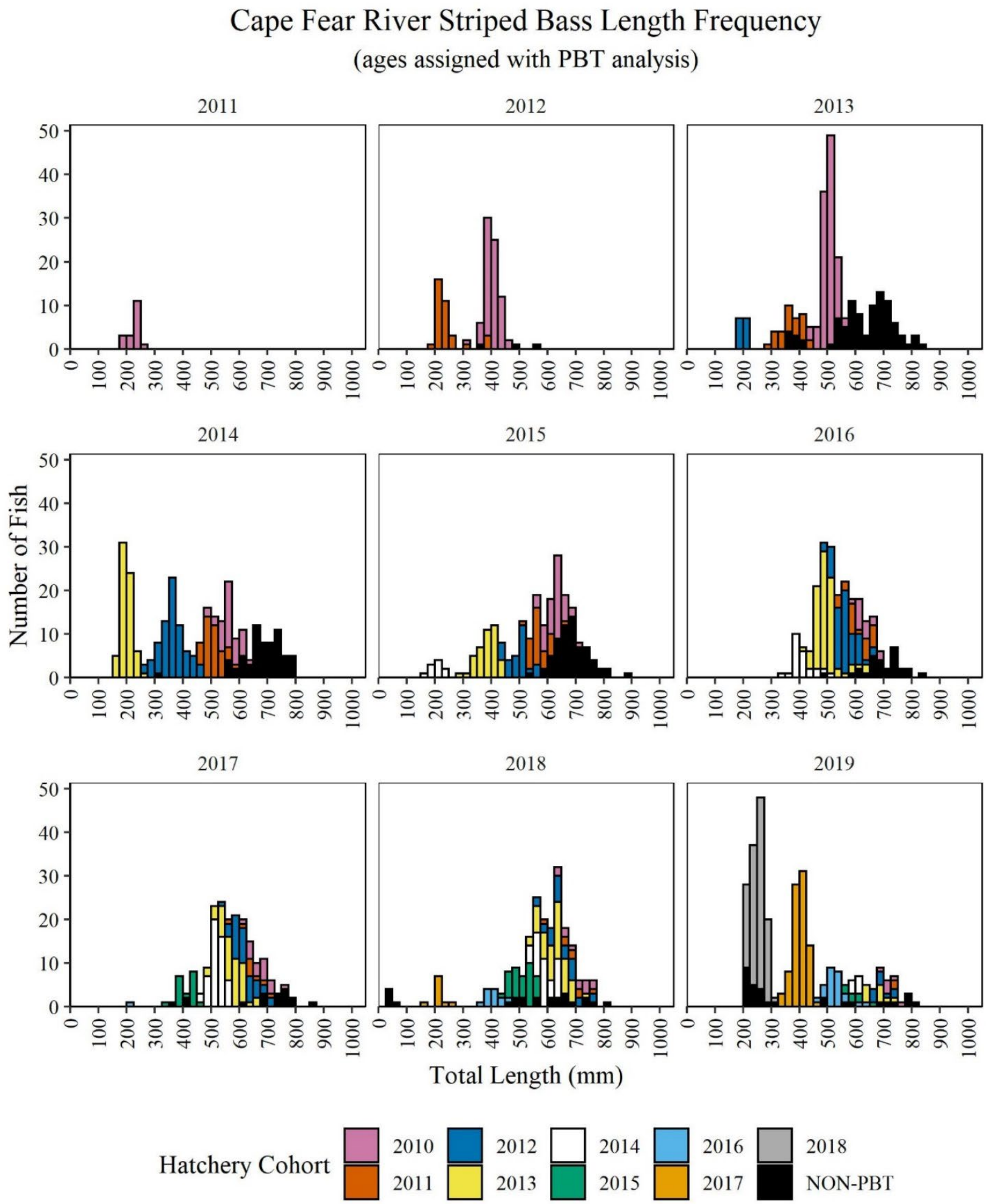

Figure 1.5. Length-frequency histograms for at-large striped bass collected in the Cape Fear River basin by WRC and DMF, 2011–2019. Hatchery cohorts identified by parentage-based tagging analysis (PBT) are plotted within each 25-mm length group. Fish identified as non-PBT were not assigned to a hatchery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

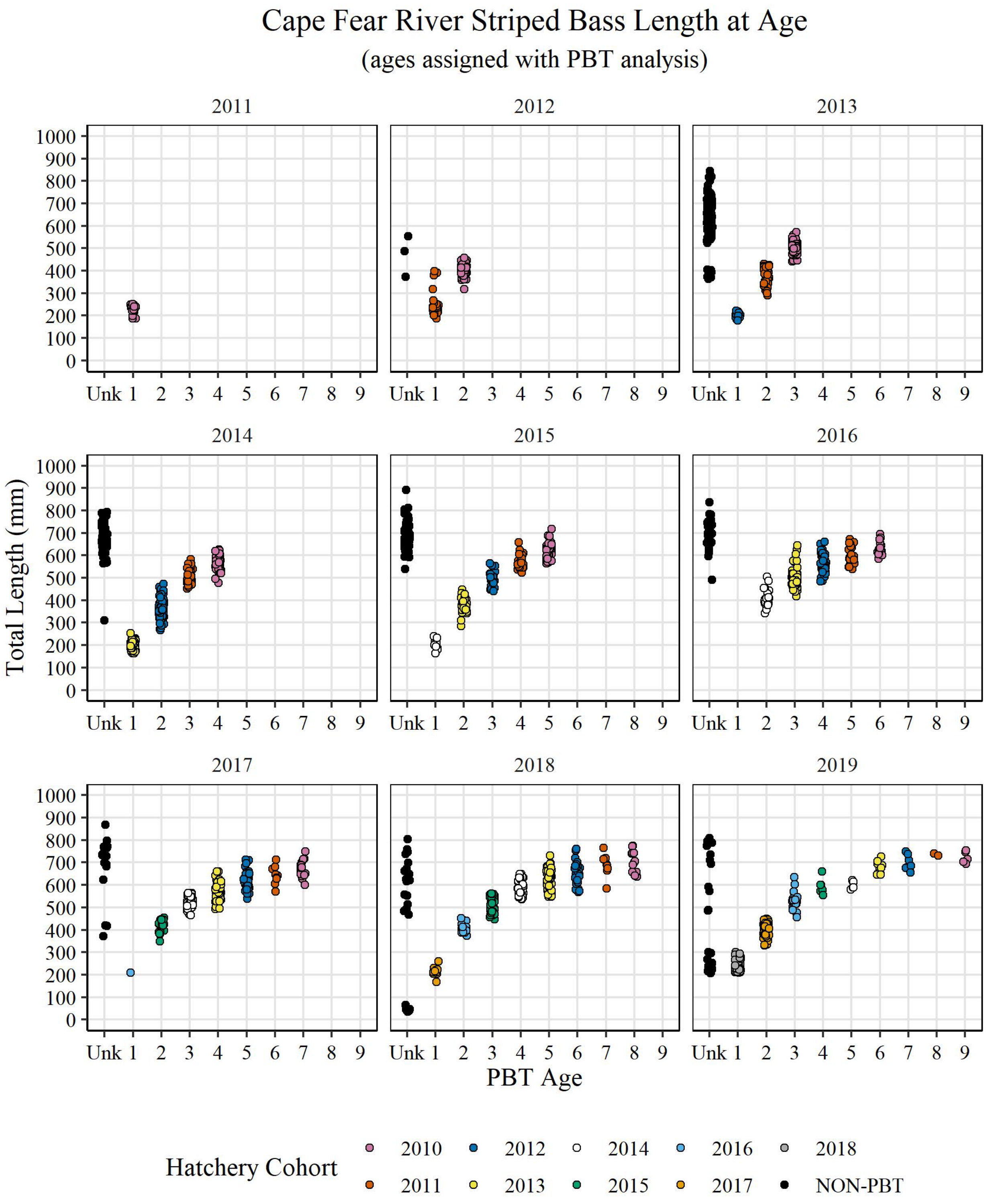

Figure 1.6. Length at age for at-large Cape Fear River striped bass collected by WRC and DMF, 2011–2019. Ages were identified using parentage-based tagging (PBT) analysis. Those fish with an unknown age (Unk) each year were not identified as hatchery cohorts by PBT analysis and could not be assigned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

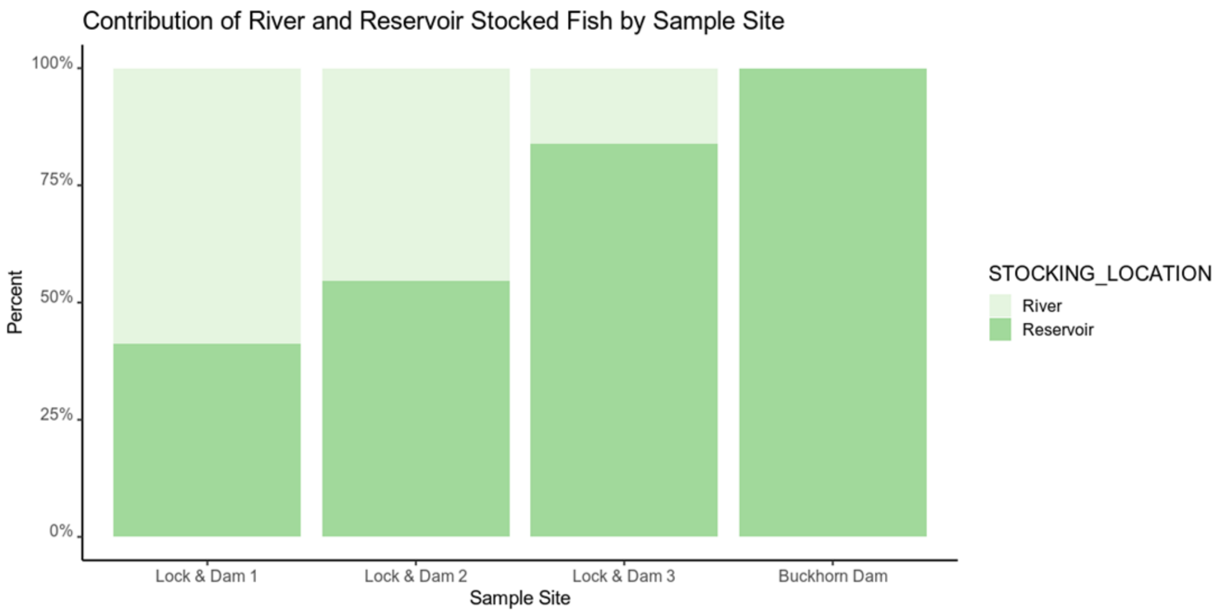

Figure 1.7. Relative contribution of hatchery-origin striped bass by stocking location to each WRC electrofishing sample site in the Cape Fear River, 2015–2019.

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 intrastate agreement between the North Carolina Wildlife Resources Commission 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: ______
S. Thomas Rhodes, Secretary
North Carolina Department of Natural Resources and Community Development

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

Date 12/12/86 By: ______
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 $F_{\text{Threshold}}$ = 0.18 and overfished BRPs are based on a level of spawning stock biomass (SSB) of SSB_{Target} = 350,371 pounds and $SSB_{\text{Threshold}}$ = 267,390 pounds (Lee et al. 2020). In the terminal year of the assessment *F*=0.27, above the $F_{\text{Threshold}}$, meaning overfishing is occurring. Female SSB was 78,576 pounds, below the $SSB_{\text{Threshold}}$, 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

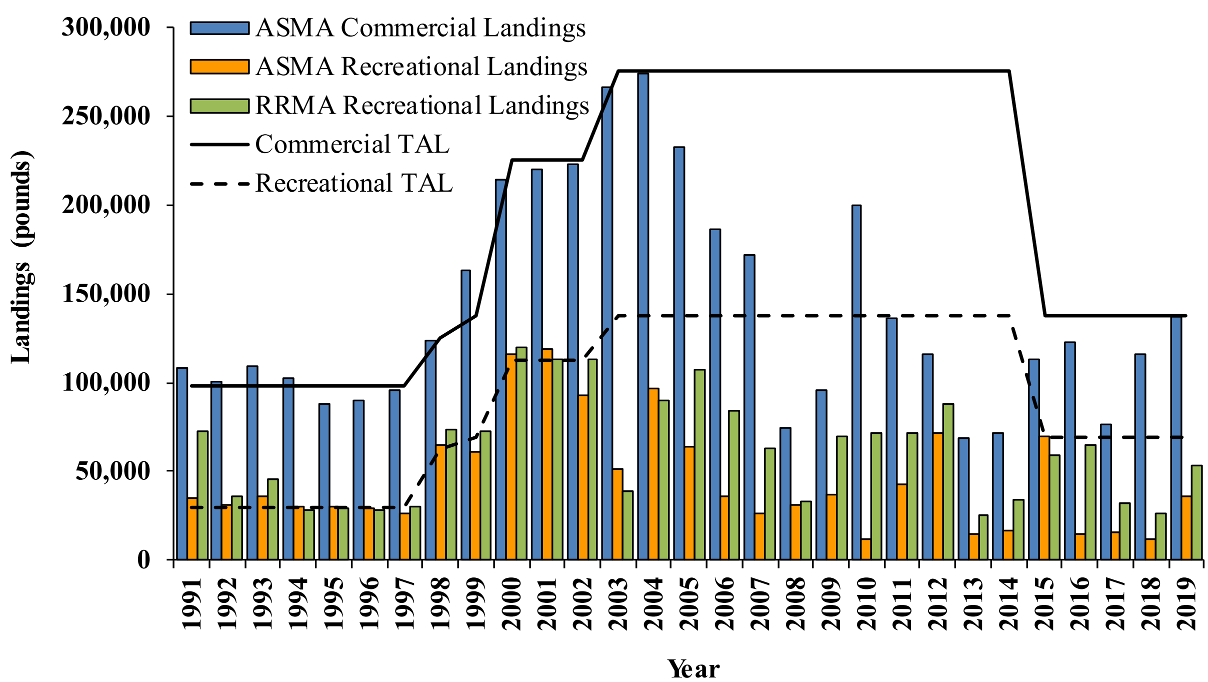

Figure 2.1. Striped bass landings from the Albemarle Sound Management Area (ASMA) commercial and recreational sectors, the Roanoke River Management Area (RRMA) recreational sector, and the annual total allowable landings (TAL) by sector, 1991–2019.

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				
Year	**TAL**	**Landings**	**(+)/-**	**TAL**	**Landings**	**(+)/-**	**TAL**	**Landings**	**(+)/-**	**Total TAL**	**Total 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	36,351	32,399	68,750	53,379	15,371	275,000	226,886

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_{Target}, adaptive management allows for calculation of a new TAL to reduce *F* 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_{Target} may be exceeded and SSB may fall below the $SSB_{\text{Threshold}}$, 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.

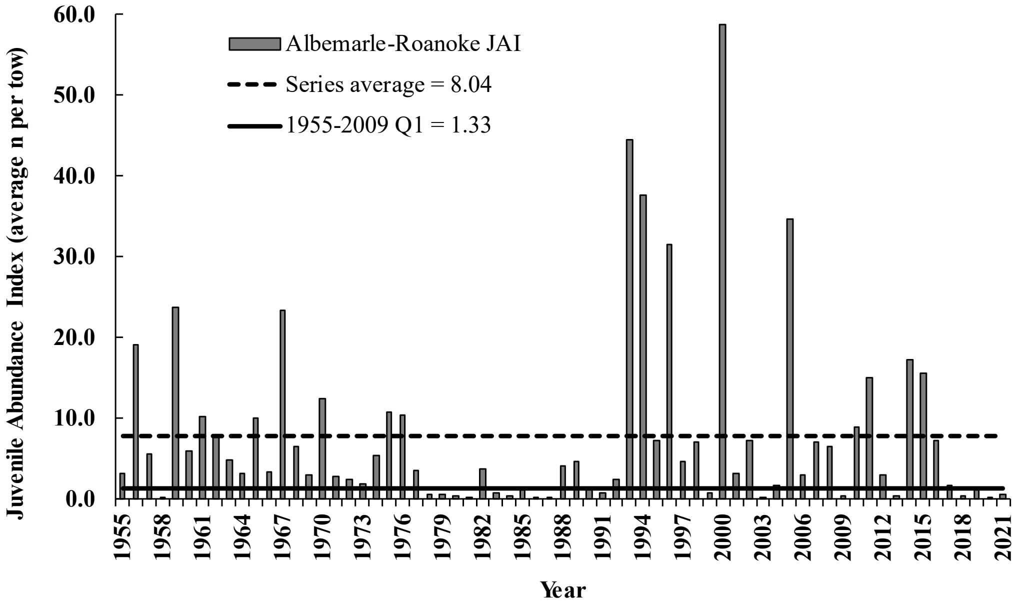

Figure 2.2. The juvenile abundance index (JAI) for Albemarle Sound-Roanoke River striped bass, North Carolina, 1955–2021. A JAI value below the first quartile (Q1 solid black line) is considered a spawning failure.

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.

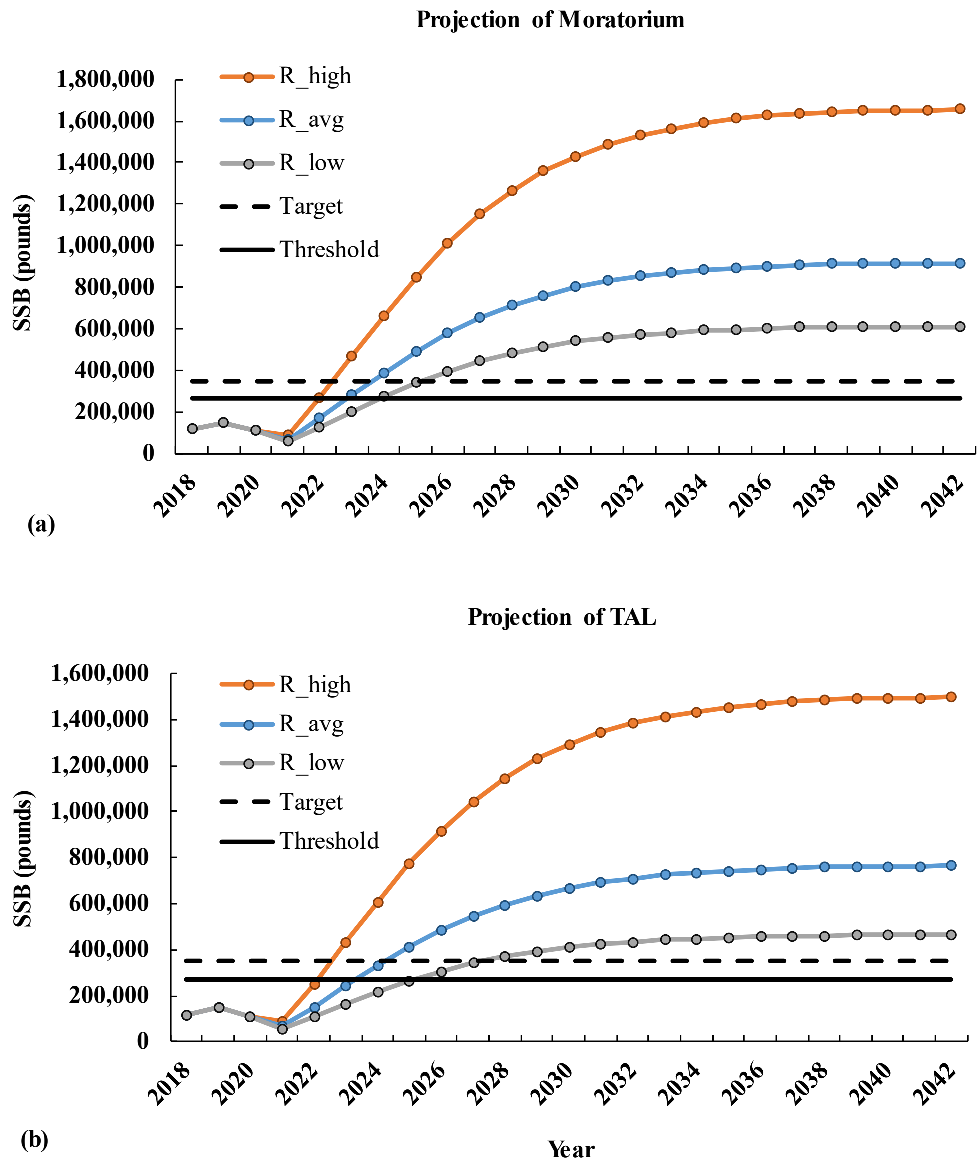

Figure 2.3. Projections of spawning stock biomass (SSB) in pounds for the Albemarle Sound-Roanoke River striped bass stock under the current total allowable landings (TAL) of 51,216 lb (a) and a harvest moratorium (b). Average recruitment (R_avg), low recruitment (R_low), and high recruitment (R_high) 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).

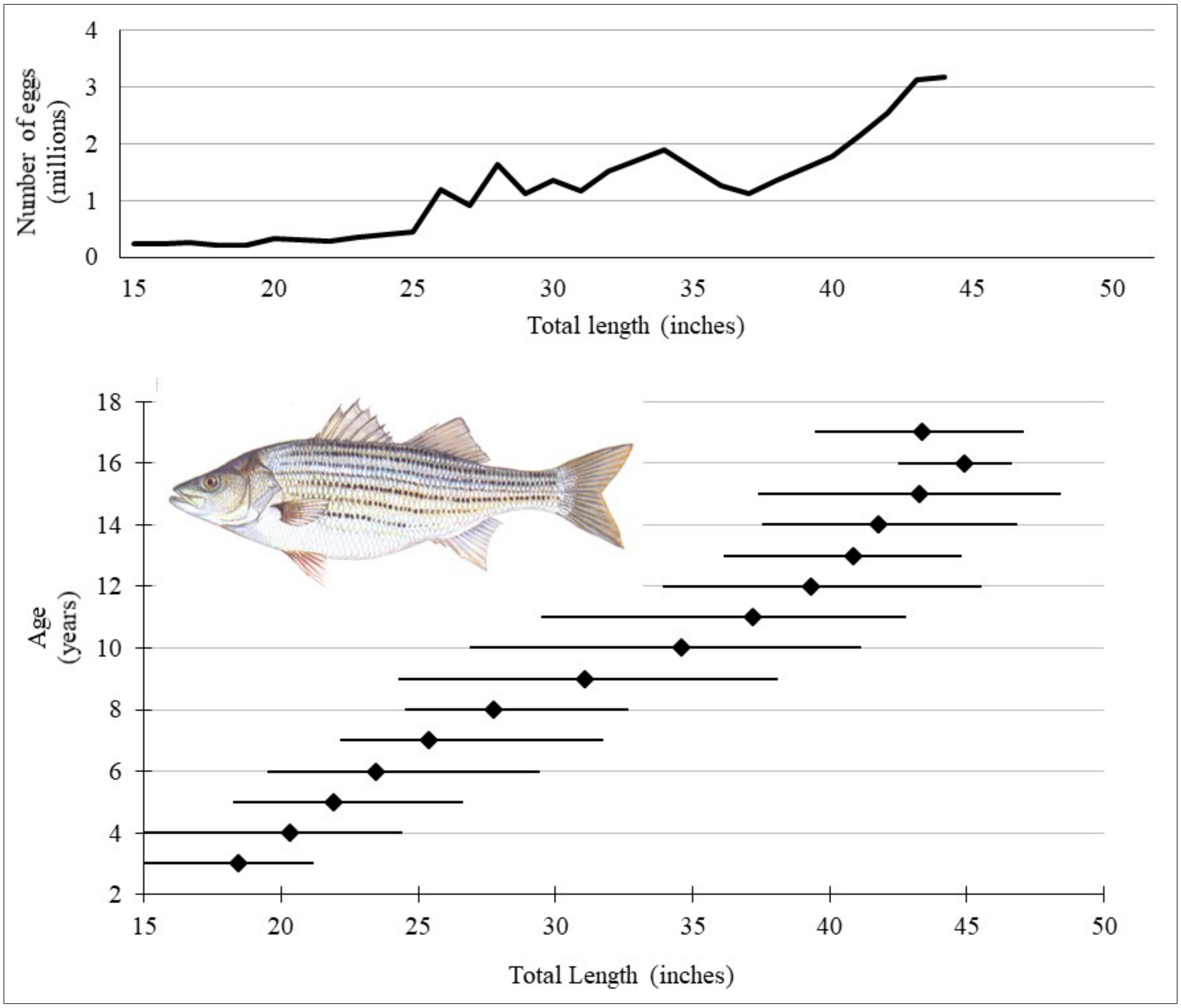

Figure 2.4. Number of eggs produced by female Albemarle-Roanoke striped bass at age and the average length of female striped bass at age. The diamond represents the average total length, and the lines represent the minimum and maximum observed length. Number of eggs at age data from Boyd 2011. Length 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.

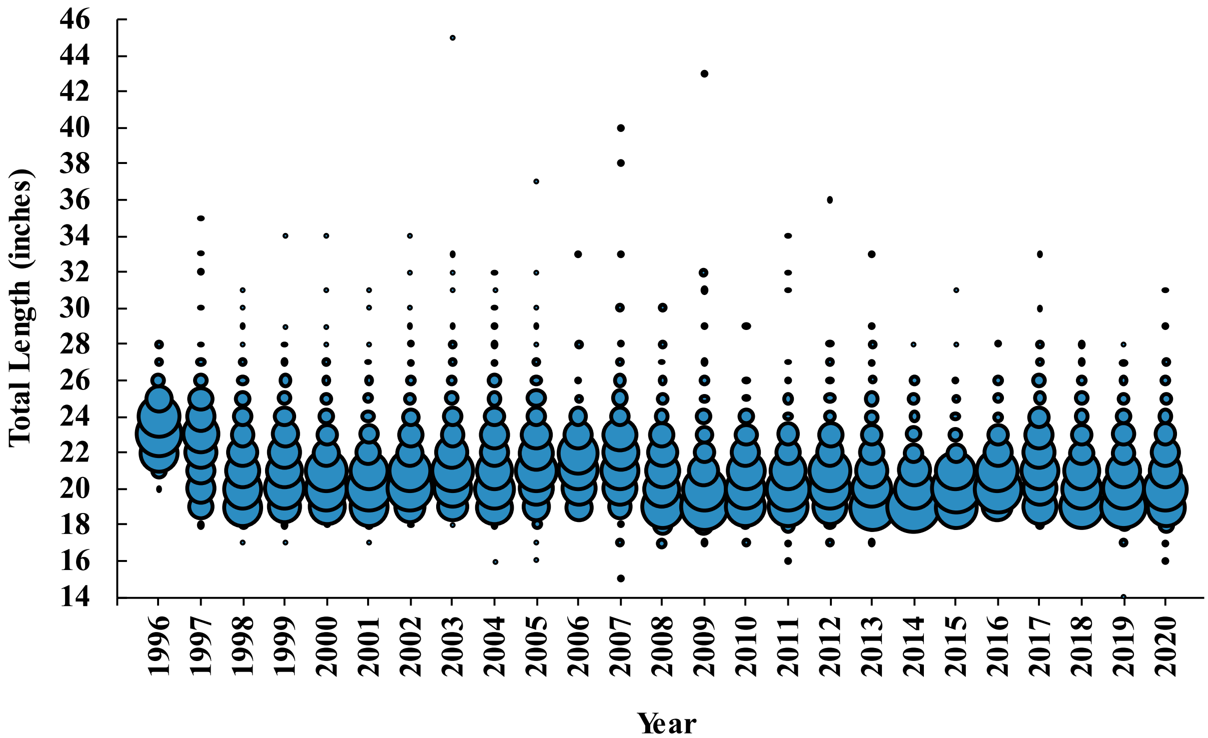

Figure 2.5. Recreational length frequency (total length, inches) of striped bass harvested in the ASMA, NC, 1996–2020. Bubble size represents the proportion of fish at length.

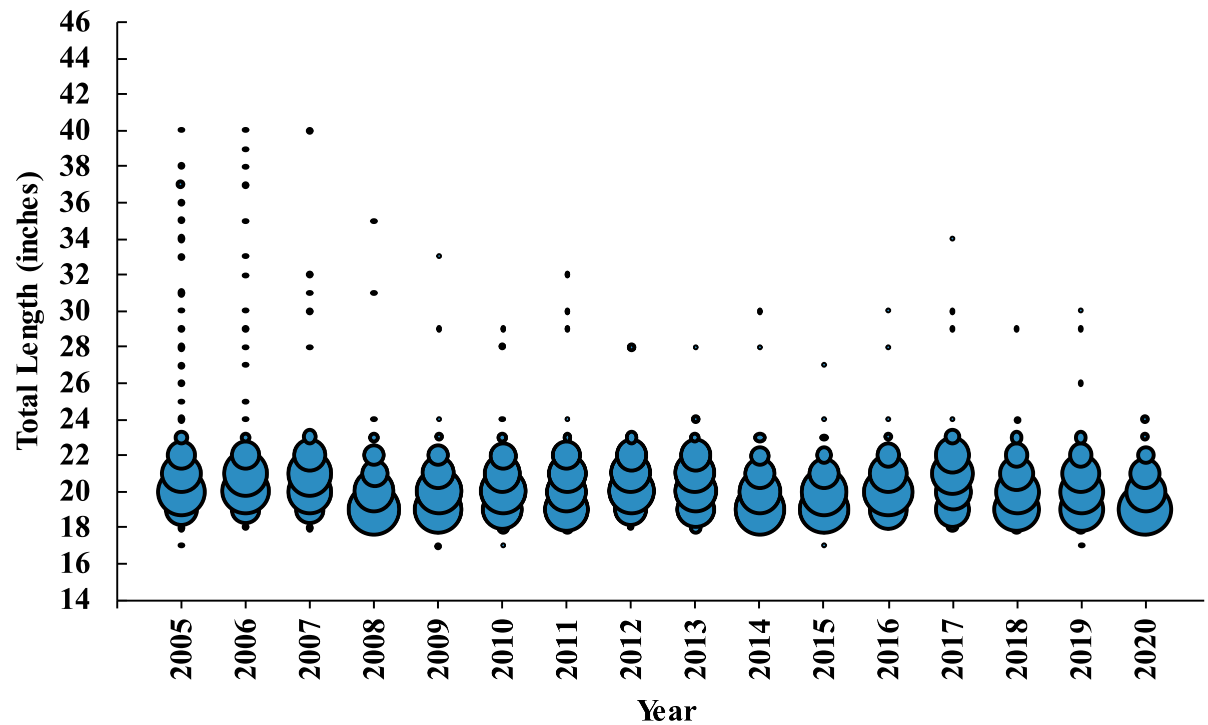

Figure 2.6. Recreational length frequency (total length, inches) of striped bass harvested in the RRMA, NC, 2005–2020. Bubble size represents the proportion of fish at length.

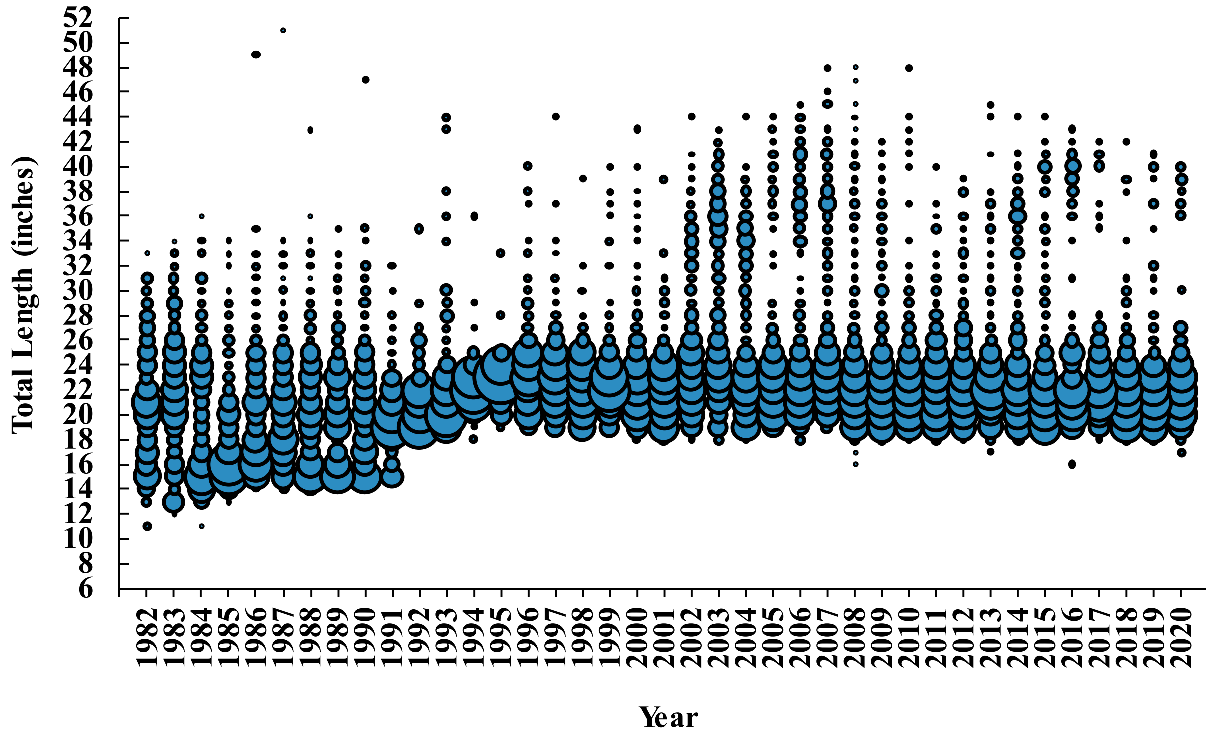

Figure 2.7. Commercial length frequency (total length, inches) of striped bass harvested in the ASMA, NC, 1982–2020. Bubble size represents the proportion of fish at length.

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).

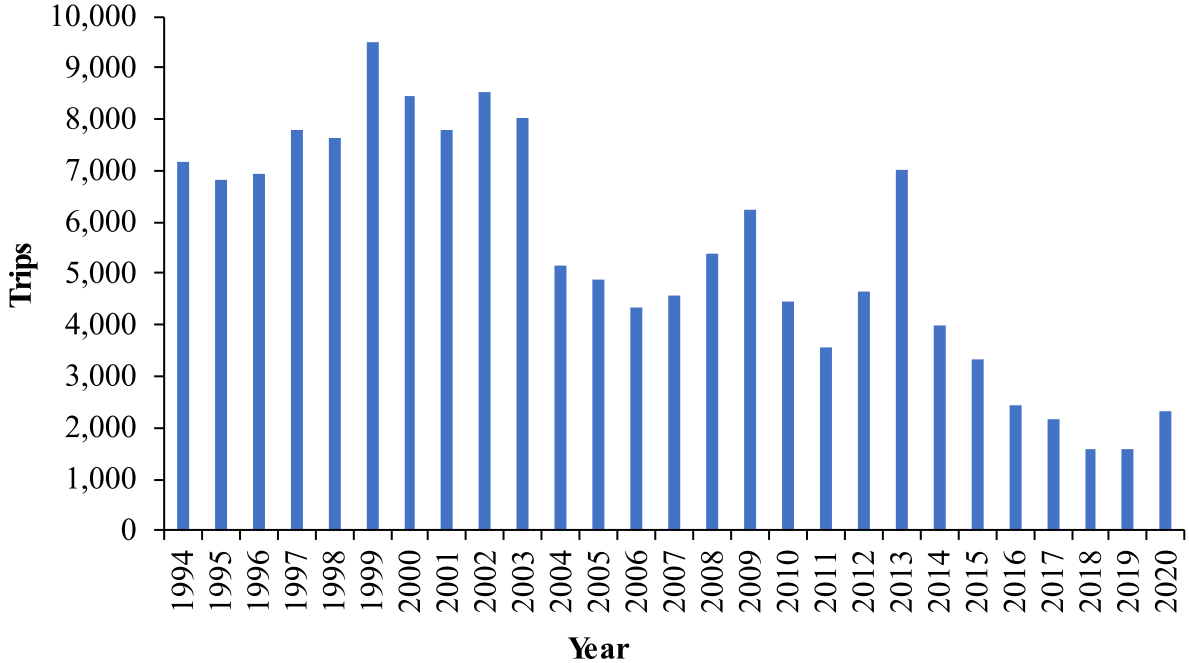

Figure 2.8. Number of anchored gill net trips in the ASMA that landed either river herring, white perch, striped mullet, spotted seatrout, yellow perch, or spot. These species were selected to determine a "small mesh" gill net trip in the ASMA.

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 of estimates of *F* from stock assessments to compare to the *F* BRP and if *F* exceeds the F_{Target} reduce the TAL to the appropriate level 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	12,804	13,444	14,000	1,196			1,196 lb	11,608	ASMA recreational landings exceeded TAL+5% so must pay back full overage.
			ASMA Commercial	25,608	26,888	26,200	392			0	25,608	ASMA commercial exceeded TAL by less than 5% buffer so no paybacks are necessary.
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 the F_{Target} through a Revision to the Amendment (ASMFC requirement under Amendment 6 to the Interstate FMP for Atlantic striped bass).
- 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

The DMF, WRC, and advisory committees' recommendations and a summary of online public comments can be found in Appendix 6.

The DMF recommended management is option: 1.A., 2.A., 3.D., 4.C. and 4.E., 5.A. and 5.E., and 6.

The WRC recommended management is in line with the DMF recommendations except concerning Option 3. WRC preferred option for 3: 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 more than 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.

<u>Rationale</u>

Past management has indicated the striped bass stock can rebound from an overfished stock with a limited TAL for all fisheries and therefore the DMF and WRC support a limited TAL. The DMF recommends continuing with the bycatch provision in the commercial fishery. Adaptive management can address the bycatch provision for hook and line if that gear is allowed. Implementing a slot limit in the ASMA would increase protections to the spawning stock. Not allowing gill nets to harvest striped bass would increase commercial dead discards and negatively impact the commercial shad and southern flounder fisheries. Since striped bass may be caught on the way to and from the spawning grounds, catch-and-release on the spawning grounds is not expected to impact the stock. Expanding the single barbless hook requirement to the entire RRMA is not recommended since it would negatively impact fishers targeting many sport fish species. However, both the DMF and WRC staff will continue to educate anglers on best fishing practices and ways to reduce discard mortality. Finally, adaptive management is necessary to allow flexibility in management when data indicates an adjustment is necessary between plans. It needs to be noted, the WRC has limited proclamation authority and temporary rules require a 30-day implementation period.

The one recommendation on which the DMF and WRC are not in agreement is Option 3. The difference in recommendations is based on differences in risk and degree of correction needed to address overages. The DMF recommendation is more risk adverse and more punitive in nature. Whereas the WRC recommendation affords a marginal level of risk due to estimations in recreational catch. Additionally, the WRC feels one year of a closed season is the most punitive measure that should be implemented.

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).

<u>Tar-Pamlico and Neuse Rivers Striped Bass Stocks Life History</u>
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.

<u>Striped Bass Fisheries</u>
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.

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.

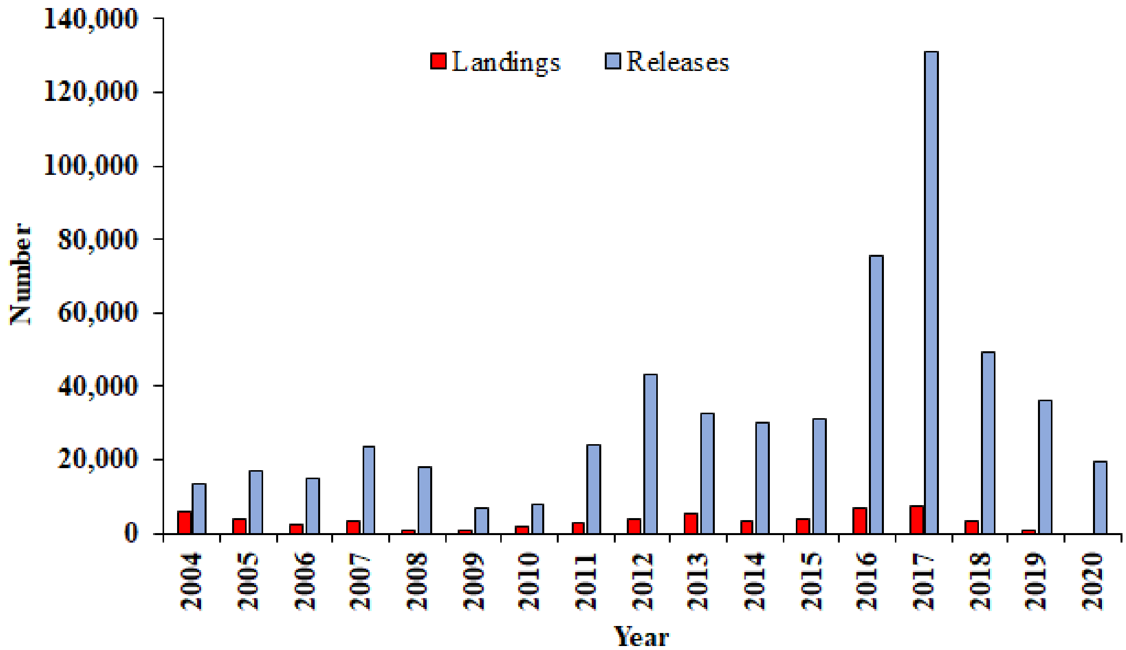

Figure 3.1. Annual recreational catch (harvested and/or released) of striped bass in the CSMA, 2004–2020. There was a limited recreational harvest season in 2019 prior to the closure, lasting from January 1 to March 19, 2019.

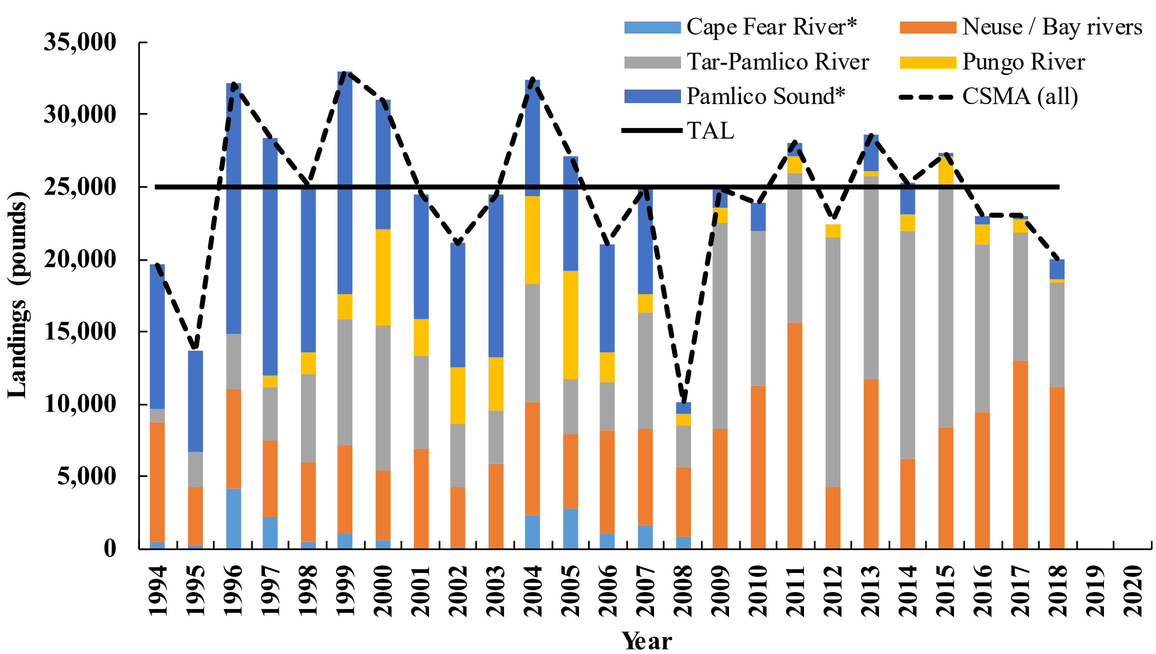

Figure 3.2. Commercial striped bass harvest by system, and the TAL in the CSMA, 1994–2020. There has been a harvest no-possession measure in the Cape Fear River since 2008 and in the CSMA since 2019. *Landings data for the Cape Fear River (2001) and for the Pamlico Sound (2012) are confidential.

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).

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.

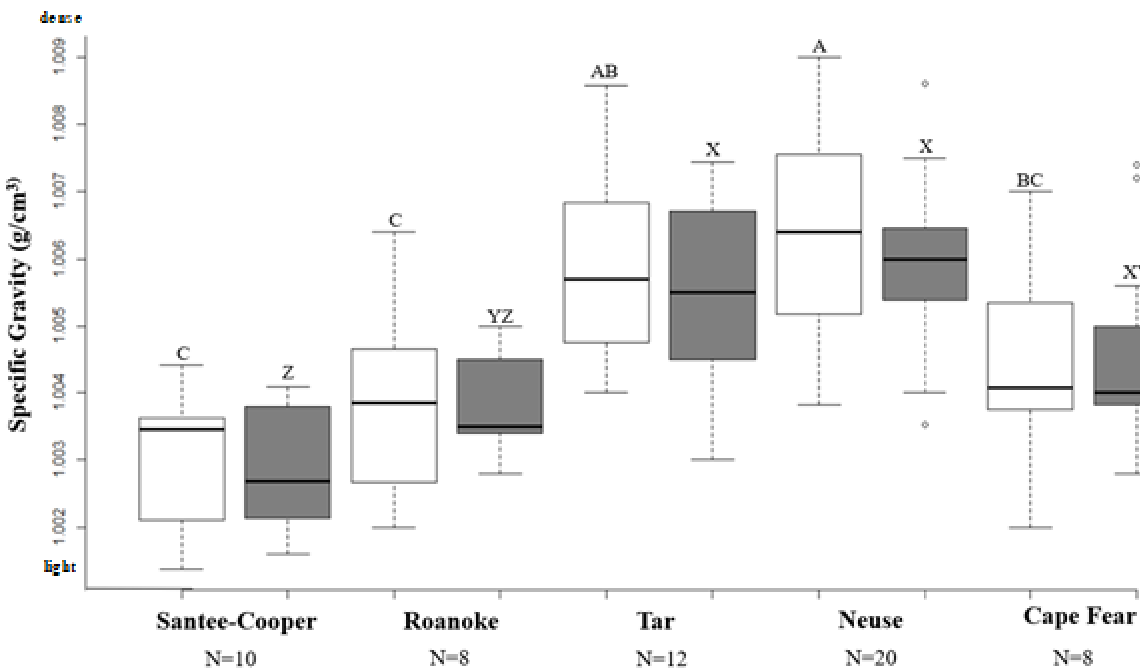

Figure 3.3. Specific gravity (buoyancy; g/cm^3) measurements from stage 1 (white boxes) and 4 (gray boxes) fertilized eggs from 2018/2019 hatchery broodstock sampling. Tukey pair wise comparisons are labeled above the boxplots with ABC indicating stage 1 significant differences and XYZ indicating stage 4 significant differences (Tukey HSD, α=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.

<u>Continue or discontinue the no-harvest measure</u>

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.

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

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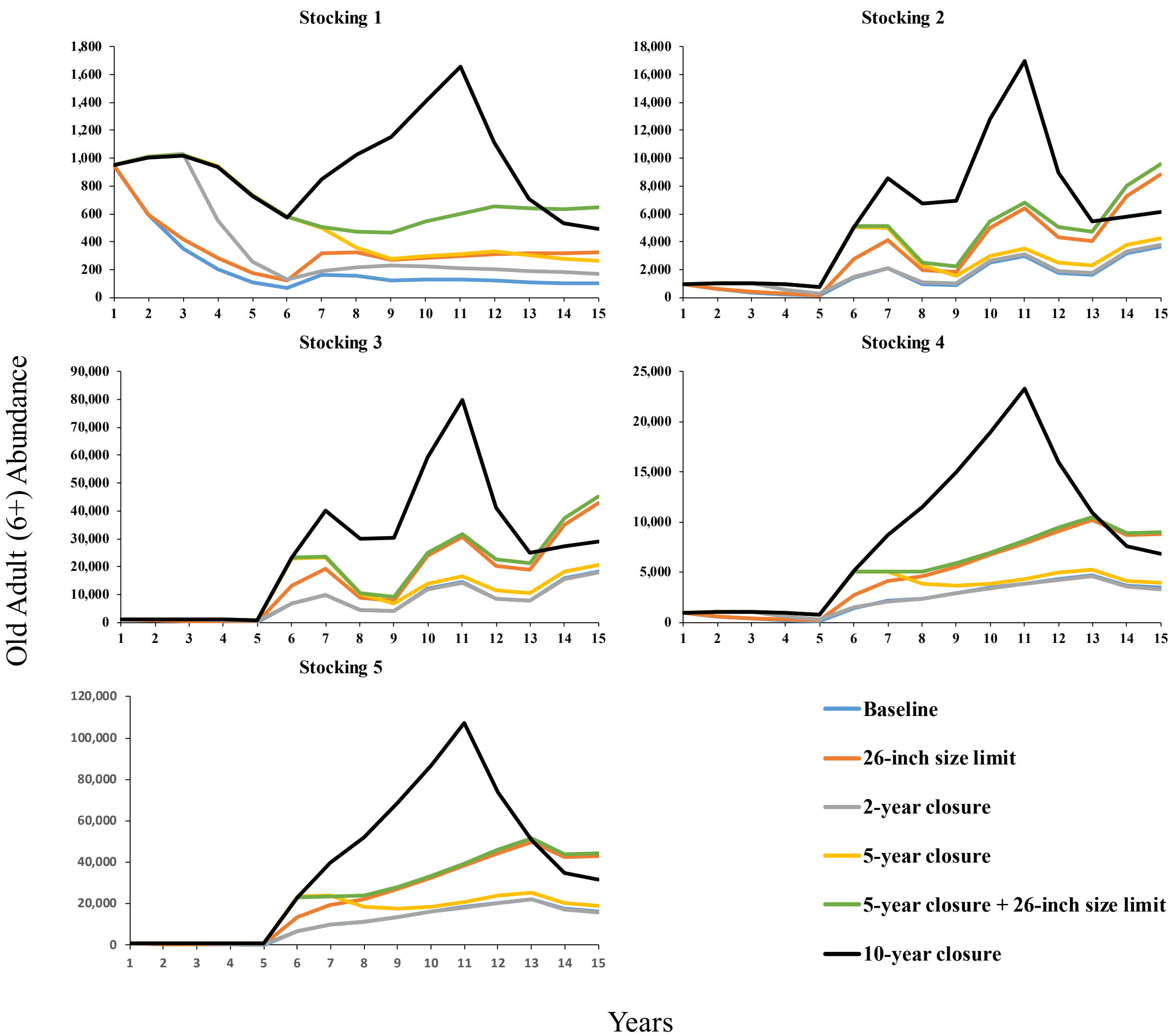

Figure 3.4. Abundance of old adults (age 6+) projected under five stocking strategies and six fishing strategies. Stocking 1 - no stocking; Stocking 2 - stocking 100,000 fish per year with 2-year stocking and 2-year no stocking alternating for 15 years (8 years of stocking in total); Stocking 3 - stocking 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

From 2012 to 2022, recreational striped bass dead discards in the Tar-Pamlico and Neuse rivers averaged 3,340 fish (Table 3.1). Measures to reduce recreational angling discard mortality may be necessary for the Tar-Pamlico and Neuse stocks. The use of single barbless hooks is required by WRC on the Roanoke River to reduce discard mortality. Similar measures and other methods, such as requiring circle hooks for natural bait and restricting the use of treble hooks, could be considered in the Tar-Pamlico and Neuse rivers. This type of restriction could be done seasonally or year-round. However, recreational gear limitations would likely impact other fisheries.

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.

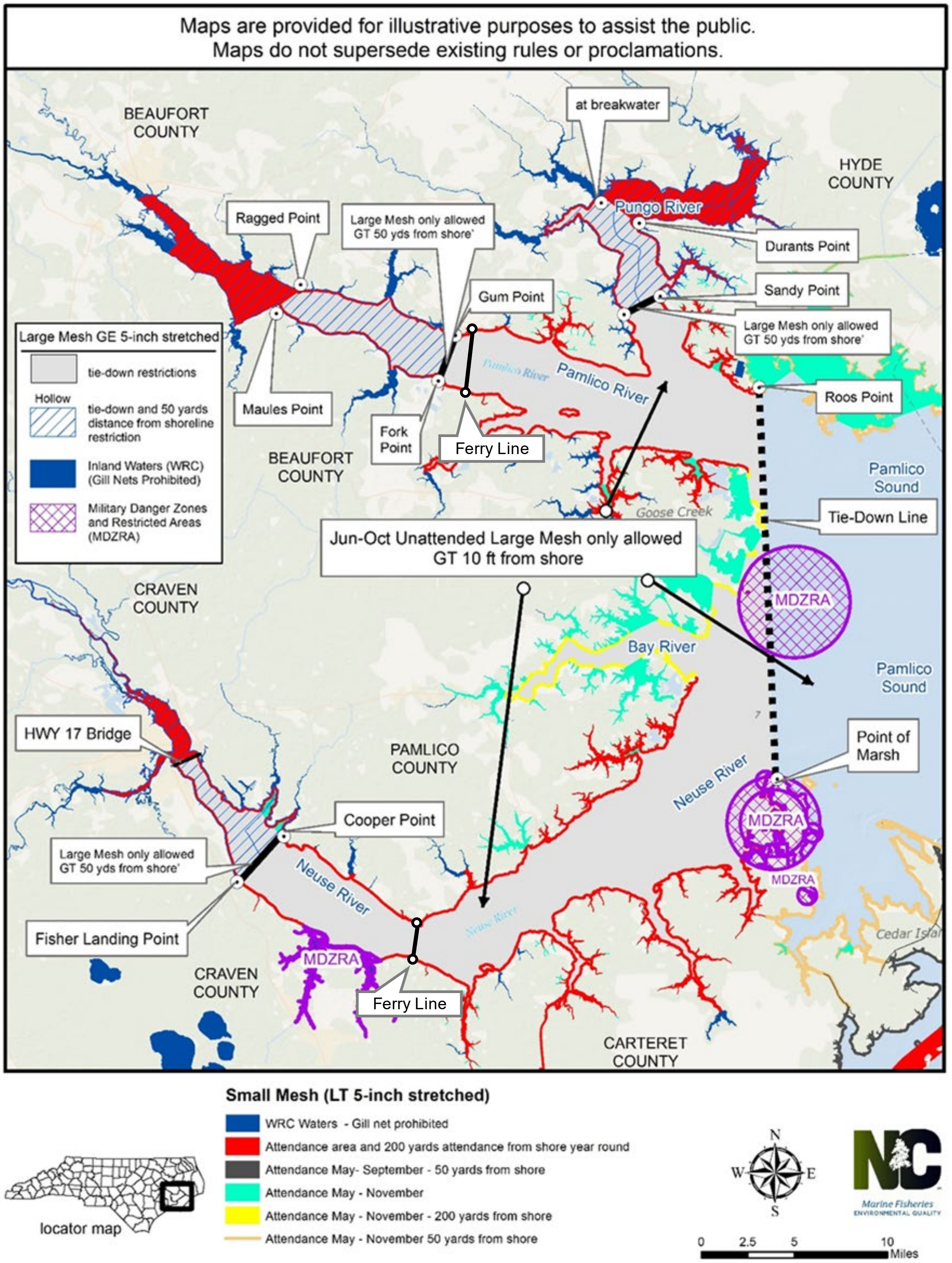

Figure 3.5. Gill net regulation map for various gill net types and seasons in the Central Southern Management Area.

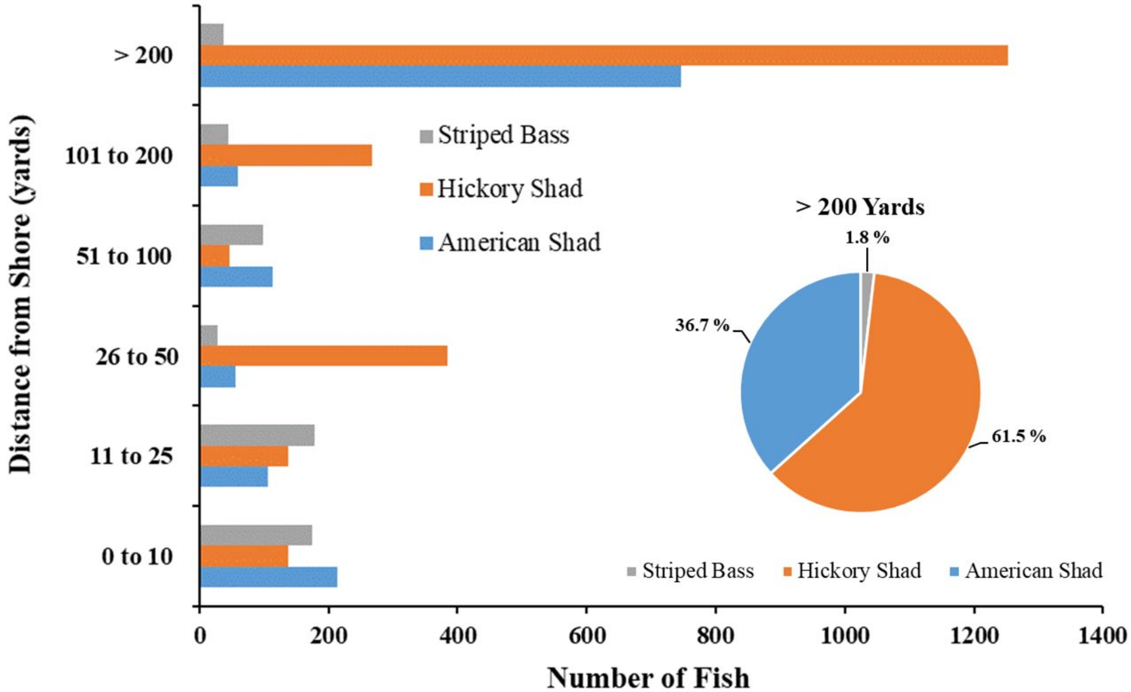

Figure 3.6. DMF observer data for striped bass, hickory shad, and American shad from gill nets set above the ferry lines on the Tar-Pamlico and Neuse rivers (2012–2020; Feb 15 – Apr 14; n=162 trips), separated by the distance from shore (yards). The insert shows the percentage of fish that were observed 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

The DMF, WRC, and advisory committees' recommendations and a summary of online public comments can be found in Appendix 6.

The DMF recommended management is option: 1.A. and 3.

The WRC recommended management is option: 1.A., 2.A., and 3 (with additional language).

The DMF and WRC also support formalizing discussions on controlling flows in the Tar-Pamlico and Neuse rivers.

<u>Rationale</u>

Maintaining no-possession will continue to protect important age classes in this system and increase the age structure of the stock. In 2025, DMF and WRC biologists will review data to evaluate management implemented in this plan. The WRC staff support adaptive management that allows changing management strategies to put-grow-take fisheries before the next comprehensive FMP review if progress toward self-sustaining populations is not occurring.

<u>MFC Actions</u>

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.

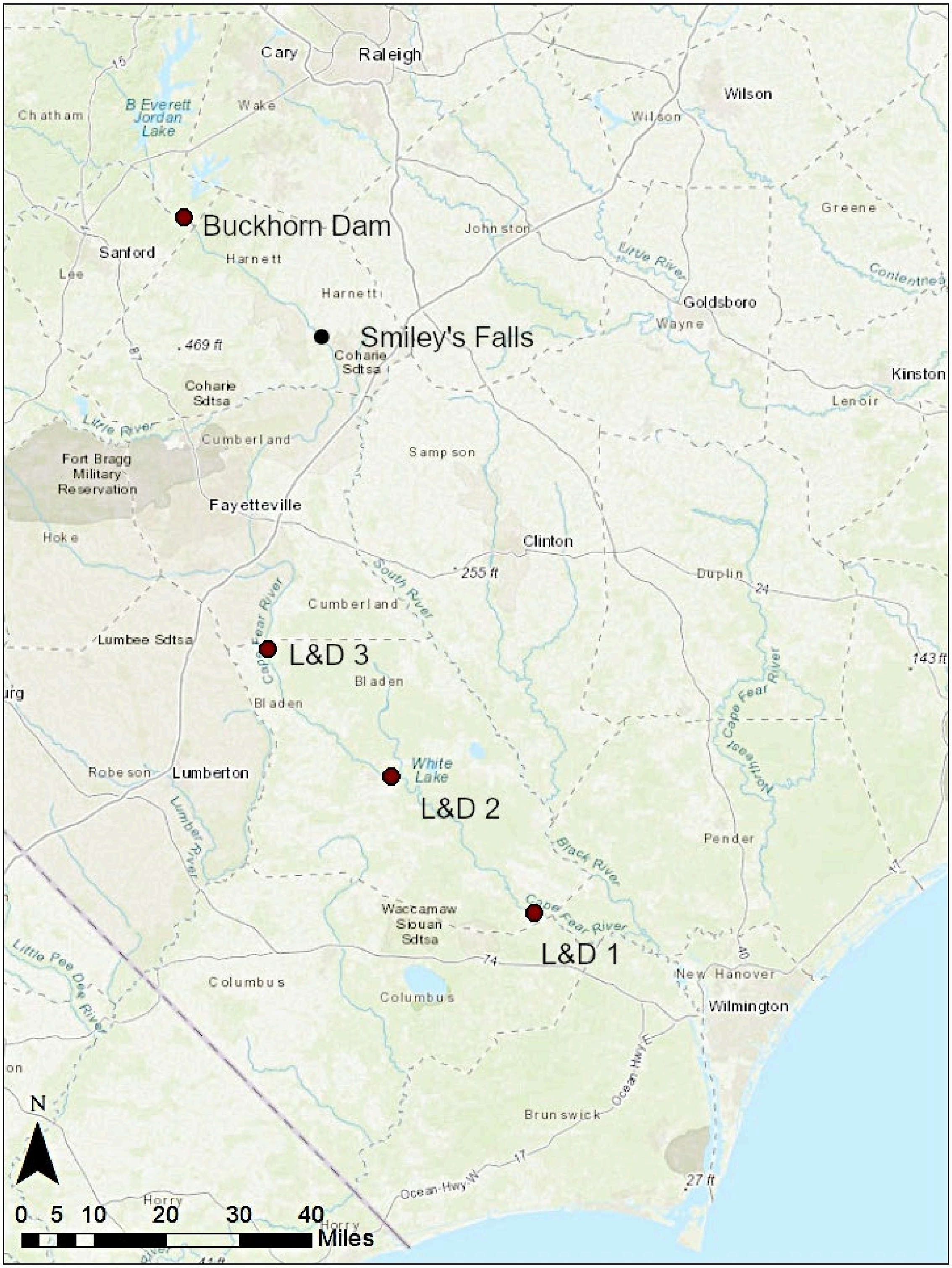

Figure 4.1. A map showing the locations of the three locks and dams on the mainstem of the Cape Fear River downstream of the historic spawning area near Smiley's Falls.

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).

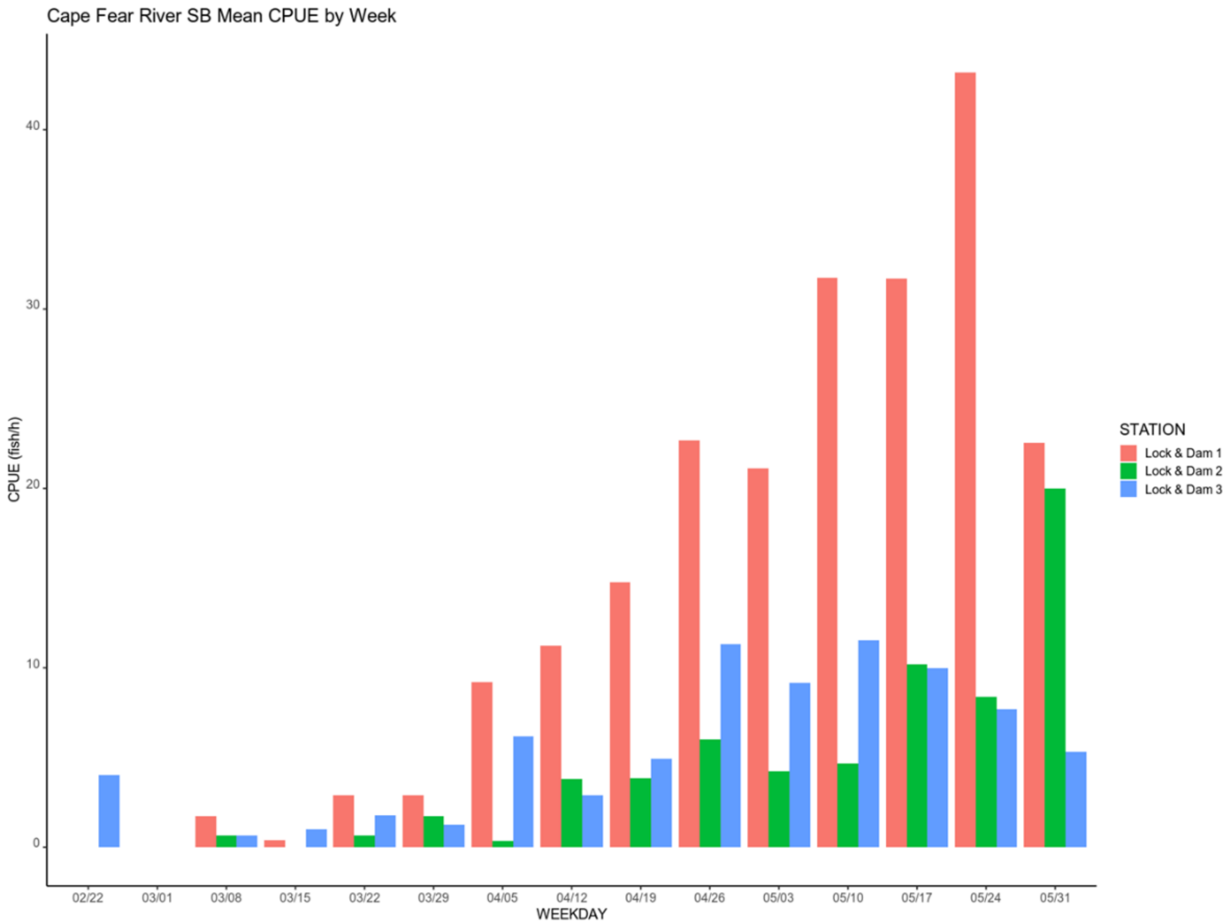

Figure 4.2. Weekly striped bass catch-per-unit-effort (CPUE) by sample site February through May 2008–2019.

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.

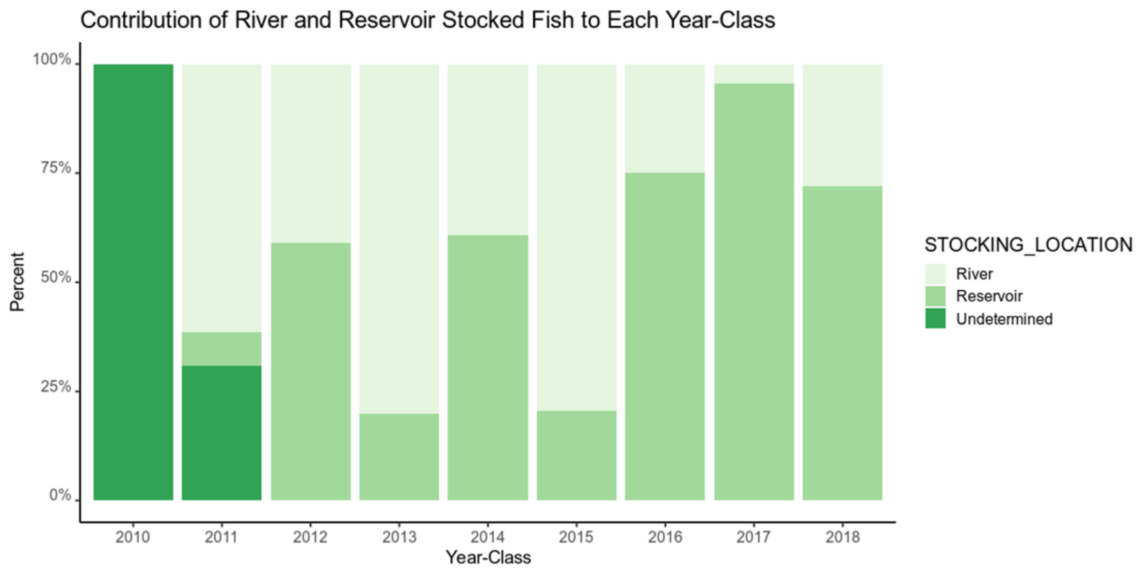

Figure 4.3. Relative contribution of hatchery-origin fish to the hatchery-origin year-class by stocking location of fish collected in WRC electrofishing surveys, 2010–2018.

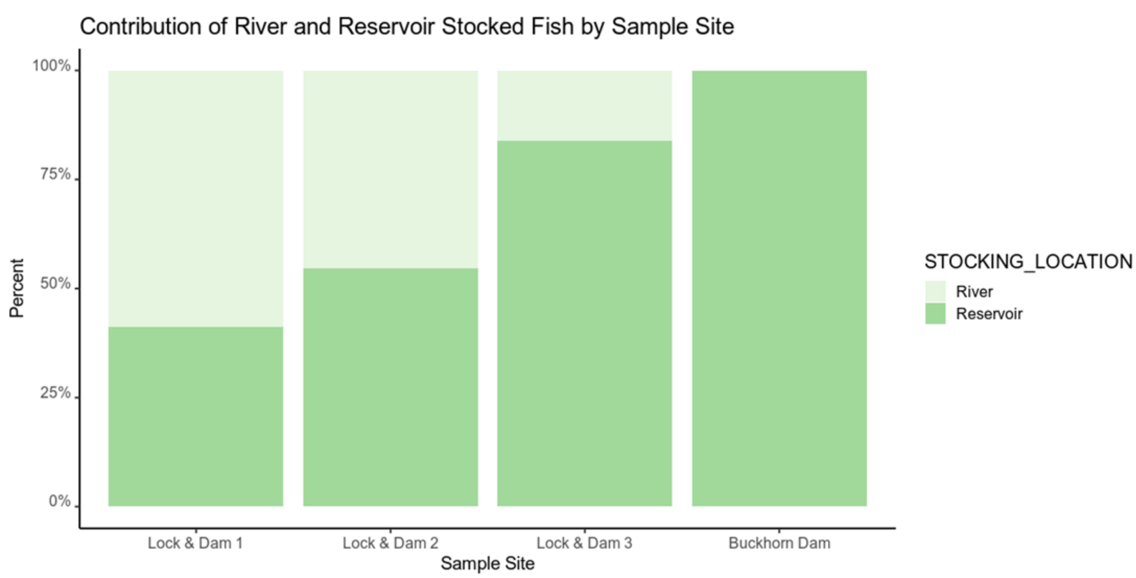

Figure 4.4. Relative contribution of hatchery-origin fish by stocking location to each WRC electrofishing sample site, 2015–2019.

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 existing rock arch ramp design at Lock and Dam #1 does 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 has 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 2.4 Use of Hook and Line as a Commercial Gear in the Estuarine Striped Bass Fishery.

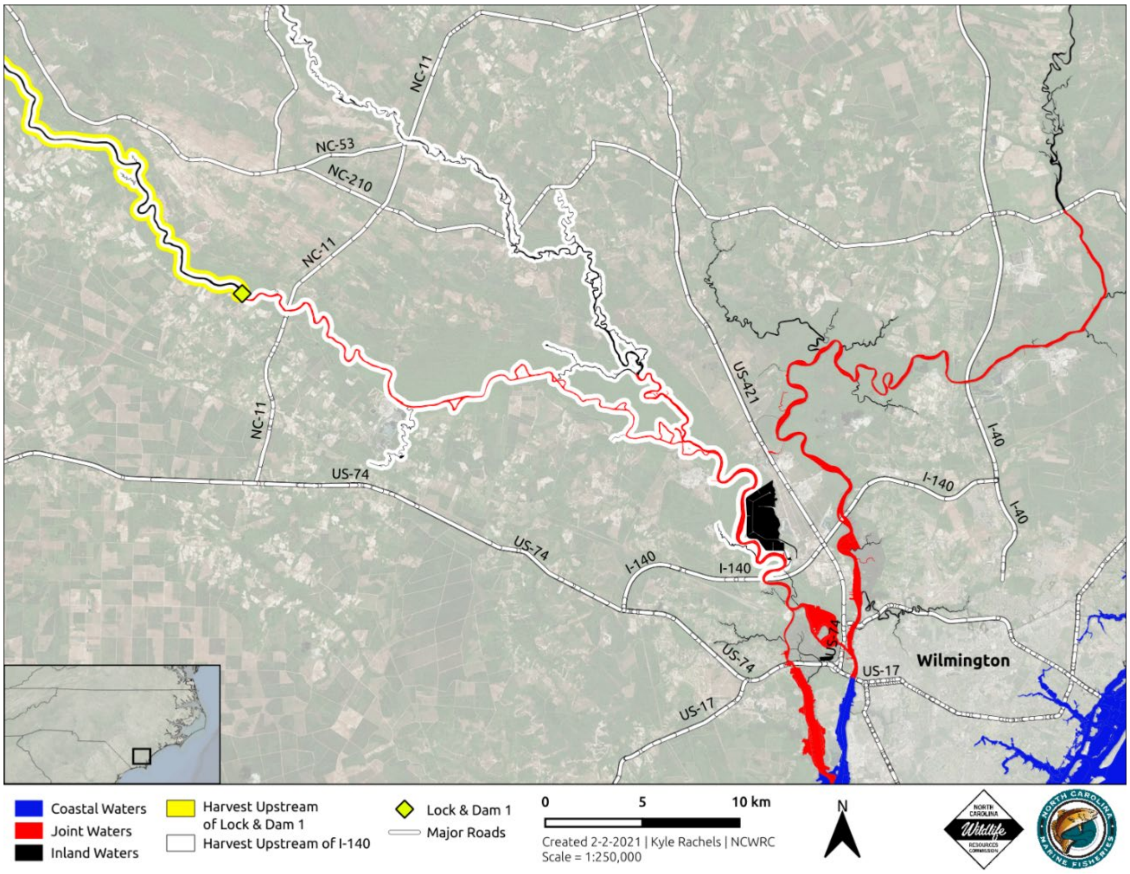

Figure 4.6. A map showing Inland, Joint, and Inland Fishing waters, as well as the harvest area boundaries for the proposed management options.

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

The DMF, WRC, and standing and regional advisory committees' recommendations and a summary of online public comments can be found in Appendix 6.

The DMF recommended management is option: 1.A. and 2.

The WRC recommended management is option: 1.B., and 2.

Rationale

The DMF recommends maintaining no-possession to evaluate recent changes which may allow improved passage over the Locks and Dams. Modifications to the passage structure at Lock and Dam 1 (completed in November 2021) and dam release flow pulses (implemented spring 2021) may give striped bass better access to the spawning grounds. Juvenile surveys indicate wild spawning occurring in the system. The DMF is concerned that allowing any harvest on a stock with such low abundance would target and impact the fish which are successfully spawning or passing the locks and dams. Given the low abundance and observed angler catch rates of striped bass in the Cape Fear River, allowing any harvest at this time regardless of area, season, size, or bag limits, will negatively affect the ability to establish a self-sustaining population in this system.

The WRC recommends allowing harvest in the Cape Fear to provide harvest opportunities on a hatchery-supported stock. The WRC thinks it is unlikely fish will have access to spawning grounds until the next plan review. Because the population remains stocked fish with limited spawning after 13-years of no-harvest, the WRC does not think spawning stock would be impacted. The WRC also notes that harvest restrictions (season, minimum length limit, and creel limit) will ensure striped bass remain in the system to take advantage habitat improvements if they occur and that adaptive management could be used to reinstate the moratorium if restoring a self-sustaining population becomes achievable.

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 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).
   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

The DMF, WRC, and advisory committees' recommendations and a summary of online public comments can be found in Appendix 6.

The DMF recommended management is option: 1.A. and 2.

The WRC recommended management is option: 1.B. and 2.

Due to the stock status and limited TAL, the DMF recommends management remain status quo with Amendment 1 management. Amendment 1 did not approve use at the time, however, allows for hook and line as an adaptive management tool. The adaptive management in Amendment 2 clarifies Amendment 1 adaptive management and allows management to be adjusted to respond to changes between FMP reviews.

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. 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. 41% Option 1.A. If a moratorium was in place 56% would still target striped bass for recreational catch-and-release
	DMF: Option 2.A. 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. 8% Option 2.B.
	DMF: Option 3.D. WRC: Recommends an option not in the plan which includes overages above a buffer and only a single year	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 9% divide across all fisheries 8% single fishery pay back a portion of landings above TAL (buffer) 5% no payback
	DMF: Options 4.C. and 4.E. 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 71% Options 4.C. and 4.E. 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. 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. 19% Option 5.D. 17% Option 5.E. 11% Option 5.C.
	DMF: Support all Adaptive Management measures 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. 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. 32% Option 1.B.
	DMF: No recommendation 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 12% opposed
	DMF: Support all Adaptive Management measures 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. 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 14% opposed
	DMF: Support all Adaptive Management measures 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. 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 If harvest is allowed: 15% Option 1.B. 16% Option 1.C. 16% Option 1.D. 54% uncertain or no opinion.
	DMF: Support all Adaptive Management measures 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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Southern Flounder Fishery Management Plan
Amendment 3
Decision Document

May 2022

N.C. Division of Marine Fisheries
3441 Arendell Street
Morehead City, North Carolina 28557

This Decision Document is a companion document to Amendment 3 to the Southern Flounder Fishery Management Plan. It provides a brief overview and context for the issue. The document also provides references to the full Amendment document where more detailed information is located. The Southern Flounder Fishery Management Plan Amendment 3 document is the plan under consideration and is the focus of all MFC action.

Summary

In May 2022, the North Carolina Marine Fisheries Commission (MFC) will review draft Amendment 3 to the Southern Flounder Fishery Management Plan (FMP) and vote on final approval of the plan. Once approved, the Division of Marine Fisheries (DMF) will implement the selected management strategies.

Following the 2019 Coast-wide Stock Assessment that determined southern flounder to be overfished and overfishing to be occurring, the MFC approved Amendment 2 to the Southern Flounder FMP. Amendment 2 was intended as a stop-gap to reduce harvest pressure on the portion of the stock in North Carolina and to allow for development of long-term management measures. Florida and South Carolina have also implemented management measures to address the status of the stock.

Amendment 3 has been developed to address comprehensive, long-term management strategies to continue rebuilding the southern flounder stock. The DMF has drafted seven issue papers (see Appendix 4, pg. 61) which address sustainable harvest, increased recreational access, inlet corridors, adaptive management, sector allocations, slot limits, and phasing out large-mesh gill nets.

Amendment Timing

December 2019	Division holds public scoping period
February 2020	MFC approves goal and objectives of FMP
February – October 2020	Division drafts FMP
October 2020 & August 2021	Division holds workshops to further develop draft FMP with Plan Advisory Committee
November 2020 – October 2021	Division updates draft plan
November 2021	MFC votes to send draft FMP for public and AC review
January 2022	MFC Advisory Committees meet to review draft FMP and receive public comment
February 2022	MFC selects preferred management options
March – April 2022	DEQ Secretary for disbursement to legislative bodies for review
May 2022	**MFC votes on final adoption of FMP**
May 2022	**DMF and MFC implement management strategies**

Goal and Objectives

The goal of Amendment 3 is to manage the southern flounder fishery to achieve a self-sustaining population that provides sustainable harvest using science-based decision-making processes. The following objectives will be used to achieve this goal.

- Implement management strategies within North Carolina and encourage interjurisdictional management strategies that maintain/restore the southern flounder spawning stock with expansion of age structure of the stock and adequate abundance to prevent overfishing.
- Restore, enhance, and protect habitat and environmental quality necessary to maintain or increase growth, survival, and reproduction of the southern flounder population.
- Use biological, environmental, habitat, fishery, social, and economic data needed to effectively monitor and manage the southern flounder fishery and its ecosystem impacts.
- Promote stewardship of the resource through increased public outreach and interjurisdictional cooperation throughout the species range regarding the status and management of the southern flounder fishery, including practices that minimize bycatch and discard mortality.
- Promote the restoration, enhancement, and protection of habitat and environmental quality in a manner consistent with the Coastal Habitat Protection Plan.

Background

The southern flounder found in North Carolina waters are part of a larger regional stock shared with South Carolina, Georgia and the east coast of Florida. This means the stock is impacted by harvest and management in all states within the region. As a result, and unlike previous assessments, the most recent stock assessment was conducted collaboratively with academics, scientists, and managers from North Carolina, South Carolina, Georgia, and Florida. The resulting stock assessment showed the regional southern flounder stock to be overfished and overfishing occurring. It also indicated recovery is dependent on action by all states in the region. North Carolina took decisive action to end overfishing and begin recovering the regional stock by adopting substantial harvest reductions in 2019 and continuing to develop improved management measures.

The southern flounder fishery is currently managed under Amendment 2 to the Southern Flounder FMP. In August 2019, the MFC approved Amendment 2 which implemented reductions in total removals (harvest + dead discards) of southern flounder of 62% in 2019 and 72% in 2020 and on. These reductions were more conservative than the 52% reductions that were required, and were recommended and selected to increase the likelihood of meeting management targets. These reductions were applied across all fishery sectors and were implemented using seasonal management. Approval of Amendment 2 specified the development of Amendment 3 begin immediately to develop more comprehensive, long-term management measures to address the stock status. While the seasonal management implemented under Amendment 2 has been successful in reducing removals at a level expected to end overfishing, it may not be sufficient to rebuild the stock within 10 years because of potential overages due to shifts in fishing behavior. The draft of Amendment 3 contains a suite of management options, including adaptive management, that will increase the likelihood for long-term rebuilding of the stock. For more information please refer to Amendment 2.

In November 2020, during development of Amendment 3, the MFC requested the DMF prepare an issue paper to consider various sector allocations of the total allowable removals remaining after the 72% reductions across the fishery. While the MFC initially approved a 70/30 commercial/recreational allocation, they revisited the allocation decision and voted to amend the allocation to a stepped approach to reach a 50/50 allocation by 2024. Due to the complicated nature of the allocation decision, Amendment 3 timing was shifted, giving the DMF time to evaluate how sector allocations would effect the management measures contained in the Sustainable Harvest, Increased Recreational Access, and Adaptive Management issue papers and to revise the FMP as needed. Staff incorporated these changes and developed a suite of sustainable harvest management options for the MFC to consider. In addition, per the request of various commissioners, DMF staff also addressed additional management options, such as slot limits and inlet corridors, in the existing issue papers as well as developed an issue paper considering the phasing out of large mesh gill nets from the southern flounder fishery.

Amendment 2 Management

At the February 2022 MFC business meeting, staff provided an update to the commission on the 2019, 2020, and 2021 southern flounder harvest during the commercial and recreational seasons established under Amendment 2. As a result of overages in the fishery, particularly in the recreational sector, the DMF revised the 2021 season dates accordingly. (*2021 removals are preliminary).

	Total Removals (pounds)			Realized Percent Reduction from 2017 landings
	Allowable	Actual	Overage	
Commercial				
2019	531,629	804,117	272,488	43%
2020	391,726	484,595	92,869	65%
2021*	391,726	480,054	88,328	66%
Recreational				
2019	207,382	461,588	254,206	15%
2020	152,808	456,636	303,828	16%
2021*	152,808	627,444	474,636	-15%
Overall				
2019	739,011	1,265,705	526,694	35%
2020	544,534	939,468	394,934	52%
2021*	544,534	1,107,498	562,964	43%

Amendment 3 to the Southern Flounder FMP

Draft Amendment 3 to the Southern Flounder FMP provides an overview of the southern flounder fishery, including a discussion of the current stock status, which informs all of the management options in Amendment 2 and Amendment 3.

All seven issue papers are located in Appendix 4 of the FMP and were developed with the aim of rebuilding the southern flounder population and achieving a sustainable fishery. Management measures are based on the 72% reduction in harvest established in Amendment 2. Quota and seasonal management targets are based the sector allocations set by MFC (Appendix 4.5, pg. 136-144) which are discussed briefly below. The 10-year rebuilding timeline began with Amendment 2 (2019) and will not restart with the adoption of Amendment 3. In addition, several management measures from Amendment 2 will be clarified and carried forward in Amendment 3 (See Appendix 4.1, pg. 69).

Please note that several options for the recreational fishery are dependent on others for management to be successful. The MFC preferred management strategies are listed on page 6 of this document. The DMF recommendations are listed on page 5 of this document, and a summary of DMF and MFC Advisory Committee recommendations, and public review, is in Appendix 6 (pg. 171-172).

Commercial and Recreational Sector Allocation

Quota management of the southern flounder fishery is one of the management options under consideration in Amendment 3 (See Sustainable Harvest). Establishing a quota, sets the harvest for the fishery at a sustainable level. Quota allocations describe the portion of the quota that is available to each sector of the fishery. In this case, the quota is divided between the commercial and recreational sectors.

For Amendment 2 and during the development of Amendment 3 the DMF identified the historical sector harvests for the commercial and recreational fisheries, then reduced both by 72%. At the MFC November 2020 quarterly business meeting the MFC approved a motion requesting the DMF consider several alternative sector harvest allocation options for Amendment 3. The motion specified consideration of the following commercial/recreational percentage splits: 70/30, 65/35, 60/30 with a 10 percent allotment for gigging, 60/40, and 50/50. Division staff drafted an issue paper in response and staff presented analysis of the options at the February 2021 business meeting (see Appendix 4.5; p136—144).

The DMF did not endorse, recommend, or advocate any one of these options including the status quo option. Allocation does not impact the total allowable catch levels needed to rebuild the stock. If the catch reductions are met in the southern flounder fishery, then the stock is predicted to rebuild.

MFC Selected Management

At the March 2021 special meeting, the MFC approved the following stepped allocations: 70/30 in 2021 and 2022; 60% commercial and 40% recreational in 2023; and 50/50 parity in 2024. The Total Allowable Catch available to both the commercial and recreational sectors combined is 548,034 pounds (532,352 pounds of Total Allowable Landings + 15, 682 pounds of Dead Discards).

At the February 2022 quarterly business meeting, as part of their preferred management options, the MFC voted to delay the shift to 50/50 parity by two years to 2026.

Total Allowable Landings by Sector

Based on the MFC-Selected Allocations

		Total Allowable Landings	
Year	**Allocation**	**Commercial**	**Recreational**
2021	70/30	372,646	159,706
2022	70/30	372,646	159,706
2023	70/30	372,646	159,706
2024	70/30	372,646	159,706
2025	60/40	319,411	212,941
2026	50/50	266,176	266,176

MFC Preferred Management Measures

At its February 2022 business meeting and following consideration of MFC Advisory Committee and public input, the MFC selected their preferred management strategies for draft Amendment 3 to the Southern Flounder FMP. The MFC voted to accept the DMF recommendations. In addition, the MFC passed a motion delaying the shift to 50/50 parity by two years and passed a resolution concerning continued overages in the fishery.

Sustainable Harvest

Set annual harvest quotas for the commercial fisheries

- Two Gear categories: Mobile Gears and Pound Nets
- Divide Mobile Gears into 2 areas
- Divide Pound Nets into 3 areas
- Maintain 72% reduction and current allocation for Pound Net fishery
- Trip limits for gigs and pound nets only after meeting closure threshold

Set annual harvest quotas for the recreational fisheries

- Implement single hook-and-line and gig season to constrain to quota
- Reduce bag limit to 1-fish/per person/per day
- Do not allow harvest of southern flounder with RCGL

Several management measures from Amendment 2 will be carried forward, and include minimum distance requirements between commercial gears, commercial gear requirements, commercial gear removal outside of season, commercial possession requirements outside of season, and recreational requirements. A comprehensive list can be found in the Sustainable Harvest Issue Paper on pg. 71.

Increased Recreational Access

Allow a one-fish ocellated bag limit in an early season from March 1 – April 15

Inlet Corridors

Do not establish inlet corridors for southern flounder during spawning migrations

Adaptive Management

Implement adaptive management strategy for the southern flounder fishery

Slot Limits

Do not implement a slot limit at this time

Phasing Out Large-mesh Gill Nets

Continue to allow anchored large-mesh gill nets to harvest southern flounder during the commercial season

Additional MFC Management

1. Based on recognition of a series of coincident concerns specific to the initial steps in rebuilding the southern flounder fishery, the transition to a 50/50 commercial/recreational parity allocation be delayed by 2 years (time for at least 1 cycle of larval to female maturity) with allocations: 2023: 70/30; 2024: 70/30; 2025: 60/40; 2026: 50/50. In 2024, as the start of the allocation shift is approached, the DMF will provide recommendations to the MFC on approaches to maintaining a sustainable suballocation for the commercial pound net fishery (as needed based on the economic and biotic conditions at that time).
2. A resolution that the MFC recognizes that there may need to be consideration of a moratorium if there are continued excesses in the allowable catch of flounder in both sectors.

DEQ Secretary and Legislative Review

Draft Amendment 3, including the Commission's preferred management measures, was reviewed by the Department of Environmental Quality Secretary and the Joint Legislative Oversight Committee on Agriculture and Natural and Economic Resources. No additional comments were received during the review period.

AMENDMENT 3 DRAFT

North Carolina
Southern Flounder (*Paralichthys lethostigma*)
Fishery Management Plan

Amendment 3

By

North Carolina Division of Marine Fisheries

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ACKNOWLEDGMENTS

Amendment 3 to the North Carolina (NC) Southern Flounder Fishery Management Plan (FMP) was developed by the NC Department of Environmental Quality (NCDEQ), North Carolina Division of Marine Fisheries (NCDMF) under the direction of the NC Marine Fisheries Commission (NCMFC) with the advice of the Southern Flounder Advisory Committee (AC). Deserving special recognition are the members of the Southern Flounder AC and the NCDMF Plan Development Team (PDT) who contributed their time and knowledge to this effort.

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

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GLOSSARY OF TERMS

Several links to resources with a glossary of fishery terms are available below.

NCDMF: Defining Fisheries: A User's Glossary
ASMFC: Acronyms and Glossary of Commonly Used Terms
NOAA: Fisheries Glossary
FAO: Term Portal

LIST OF ACRONYMS

ACCSP—Atlantic Coast Cooperative Statistics Program
APAIS—Access Point Angler Intercept Survey
APT—Average Landings Per Trip
ASAP—Age Structured Assessment Program
ASMFC—Atlantic State Marine Fisheries Commission
CAP—Coastal Angling Program
CHPP—Coastal Habitat Protection Plan
CRFL—Coastal Recreational Fishing License
EEZ—Exclusive Economic Zone
ESA—Endangered Species Act
F—Fishing Mortality
FAO—Food and Agriculture Organization of the United Nations
FES—Fishing Effort Survey
FEUS—Fishery Economics of the U.S.
FMP—Fishery Management Plan
G.S. —General Statute
IMPLAN—Impact Analysis for Planning
ISM—Inch Stretched Mesh
ITP—Incidental Take Permits
MAFMC—Mid-Atlantic Fishery Management Council
MRIP—Marine Recreational Information Program
NCAC—North Carolina Administrative Code
NCDEQ—North Carolina Department of Environmental Quality
NCDMF—North Carolina Division of Marine Fisheries
NCDWR—North Carolina Division of Water Resources
NCMFC—North Carolina Marine Fisheries Commission
NCTTP—North Carolina Trip Ticket Program
NMFS—National Marine Fisheries Service
NOAA—National Oceanic and Atmospheric Administration
PSE—Proportional Standard Error
RSCFL—Retired Standard Commercial Fishing License
RCGL—Recreational Commercial Gear License
SAV—Submerged Aquatic Vegetation

SCFL—Standard Commercial Fishing License
SSB—Spawning Stock Biomass
TAC—Total Allowable Catch
TAL—Total Allowable Landings
TL—Total Length
#PAR—Number of Participants

EXECUTIVE SUMMARY

North Carolina's southern flounder resource has been harvested since the 1800s, with the first recorded landings in 1889. Southern flounder supports one of the largest and most valuable commercial fisheries in North Carolina and accounts for approximately 99% of the Atlantic coast commercial southern flounder landings. Recreationally, southern flounder in North Carolina has been the most targeted species for 20 of the last 30 years. The North Carolina recreational southern flounder fishery ranks second on the east coast for harvest and has more releases than any other state.

The 2019 coast-wide stock assessment, including data through 2017, determined the southern flounder stock is overfished and overfishing is occurring. North Carolina law requires management action to end overfishing within two years. Recovery of the stock from an overfished condition must occur within 10 years and provide at least a 50% probability of success from the date the plan is adopted. Rebuilding of this stock in 10-years requires a minimum reduction of 52% in total annual removals by weight for both the commercial and recreational fisheries based on 2017 harvest (landings and dead discards). Amendment 3 further refines and builds on action taken in Amendment 2, which adopted a more conservative 72% reduction for the fisheries to help ensure the statutory requirements for rebuilding the southern flounder stock, described above, are met. Management strategies implemented through Amendment 3 will not restart the time requirements set in Amendment 2 as approved in August 2019, that are necessary to meet the statutory mandates.

The goal of Amendment 3 is to manage the southern flounder fishery to achieve a self-sustaining population that provides sustainable harvest using science-based decision-making processes. The objectives to achieve this goal include: maintain/restore the southern flounder spawning stock with expansion of age structure and abundance to prevent overfishing; restore, enhance, and protect habitat and environmental quality; monitor and manage the southern flounder fishery and its ecosystem impacts; promote stewardship of the resource through outreach and interjurisdictional cooperation; and promote the restoration, enhancement, and protection of habitat consistent with the Coastal Habitat Protection Plan (CHPP).

To meet statutory requirements to achieve a self-sustaining southern flounder population, sustainable harvest is addressed in the FMP to ensure the long-term viability of the commercial and recreational fisheries. Other issues in the plan include increased recreational access, inlet corridors, adaptive management, sector allocations, slot limits, and phasing out anchored large-mesh gill nets from the North Carolina southern flounder fishery. Specific recommendations for each issue are as follows:

1) Sustainable Harvest:
   Selected quantifiable management measures for recovering the stock are:
   - implementation of a commercial quota allocated between mobile gears and pound nets where the state's mobile commercial gears are divided into two areas using the existing Incidental Take Permit (ITP) boundary line for management units B–

D and the state's pound net fishery is divided into three areas, consistent with Amendment 2;
- maintain 72% reduction and current sub-allocation for the pound net fishery with direction from the North Carolina Marine Fisheries Commission (NCMFC) as follows: "In 2024, as the shift in allocation is set to start the Division will provide recommendations to the NCMFC on approaches to maintaining a sustainable sub-allocation for the commercial pound net fishery, as needed based on the economic and biotic conditions at that time"; and
- implement a single season for the recreational gig and hook-and-line fisheries to constrain them to an annual quota.

These management measures in conjunction with accountability measures that will better maintain flounder harvest to the overall quota are estimated to result in a 72% harvest reduction from the 2017 harvest value.

Selected non-quantifiable management measures include:
- the use of trip limits specifically for pound nets and gigs to allow limited harvest within the quota after reaching the division's initial closure threshold;
- a reduction in the recreational bag limit to one fish per person per day; and
- prohibit the use of Recreational Commercial Gear License (RCGL) gear for the harvest of southern flounder.

These management measures, while not having measurable reductions, could help improve the condition of the southern flounder stock and provide tools for meeting management targets.

Additionally, a resolution was passed that the NCMFC recognizes that there may need to be consideration of a moratorium if there are continued excesses in the allowable catch of flounder in both sectors.

2) Increased Recreational Access by Managing Southern Flounder Separately from other Flounder Species:
The selected management measures include:
- one-fish ocellated flounder bag limit during March 1 – April 15 for hook-and-line in ocean waters only
- one-fish any flounder bag limit during the southern flounder season.

These measures increase recreational access to summer and Gulf flounder while maintaining the harvest reductions in the southern flounder fishery. The earliest this spring season could occur is 2023 as summer flounder management conservation equivalency is needed from the Atlantic States Marine Fisheries Commission (ASMFC) and Mid-Atlantic Fishery Management Council (MAFMC). Any harvest of southern flounder in this early season will impact the length of the fall southern flounder season.

3) Inlet Corridors:
The selected management strategy is to not implement inlet corridors for southern flounder at this time. Landings and tagging data have not identified inlets as areas of increased exploitation for southern flounder, and research is being conducted to provide additional information about southern flounder inlet use.

4) Adaptive Management:
The selected management strategy is to adopt the adaptive management framework based on the approved peer-reviewed stock assessment. Implementation of an adaptive management strategy for the North Carolina southern flounder fishery provides flexibility for maintaining the total allowable landings. The framework allows for additional protections for the fishery while ensuring future sustainability.

5) Sector Allocations in the Southern Flounder Fishery:
At the Nov. 2020 business meeting, the NCMFC requested analysis of various recreational and commercial allocation percentages. In March 2021, the NCMFC voted on and approved sector allocations of 70/30 commercial to recreational for 2021 and 2022 and shifting to 60/40 for 2023, and 50/50 parity beginning in 2024.

Based on recognition of a series of coincident concerns specific to the initial steps in rebuilding the southern flounder fishery, the NCMFC voted in Feb. 2022 to delay the transition to 50/50 parity by two years (time for at least one cycle of larval to female maturity). The selected allocations will be 70/30 for 2023 and 2024, 60/40 for 2025, and 50/50 parity starting in 2026.

6) Implementing a Slot Limit in the Southern Flounder Fishery:
The impacts of harvest size slot limits at various sizes in the recreational hook-and-line southern flounder fishery were examined. The selected management measure is not to implement a slot limit and maintain the 15-inch total length (TL) minimum size.

7) Phasing Out Large-Mesh Gill Nets in the North Carolina Southern Flounder Fishery:
The selected management strategy is to continue to allow anchored large-mesh gill nets to harvest southern flounder in the North Carolina southern flounder fishery. The issue to phase out large-mesh gill nets by the end of the current sea turtle ITP in 2023 originated from a request by the NCMFC. Sustainable harvest in the southern flounder commercial fishery can be achieved with or without the use of anchored large-mesh gill nets.

INTRODUCTION

This is Amendment 3 to the N.C. Southern Flounder FMP. The last review of the plan (Amendment 2) was approved by the NCMFC in August 2019 and implemented a reduction in fishing mortality in the commercial and recreational fisheries to a level that ends overfishing within two years and allows the spawning stock biomass (SSB) to increase between the threshold and the target within 10 years. This was accomplished via targeted reductions of 62% in total removals in 2019 and 72% beginning in 2020. While the minimum statutory requirement to meet the rebuilding threshold was a 52% reduction, management actions approved through Amendment 2 exceeded the minimum in order to increase the probability of successfully rebuilding this important recreational and commercial resource. Amendment 2 followed a peer review workshop evaluating the 2018 coast-wide stock assessment for southern flounder. At the end of the peer review workshop, the Southern Flounder Review Panel accepted the pooled-sex run of the Age Structured Assessment Program (ASAP) model presented at the review workshop as a valid basis of management for at least the next five years, with the expectation that the model will be updated with data through 2017 to provide the best, most up to date estimate of stock status for management. Results of the 2019 update indicate the stock is overfished and overfishing is occurring (Flowers et al. 2019). Analyses were conducted to estimate projections of reductions to fishing mortality that is necessary to end overfishing and to determine which reductions would be necessary to rebuild the spawning stock biomass and end the overfished status.

Amendment 2 was expedited to begin rebuilding the stock immediately. Due to the shortened time frame for development, Amendment 2 incorporated a seasonal approach to meet reductions while deferring more complex and comprehensive management strategies to be developed in Amendment 3. In Amendment 3, the management strategies have been updated to include a quota-based fishery with accountability measures for both the commercial and recreational sectors based on delayed allocation changes, commercial gear sub-allocations, commercial trip limits, reductions in recreational bag limits, prohibiting recreational commercial gear license holders from harvesting southern flounder, increased recreational access through spring ocellated flounder season, and adaptive management. These strategies will be implemented through the Director's proclamation authority following the adaptive management framework adopted by this plan.

To see further details on past FMP amendments, supplements, or revisions, go to the latest annual FMP update (https://deq.nc.gov/about/divisions/marine-fisheries/public-information-and-education/managing-fisheries/fmp).

MANAGEMENT AUTHORITY

All management authority for the North Carolina southern flounder fishery is vested in the State of North Carolina. The NCMFC adopts rules and policies and implements management measures for the southern flounder fishery. While sole management authority of southern flounder rests with the state, in North Carolina recreational flounder management is by an aggregate of three species [southern, summer (*P. dentatus*), and Gulf (*P. albigutta*) flounders]. Therefore, the state's management of southern flounder is also impacted in the ocean by the joint ASMFC/

MAFMC Summer Flounder, Black Sea Bass, and Scup FMP. This impacts southern flounder management in ocean waters off North Carolina with ASMFC impacting the state waters and MAFMC impacting the federal Economic Exclusion Zone (EEZ) waters. Approval of changes by ASMFC may not be required if the changes are expected to be more restrictive than the management measures already approved by ASMFC. Changes to the summer flounder fishery in EEZ waters off North Carolina may be impacted by the MAFMC and National Marine Fisheries Service (NMFS) until conservation equivalencies are approved by NMFS.

See http://portal.ncdenr.org/web/mf/nc-fisheries-management for further information on fishery management in North Carolina.

GOAL AND OBJECTIVES

Goal: Manage the southern flounder fishery to achieve a self-sustaining population that provides sustainable harvest using science-based decision-making processes. The following objectives will be used to achieve this goal:

Objectives:

1. Implement management strategies within North Carolina and encourage interjurisdictional management strategies that maintain/restore the southern flounder spawning stock with expansion of age structure of the stock and adequate abundance to prevent overfishing.
2. Restore, enhance, and protect habitat and environmental quality necessary to maintain or increase growth, survival, and reproduction of the southern flounder population.
3. Use biological, environmental, habitat, fishery, social, and economic data needed to effectively monitor and manage the southern flounder fishery and its ecosystem impacts.
4. Promote stewardship of the resource through increased public outreach and interjurisdictional cooperation throughout the species range regarding the status and management of the southern flounder fishery, including practices that minimize bycatch and discard mortality.
5. Promote the restoration, enhancement, and protection of habitat and environmental quality in a manner consistent with the Coastal Habitat Protection Plan.

DESCRIPTION OF THE STOCK

BIOLOGICAL PROFILE

Physical Description

Southern flounder exhibit a unique body type compared to most other fish species, belonging to a subgroup known as flatfishes. While most fish species are bilaterally symmetrical and have body parts equally distributed on each side of their body, flatfish species, including southern flounder, possess both eyes on one side of the body and are considered to lack symmetry. Newly hatched southern flounder larvae have bilateral symmetry but after currents carry them into the estuaries they, like other left-eyed flounder (e.g., summer flounder), undergo metamorphosis (Figure 1; Francis and Turingan 2008; Schreiber 2013).

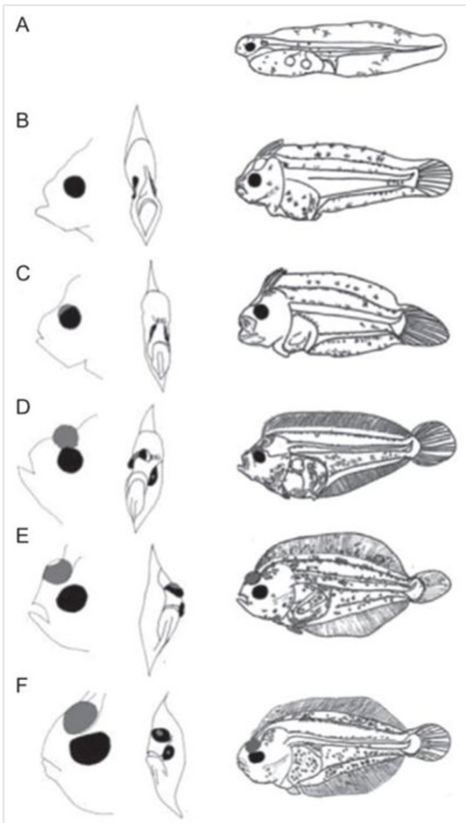

Figure 1. Metamorphosis stages of the summer flounder *Paralichthys dentatus*. (A) Hatched yolk-sac larva. (B) Pre-transformation larva before eye migration commences. (C) Early metamorphosis and the beginning of eye migration. (D) Mid-metamorphosis. (E) Metamorphic climax, right eye has migrated over the dorsal midline. (F) Young juvenile. Left column in B–D shows the migration of the eye across the skull; migrating right eye is shaded in gray. Rightmost column shows whole-body morphological changes at each stage. Image originally printed in Martinez and Bolker 2003.

Due to this metamorphosis, southern flounder are known to be “left handed” because the right eye shifts and the eye-side of the flounder is the left side (Daniels 2000). Southern flounder also exhibit a unique pattern of pigmentation where the “top” side of the fish is dark, contrasting with the white coloration typical of the “bottom” side. Southern flounder tend to be bottom dwellers and can use the dark pigmentation on the “top” side to blend into the surrounding habitat to hide from predators and ambush prey (Arrivillaga and Baltz 1999).

Distribution

Southern flounder are widely distributed along the United States (Blandon et al. 2001). In the Atlantic Ocean, southern flounder reside in coastal habitats from North Carolina to Cape

Canaveral, Florida. A small number of southern flounder have been observed north of North Carolina. In the Gulf of Mexico, southern flounder can be found from northern Mexico to Tampa, Florida. Genetic studies have indicated there is little to no movement of southern flounder between the Gulf of Mexico and Atlantic Ocean as the peninsula of Florida acts as an ecological barrier (Blandon et al. 2001; Anderson and Karel 2012; Midway et al. 2014).

Tagging studies show that individual southern flounder are capable of undergoing movements from North Carolina to the east coast of Florida (Craig et al. 2015; Loeffler et al. 2019). Additionally, genetic studies indicate that individuals from North Carolina to Florida are capable of spawning together and that the Atlantic Ocean population is well mixed (Wang et al. 2015). While each Atlantic state manages southern flounder in their own waters, based on this life history information, a multi-state cooperative group stock assessment was used to determine the status of the unit stock (see the *Stock Status* section below).

Habitat

More information is known about habitat use for southern flounder in estuarine habitats than the ocean. As southern flounder mature around age-2, they migrate out of the estuaries and spawn in the ocean but this migration to ocean spawning grounds is not well understood (Figure 2). No surveys or large-scale fisheries exist for these fish in the ocean and therefore, it is difficult to directly observe where adult southern flounder go after they leave the estuary and what drives their habitat selection once offshore. The location and/or the number of offshore spawning ground(s) is currently unknown (Midway and Scharf 2012), though research is currently underway to determine these locations and migratory pathways. Most of the direct examination of southern flounder habitat use has occurred within estuarine environments where juveniles are easily accessible for scientific study (Burke et al. 1991; Fitzhugh et al. 1996; Froeschke et al. 2013).

Larval southern flounder are transported into sounds and estuaries during late winter and early spring by wind-driven currents (Figure 2; Taylor et al. 2010) and survival is greatly influenced by a number of variables. Once within the estuary, southern flounder typically settle in low salinity areas (Burke et al. 1991; Miller et al. 1991; Lowe et al. 2011). Despite the tolerance of young juvenile southern flounder to various salinities, low dissolved oxygen values have been shown to inhibit growth of newly settled southern flounder (Taylor and Miller 2001; Del Toro-Silva et al. 2008). As southern flounder age they can tolerate prolonged periods of low dissolved oxygen, and are thought to remain in low oxygen areas as a trade-off to expending energy by moving into other areas where environmental conditions may not necessarily improve (Ellis 2007).

In addition to water quality influences, bottom structure and water depth are important drivers of juvenile southern flounder habitat selection. The presence of sea grass and/or marsh edge has been shown to have a positive effect on southern flounder abundance (Nañez-James et al. 2009; Furey and Rooker 2013) and these structures have been known to serve as refuge for estuarine juvenile fishes (Rooker et al. 1998; Stunz et al. 2002). Several studies have indicated that water depths of less than three feet are significantly related to southern flounder abundance (Walsh et al. 1999; Furey et al. 2013; Froeschke et al. 2013). Potentially, the use of shallow near-shore areas by southern flounder during their juvenile period increases survivorship by protecting individuals from predators (Manderson et al. 2004). However, southern flounder overwintering in the estuary may select deeper waters or move to higher salinity areas near ocean inlets where environmental conditions are more stable during winter months (Hollensead 2018). For additional information on how habitat and water quality affect southern flounder see the *Ecosystem and Fishery Impacts* section.

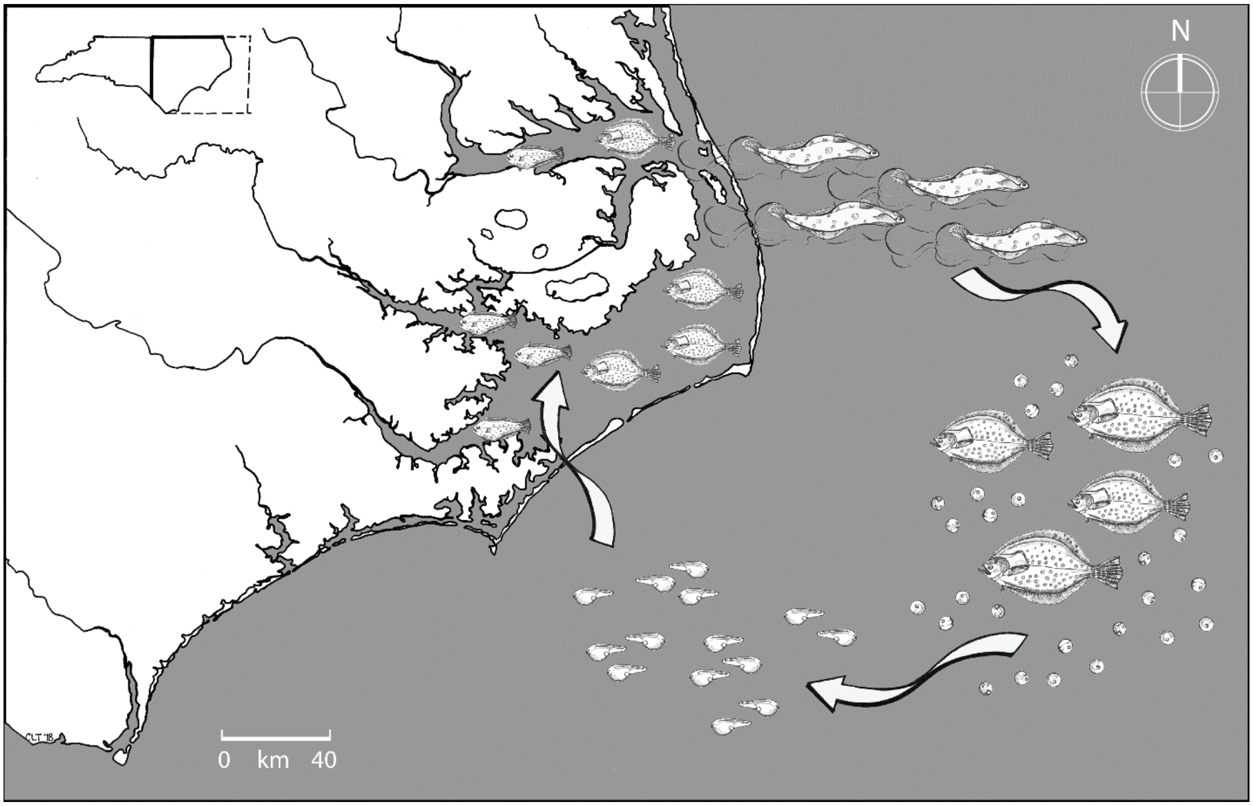

Figure 2. Artist interpretation of the southern flounder life cycle. Image originally printed in Hollensead 2018.

Reproduction

Southern flounder migrate out of North Carolina estuaries from mid-October to mid-November to spawn (Hollensead 2018). No direct observation of spawning has been observed in the wild, but laboratory experiments have been conducted to quantify southern flounder fecundity (number of eggs) and fertilization success (Watanabe et al. 2001).

In North Carolina, 50% of females are considered mature by 16 inches TL and ages 1 or 2 (Midway and Scharf 2012). This length at maturity is larger than what has been reported in Florida (8.4 inches TL; Topp and Hoff 1972) and the Gulf of Mexico (12 inches TL; Corey et al. 2017), indicating a potential shift in length-at-maturity the further south the species occurs (Lee et al. 2018).

Age and Growth

Growth rate and length-at-age in North Carolina are highly variable for southern flounder (Fitzhugh et al. 1996). Juvenile female southern flounder exhibit a higher growth rate than male southern flounder (Midway et al. 2015) and females generally attain a larger maximum size compared to males (Fischer and Thompson 2004). In North Carolina, the maximum observed age is older for females at nine years compared to six years for males and maximum observed length was 33 inches TL for females and 20 inches TL for males (Lee et al. 2018). Additional information on age and growth of southern flounder can be found in the annual Southern Flounder FMP Update located here: https://deq.nc.gov/about/divisions/marine-fisheries/public-information-and-education/managing-fisheries/fmp.

Predator-Prey Relationships

Southern flounder are bottom dwelling, ambush predators that use their unique coloring to camouflage themselves in order to opportunistically feed on a wide range of prey species (Burke 1995; Arrivillaga and Baltz 1999). Young juvenile southern flounder generally eat small invertebrate species (Ellis 2007) before shifting to a diet made up of mostly other fish species (Fitzhugh et al. 1996). In general, the most common prey fish species encountered in adult southern flounder diets are bay anchovy (*Anchoa mitchilli*), spot (*Leiostomus xanthurus*), and spotfin mojarra (*Eucinostomus argenteus*; Wenner et al. 1990). Some predators of southern flounder include sandbar sharks (*Carcharhinus plumbeus*; Ellis and Musick 2007) and bird species (Kellison et al. 2000; Hossain et al. 2002).

STOCK STATUS

Stock Unit Definition

The biological unit stock assumed for the stock assessment (Flowers et al. 2019) is based on multiple tagging studies (Ross et al. 1982; Monaghan 1996; Schwartz 1997; Craig and Rice 2008), genetic studies (Anderson and Karel 2012; Wang et al. 2015), and an otolith morphology study (Midway et al. 2014), all of which provide evidence of a single stock occurring in waters of North Carolina, South Carolina, Georgia, and the east coast of Florida.

Assessment Methodology

Landings and dead discards were incorporated into a quantitative model that estimates both historical and current population sizes and harvest rates. Landings and dead discards were available from the commercial and recreational fisheries. Eight fishery-independent surveys were also inputs into the model, including recruitment indices from North Carolina, South Carolina, and Florida and adult indices from North Carolina, South Carolina, Georgia, and Florida, and a near-shore ocean survey from Cape Hatteras, North Carolina to Cape Canaveral, Florida.

When considering population size and long-term viability, stock assessments most often use a measure of female spawning stock biomass to determine the population's health. Female spawning stock biomass includes female fish that are mature and capable of producing offspring. Fishing mortality, abbreviated as *F*, is a measure of how fast fish are being removed from the population by the different fisheries. Removals include those fish that are kept and those that are discarded dead or die after release.

The stock assessment's current (2017) estimates of female SSB and fishing mortality rates were compared to levels that are considered sustainable. These sustainable levels are based on established reference points that include a target and threshold. The threshold is the minimum level required for sustainability and when that level is achieved, the stock is considered healthy. The target is a level that provides a buffer to minimize risk and increases the probability of successfully rebuilding the stock. If current female SSB is less than the threshold for biomass, the stock is said to be overfished. If the current harvest rate is greater than the associated threshold, the current rate of removals is too high and overfishing is said to be occurring. Overfishing is the state of removing fish at an unsustainable rate that will ultimately reduce the female spawning stock biomass and result in an overfished stock.

Current Stock Status

Results show that SSB has decreased since 2006 (Figure 3) and recruitment, while variable among years, has a generally declining trend (Figure 4). Fishing mortality did not exhibit much inter-annual variability and suggests a decrease in the last year of the time series (Figure 5).

The model estimated a value of 0.35 for $F_{35\%}$ (fishing mortality target) and a value of 0.53 for $F_{25\%}$ (fishing mortality threshold; Figure 5). The estimate of $SSB_{35\%}$ (target) was 5,452 metric tons and the estimate of $SSB_{25\%}$ (threshold) was 3,900 metric tons (Figure 3).

The level of female SSB that represents the minimum level of sustainability for southern flounder was estimated at 8.6 million pounds. The stock assessment estimate of female SSB for southern flounder in 2017 was 2.3 million pounds. Because the current (2017) estimate of female SSB is below the threshold reference point, the stock is considered overfished (Figure 3). The probability that the 2017 estimate of SSB is below the threshold value is 100%.

The assessment model estimated that *F* can be no greater than 0.53 for a sustainable southern flounder population. The current (2017) estimate of *F* from the stock assessment was 0.91, which is above the threshold *F* reference point (Figure 5). Because the current (2017) *F* is above the threshold, overfishing is occurring. The probability the 2017 *F* is above the threshold value is 96%.

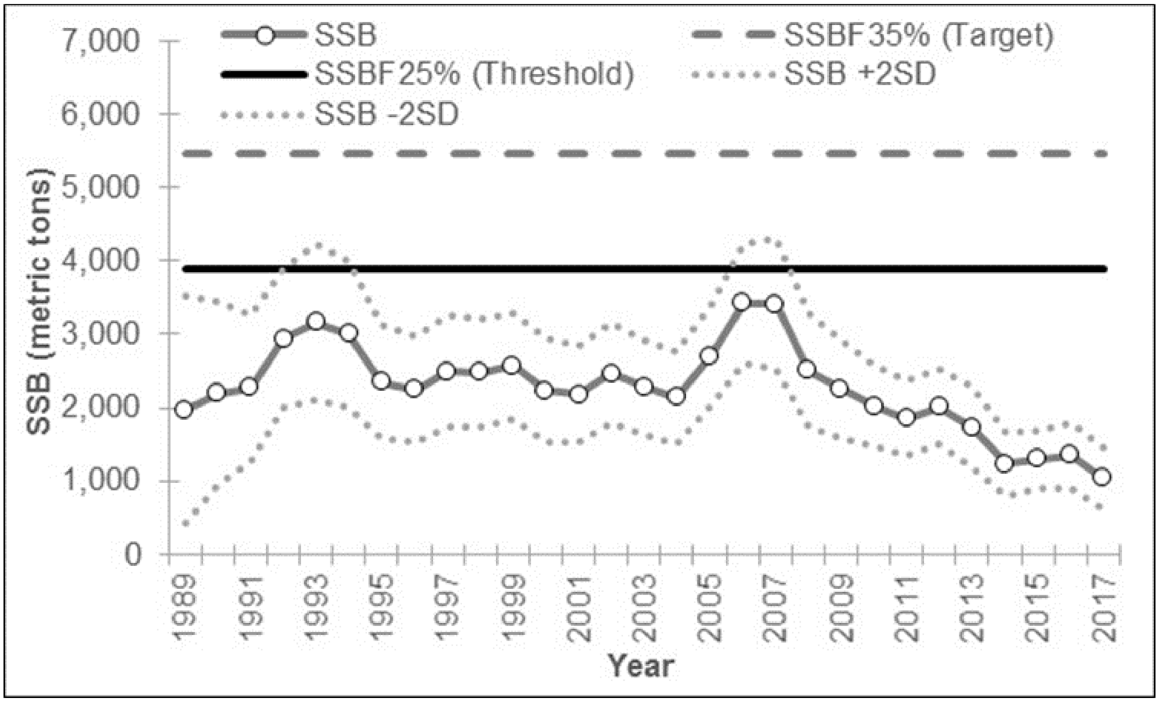

Figure 3. Predicted female spawning stock biomass (SSB) from the base run of the ASAP model, 1989–2017. Dotted lines represent ± 2 standard deviations (SD) of the predicted values. (Source: Flowers et al. 2019)

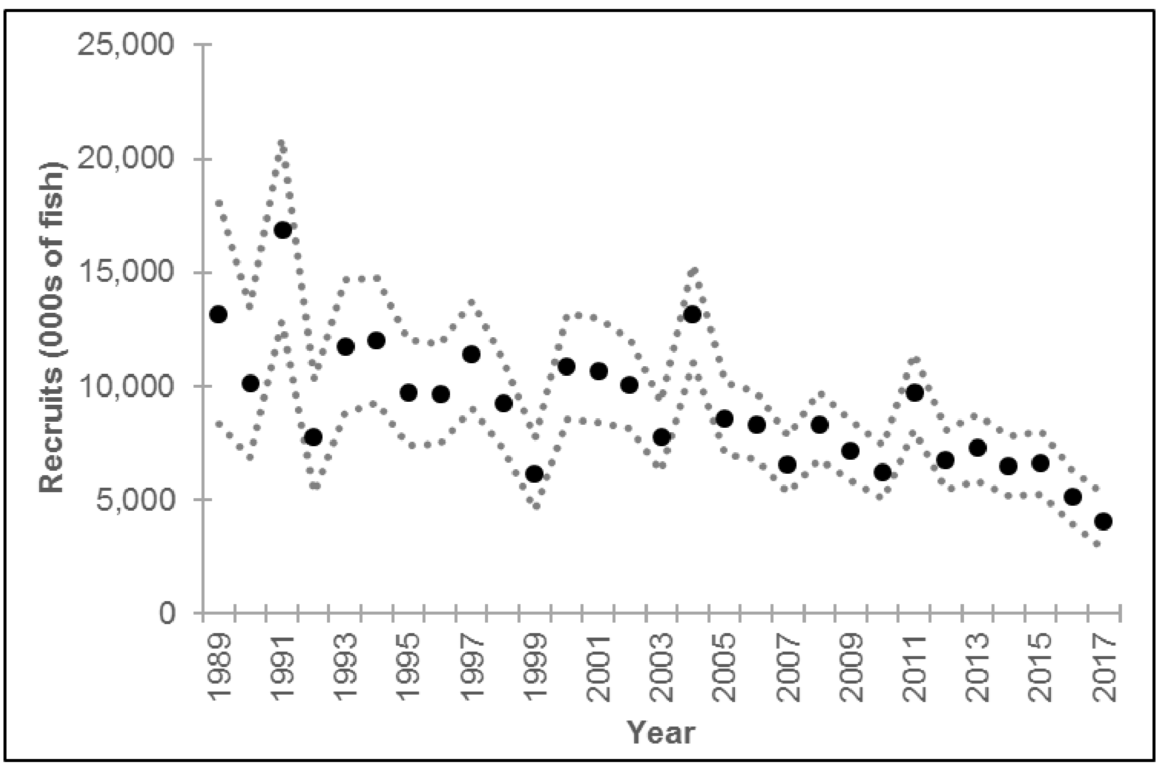

Figure 4. Predicted number of recruits (thousands of fish) from the base run of the ASAP model, 1989–2017. Dotted lines represent ± 2 standard deviations (SD) of the predicted values. (Source: Flowers et al. 2019)

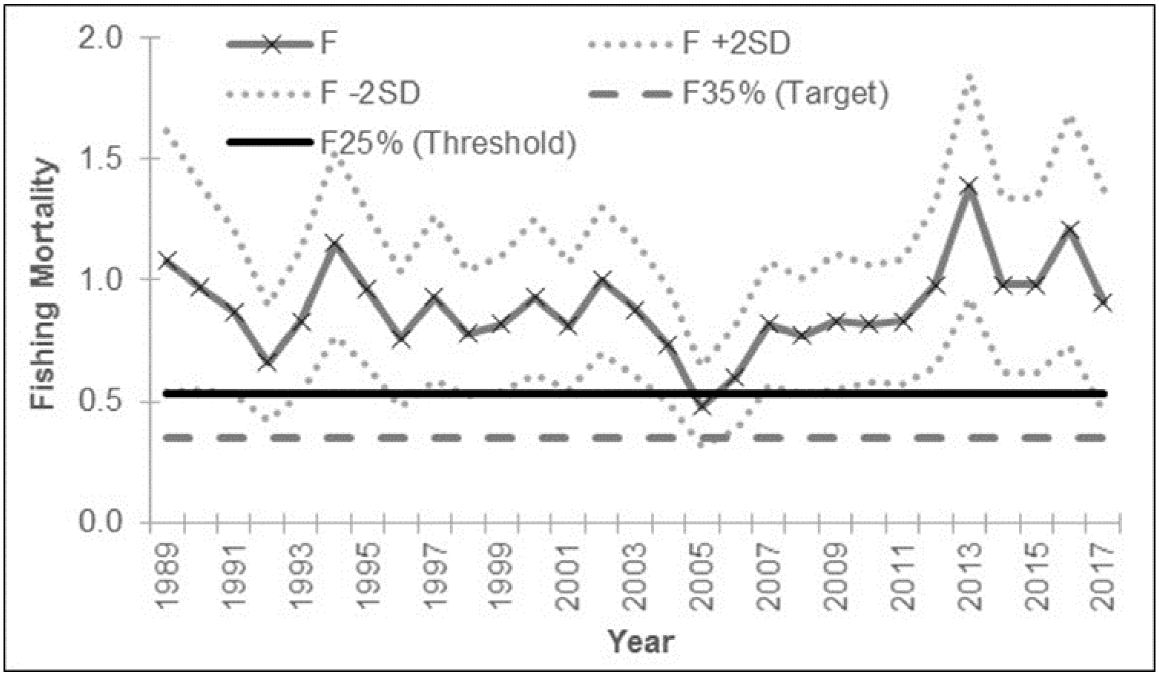

Figure 5. Predicted fishing mortality (*F*) rates (numbers-weighted, ages 2–4) from the base run of the ASAP model, 1989–2017. Dotted lines represent ± 2 standard deviations (SD) of the predicted values. (Source: Flowers et al. 2019)

Projections

Calculations were made to determine the reductions in total catch necessary to end overfishing and to reach the fishing mortality threshold and target. Additionally, a series of projections were performed to examine future stock conditions under various management scenarios. The calculations of percent reductions indicate that a minimum of a 31% reduction in total catch (landings plus discards from all fleets) would be required to end overfishing. However, while this reduction is sufficient to end overfishing in two years, it is not sufficient to rebuild SSB to meet the 10-year schedule to end the overfished status (Figure 6).

Projections were also carried out to determine the fishing mortality and the associated reduction in total catch necessary to end the overfished status and to reach the SSB target within 10 years (by 2028, assuming management imposed regulations beginning in 2019). The projections indicate that an *F* equal to 0.34 and a 52% reduction in total catch is needed to reach the SSB threshold by 2028 and end the overfished status (Figure 7). To reach the SSB target by 2028, *F* needs to be lowered to 0.18 and total catch needs to be reduced by 72% (Figure 8).

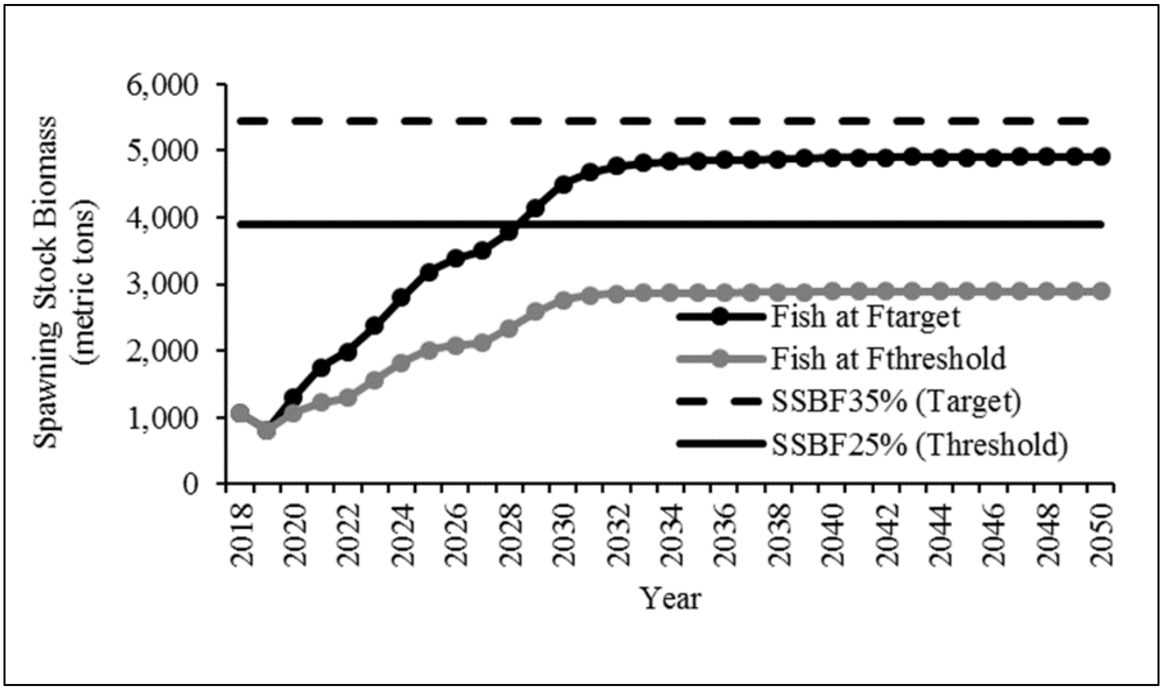

Figure 6. Projections of spawning stock biomass (SSB) related to fishing at a level to end overfishing in the required two-year period. Note: SSB does not rebuild within required ten-year time period. (Source: Flowers et al. 2019)

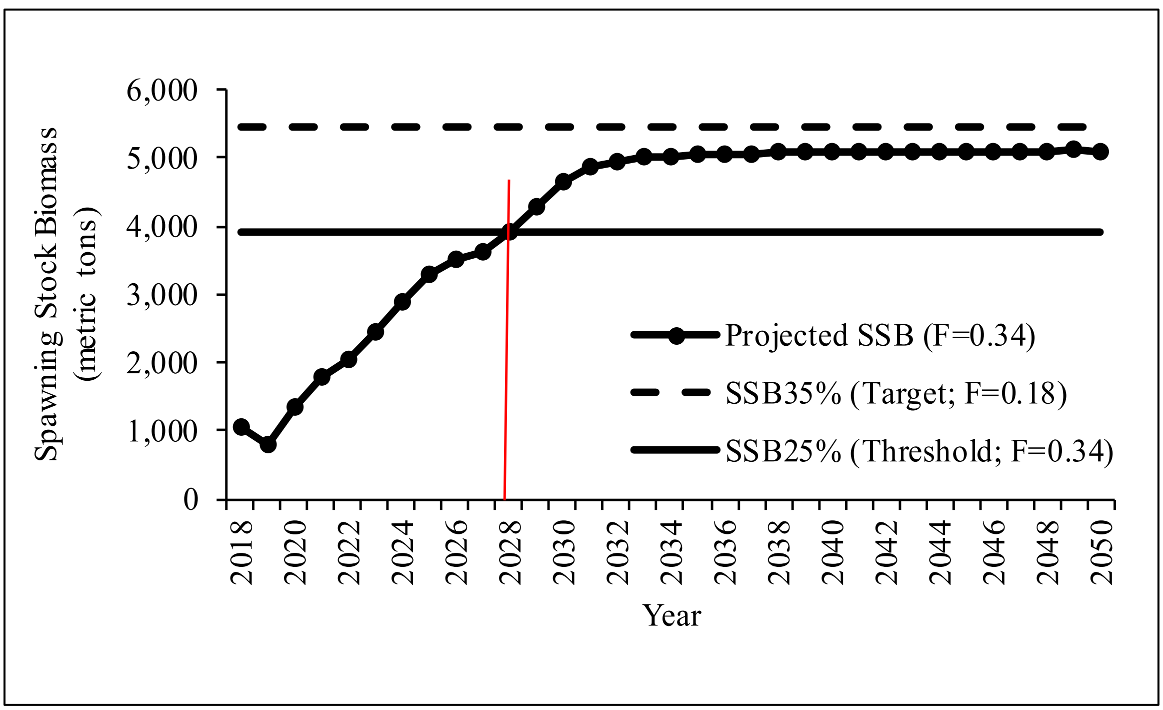

Figure 7. Predicted future spawning stock biomass (metric tons) assuming the fishing mortality value necessary to end the overfished status by 2028 (indicated by vertical red line). (Source: Flowers et al. 2019)

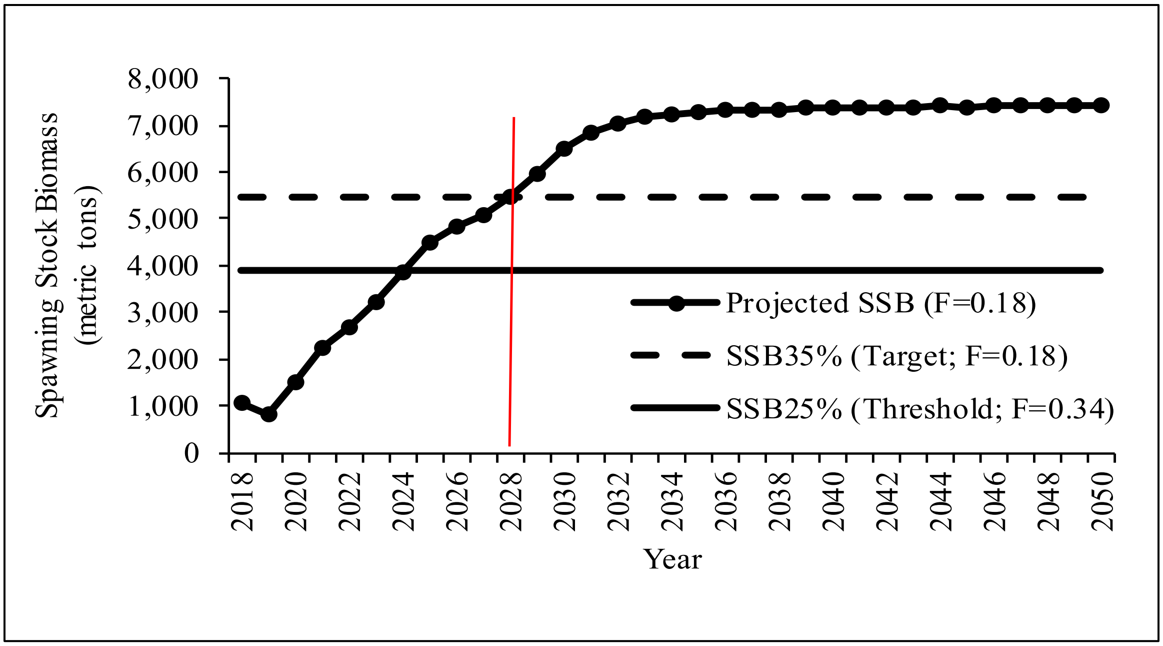

Figure 8. Predicted future spawning stock biomass (metric tons) assuming the fishing mortality value necessary to reach the SSB_{Target} by 2028 (indicated by vertical red line). (Source: Flowers et al. 2019)

ECOSYSTEM AND FISHERY IMPACTS

Habitat use patterns of southern flounder vary over time and space by life stage. The growth and survival of southern flounder within the habitats they use are maximized when water quality parameters, such as temperature, salinity, and dissolved oxygen, are within optimal ranges. For further information on habitat use by life stage and optimal water quality parameters, see the *Description of the Stock* section. Additional information on the habitats discussed below, threats to these habitats, and water quality degradation, as well as how these topics relate to fisheries can be found in the CHPP and various Division of Water Resources (NCDWR) publications (NCDWQ 2000a, 2008a; NCDEQ 2016a) (Figure 9).

While southern flounder can be found in both the estuaries and the ocean, more is known about the species as it occurs in the estuary. This section will mostly focus on the importance of the estuarine habitats, inlets, and ocean bottoms used by southern flounder and the broad effects of the southern flounder fishery on the habitat and ecosystem in these areas.

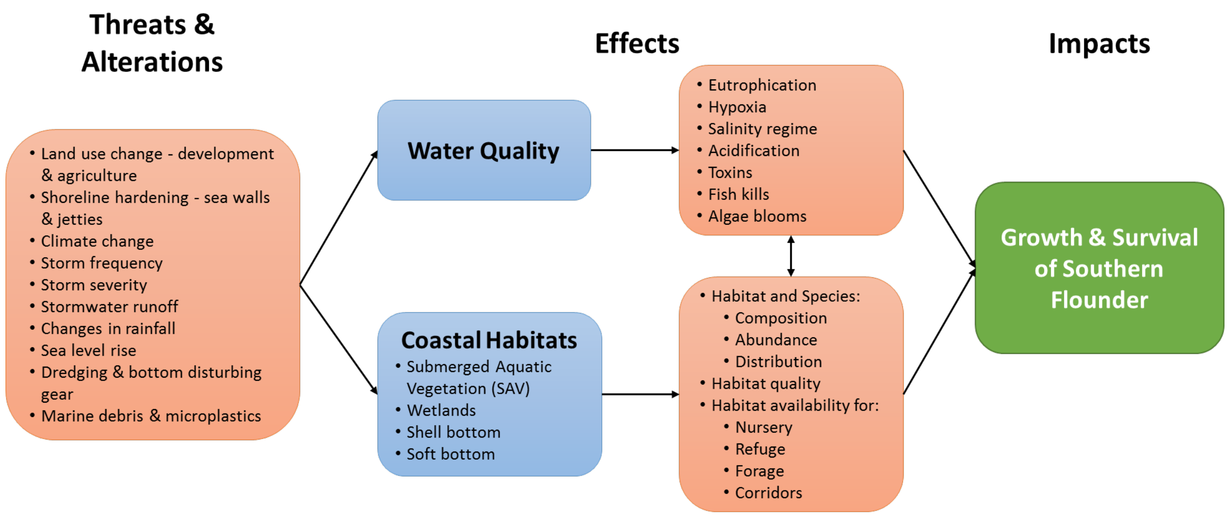

Figure 9. Effects of threats and alterations on water quality and coastal habitats and their ultimate impact on the growth and survival of southern flounder.

HABITAT DEGRADATION AND LOSS

Southern flounder migrate through the coastal ecosystem over their life cycle using multiple habitats. Many habitat types are particularly important as nursery, refuge, and forage habitats. Coastal inlets and ocean bottom also act as an important corridor from estuarine nursery habitat to ocean spawning areas. These and other potentially important flounder habitats are described in detail in the CHPP which can be found here: https://deq.nc.gov/about/divisions/marine-fisheries/public-information-and-education/habitat-information/chpp (NCDEQ 2016). Additionally, research is underway by the division and universities to identify spawning areas and associated habitats for southern flounder in the ocean.

Portions of these habitats have been degraded or lost over time by a variety of anthropogenic (human caused) sources. It is difficult to quantify how habitat degradation may alter southern flounder population dynamics, but it is important to understand how habitat loss and condition controls the growth and survival of estuarine fish species. Protection and enhancement of these areas may be particularly important for growth and survival of juveniles to adult southern flounder. Key habitats for juvenile southern flounder in estuaries for foraging, refuge, and their growth to adults include: submerged aquatic vegetation (SAV), wetlands, shell bottom, and soft bottom (Table 1; Rozas and Odum 1987; Burke et al. 1991; Mitsch and Gosselink 1993; Walsh et al. 1999; Graff and Middleton 2001; Nañez-James et al. 2009; Meyer 2011; Furey 2012; Furey and Rooker 2013; Scyphers et al. 2015; Dance and Rooker 2015).

When southern flounder reach spawning sizes, both inlets and ocean bottoms become critical habitats. Adults move to offshore ocean spawning grounds during the fall and winter to complete their life cycle. Larvae spawned offshore are transported into the estuarine system by nearshore and tidal currents entering the estuary through coastal inlets before settling in preferred estuarine habitats. It is believed that some adult southern flounder return through the inlets to the estuaries and rivers after spawning; however, some adult flounder are thought to remain in the ocean after spawning (Watterson and Alexander 2004; Taylor et al. 2008). The proportion of the adult spawning stock remaining in the ocean versus those returning to the estuaries is unknown. For more information on the importance of inlets on the southern flounder populations, see the *Inlet Corridors* issue paper.

WATER QUALITY DEGRADATION

Good water quality is essential, both for supporting the various life stages of southern flounder (Table 1) and maintaining their habitats. Naturally occurring and human caused activities can alter the preferred salinity or temperature conditions, elevate toxins, nutrients, turbidity, as well as lower dissolved oxygen levels which can degrade water quality.

Table 1. Water quality parameter ranges and habitats associated with different life stages of southern flounder.

Life Stage	Salinity (ppt)	Temperature (°C)	Dissolved Oxygen (mg/L)	Associated Habitats	Related literature
Adult	0–36	4–35	Greater than 5.0	Entire estuary and ocean	Reagan and Wingo 1985; Farmer et al. 2013; NCDEQ 2016
Larvae	9–36	16–35	Greater than 3.7	Inlet and ocean water column, estuarine soft bottom	Williams and Duebler 1968; Reagan and Wingo 1985; Burke et al. 1991; Moustakas et al. 2004; NCDEQ 2016
Juveniles	0.02–35	16–35	Greater than 3.7	Wetlands, SAV, shell bottom, soft bottom	Reagan and Wingo 1985; Taylor et al. 2000; Taylor and Miller 2001; Del Toro-Silva et al. 2008; Nañez-James et al. 2009; Lowe et al. 2011; Farmer et al. 2013; NCDEQ 2016

More detailed information on water quality degradation, including the topics of hypoxia, toxins, and temperature in North Carolina and the effect on fish stocks can be found through the NCDWR guides (NCDWQ 2000, 2008) and the CHPP (NCDEQ 2016).

GEAR IMPACTS ON HABITAT

Bottom disturbing fishing gear can impact ecosystem function through habitat degradation. Static (or non-mobile) gear used in a fishery tends to have a lesser impact on habitat compared to mobile gear, as the amount of area affected by the static gear tends to be insignificant when compared to that of the mobile gear (Rogers et al. 1998). Both bottom disturbing and static gears can have impacts of bycatch while in operation and can have negative impacts if the gear is abandoned or lost.

The primary gears used in the southern flounder commercial fishery are pound nets, gill nets, and gigs. In the recreational fishery hook-and-line and gigs are the primary gears. Other gears that may harvest southern flounder as incidental catch include hard crab and peeler pots, crab and shrimp trawls, channel nets, fyke nets, and haul seines. Most gears that interact with southern flounder are considered static gear (Barnette 2001; NCDEQ 2016), thus, in general fishing gear targeting flounder have minimal impact on habitat.

BYCATCH AND DISCARDS OF NON-TARGET SPECIES

Finfish and shellfish species may be caught as incidental bycatch in fisheries targeting southern flounder and may be retained or discarded as a result of economic, regulatory, or personal considerations. For discussion on bycatch and discards of southern flounder from the commercial and recreational fisheries, see the *Description of the Fisheries* section.

Other Finfish Species

From 2013 to 2017, annual southern flounder gill net trips landed 162,141 pounds (24%) of fish other than flounder (incidental catch), while these same trips averaged 520,227 pounds (76%) of southern flounder. Four species, or groups of species, comprised over 77% of the incidental catch by weight: red drum (*Sciaenops ocellatus*), black drum (*Pogonias cromis*), catfishes, and sheepshead (*Archosargus probatocephalus)*. Over 40 additional species, including spotted seatrout (*Cynoscion nebulosus*), bluefish (*Pomatomus saltatrix*), striped mullet (*Mugil cephalus*), and striped bass (*Morone saxatilis*) comprised the remaining 23% of the catch.

Six species comprised approximately 76% of the observed discards (live and dead; by number): Atlantic menhaden (*Brevoortia tyrannus*), blue crab (*Callinectes sapidus*), common carp (*Cyprinus carpio*), cownose rays (*Rhinoptera bonasus*), red drum, and Atlantic stingrays (*Dasyatis sabina*). Additionally, southern flounder make up 10% of the overall discards from the southern flounder gill net fishery (for further discussion see the *Description of the Fishery* section). An additional 135 species make up the remaining 14% of discarded catch, including bluefish, Atlantic croaker (*Micropogonias undulatus*), and horseshoe crab (*Limulus polyphemus*). From June through October (2013–2017) greater than 75% of all gill net trips made were targeted flounder trips.

Over 70% of the landings from flounder pound nets were southern flounder from 2013 to 2017. Summer and Gulf flounders comprised approximately 2% of the harvest during the same time frame. Other species commonly captured included black drum, harvest fish (*Peprilus alepidotus*), and red drum. More than thirty additional species including sheepshead, butterfish (*Peprilus triacanthus*), and catfish made up the remaining catch; with none of these species individually exceeding 1% of the total catch. Mortality of non-target species discarded from pound nets is likely minimal, provided fishing practices are such that non-harvested fish are handled carefully and released immediately.

Gigging for southern flounder results in very little bycatch of non-flounder species since fish are gigged by sight. Other flounder species, such as Gulf and summer flounder, are subject to the same size restrictions and may be taken in fishing operations targeting southern flounder. Giggers in both the recreational and commercial fisheries can be prone to gig undersized flounder, resulting in some regulatory discards of these other flounder species.

Protected Species

Protected species (sometimes referred to as "protected resources") is a broad term that encompasses a range of organisms that are protected by federal or state statutes because their populations are at risk or vulnerable to risk of extinction. Federal statutes include the Endangered Species Act (ESA), Marine Mammal Protection Act, and the Migratory Bird Treaty Act. Of the federally protected species, the following are known or suspected to be incidentally taken in the southern flounder fishery: sea turtle species, sturgeon species, common bottlenose dolphin (*Tursiops truncatus*, and various bird species. There may be additional protected species that occasionally occur in estuarine waters and rarely interact with the southern flounder fisheries. The division currently has two ITPs (Section 10(a)(1)(B) of the ESA) that establish legal take thresholds for sea turtles and Atlantic sturgeon (*Acipenser oxyrinchus*) in estuarine gill nets (NMFS 2013, 2014). As part of the ITPs, the division operates an observer program to monitor take levels and implement adaptive management measures based on those levels (for the most recent annual reports see Byrd et al. 2020a, 2020b).

The bottlenose dolphin is the predominant marine mammal in North Carolina estuarine waters (Hayes et al. 2018). Incidental takes of bottlenose dolphins in ocean gill nets have been documented by federal fisheries observers (Lyssikatos and Garrison 2018). Evidence of incidental takes in estuarine and ocean gill nets has been documented on bottlenose dolphin strandings; however, the level of bycatch in estuarine gill nets is unknown (Byrd et al. 2014; Byrd and Hohn 2017). State-wide observer coverage of estuarine gill nets (ITP year 2014–present) conducted by the division documented only one incidental take of a bottlenose dolphin (small-mesh; McConnaughey et al. 2019). Entanglement of bottlenose dolphins in North Carolina pound nets is thought to be uncommon, but the NMFS recovered one dead bottlenose dolphin entangled in a pound net during 2008 (Byrd et al. 2014).

North Carolina has a great diversity of birds, including migratory waterbirds (Potter et al. 1980). Within North Carolina estuarine waters, there are several species of birds that may be unintentionally caught in the southern flounder gill-net fishery. Bycatch estimates for the estuarine gill-net fishery are not available, though Warden (2010) documented bycatch of common loons (*Gavia immer)* and red-throated loons (*G. stellate)* in ocean-side and estuarine gill nets operating from Maine to North Carolina. Gill-net interactions with waterbirds have been documented in several division sampling programs; however, in-depth studies are needed to determine quantifiable bycatch estimates in the estuarine gill-net fishery and the levels of impact.

CLIMATE CHANGE AND RESILIENCY

Extreme weather events have always occurred, but scientists anticipate that changes to North Carolina's climate in this century will be larger than anything experienced historically (Kunkel et al. 2020). It is predicted that average annual temperatures will continue to increase, sea level will continue to rise, the intensity of hurricanes will increase, total annual precipitation from hurricanes and severe thunderstorms will increase resulting in increased flooding events, while severe droughts will also likely increase due to higher temperatures (Kunkel et al. 2020). Flood events can flush contaminated nutrient-rich runoff into estuaries causing degraded water quality. Runoff from flood events can cause eutrophication resulting in fish kills due to hypoxia, algal blooms, and alteration of the salinity regime. Flood events can also cause erosion of shorelines resulting in loss of important coastal habitats, such as SAV, shell bottom, and wetlands, that are critical to southern flounder throughout their life history. Potential increases in extreme weather events could have an inverse effect on the recruitment and survival of southern flounder in the estuarine system.

Increasing temperatures will also impact the distribution of finfish and invertebrate populations and the coastal habitats they use. 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). North Carolina already exhibits one of the greatest northward shifts in commercial fishing effort, with average vessel landings occurring 24 km further north each year (Dubik et al. 2019). Studies have shown that the sex determination of southern flounder is sensitive to water temperatures during larval development. When southern flounder were grown in high and low water temperatures, a higher proportion of males were produced while a midrange water temperature produced a sex ratio closer to 1:1 (Luckenbach et al. 2003, 2009; Montalvo et al. 2012). Honeycutt et al. (2019) found the more southerly habitats of North Carolina exhibited warmer temperatures and consistently produced higher proportions of males in wild populations (up to 94%), indicating latitudinal variation in sex ratios. With trends in increasing water temperatures, this is an important factor in the understanding of population dynamics of southern flounder.

The repeated impacts and compounding losses from the effects of climate change can be catastrophic not only to the coastal communities, but to coastal habitats and the fisheries they support. While the risks and hazards associated with climate change and extreme weather events cannot be completely eliminated, the effects can be decreased by improving coastal resilience, which can be broken down into two parts: 1) community resiliency – the ability of a community to withstand, respond to, and recover from a disruption, and 2) ecosystem resiliency – the ability of the natural environment to withstand, respond to, and recover from a disruption, such as hurricanes, tropical storms, and flooding. A resilient ecosystem can bounce back from disturbances over time compared to resistant ecosystems, whose function may not be able to recover with repeated disturbances. Building a more resilient coastal community and ecosystem will help ensure the persistence of coastal habitats critical to the life history of southern flounder and many other species (NCDEQ 2016, 2020).

HABITAT AND WATER QUALITY PROTECTION

The Fishery Reform Act statutes require that a CHPP be drafted by the NCDEQ and reviewed every five years (G.S. 143B-279.8). The CHPP is intended as a resource and guide compiled by NCDEQ staff to assist the Marine Fisheries, Environmental Management, and Coastal Resources commissions develop goals and recommendations for the continued protection and enhancement of fishery habitats of North Carolina. Habitat recommendations related to fishery management can be addressed directly by the NCMFC. The NCMFC has passed rules that provide protection for southern flounder habitat including the prohibition of bottom-disturbing gear in specific areas, designation of sensitive fish habitat, such as nursery areas and SAV beds, with applicable gear restrictions. Habitat recommendations not under NCMFC authority (e.g., water quality management, shoreline development) can be addressed by the other commissions through the

CHPP process. The CHPP helps to ensure consistent actions among these commissions as well as their supporting NCDEQ divisions. The CHPP also summarizes the economic and ecological value of coastal habitats to North Carolina, their status, and potential threats to their sustainability (NCDEQ 2016).

DESCRIPTION OF THE FISHERIES

Additional in-depth analyses and discussion of North Carolina's commercial and recreational southern flounder fisheries can be found in earlier versions of the Southern Flounder FMP (NCDMF 2005, 2013, 2017, 2019); all documents are available on the division website at: https://deq.nc.gov/about/divisions/marine-fisheries/public-information-and-education/managing-fisheries/fmp. Additionally, the License and Statistics Annual Report (NCDMF 2020) produced by the division can be found at: https://deq.nc.gov/about/divisions/marine-fisheries/science-and-statistics/fisheries-statistics.

The socio-economic information presented here is about the fishery as of 2017 and is not intended to be used to predict potential impacts from management changes. This and other information pertaining to FMP's are included to help inform decision-makers regarding the long-term viability of the state's commercially and recreationally significant species or fisheries. For a detailed explanation of the methodology used to estimate the economic impacts, please refer to the division's License and Statistics Section Annual Report (NCDMF 2020).

COMMERCIAL FISHERY

Southern flounder supports one of the largest and most valuable commercial fisheries in North Carolina, accounting for landings of 1.39 million pounds with a dockside value of $5.66 million in 2017. Historically, North Carolina has accounted for approximately 99% of annual southern flounder commercial landings from the U.S. South Atlantic coast since 1978 (Figure 10). Southern flounder have been harvested commercially since the 1800s in North Carolina, with the earliest documented landings reported in 1889 (Chestnut and Davis 1975). The average commercial fisherman in the southern flounder fishery is a middle-aged Caucasian male with more than 50% of their income coming from commercial fishing (Diaby 2000, 2001; Cheuvront 2002, 2003; Cheuvront and Neal 2004; Crosson 2010; Hadley 2012; Hadley and Wiegand 2014; Stemle and Wiegand 2017; Gambill and Bianchi 2019).

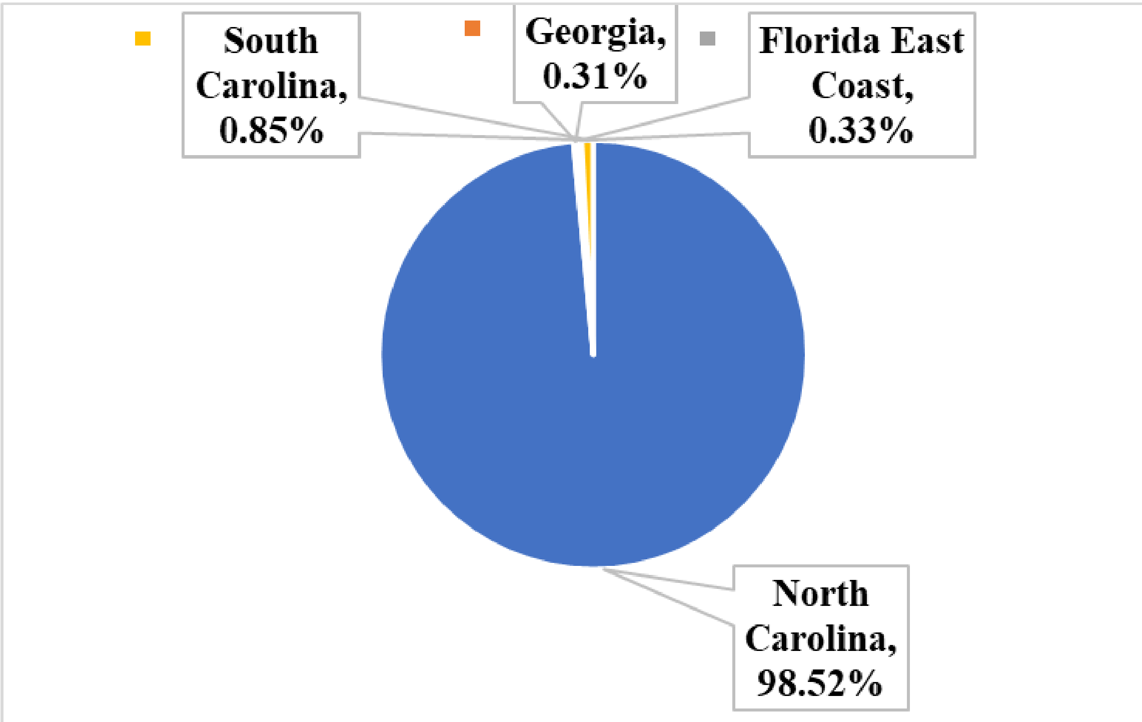

Figure 10. Average contribution to U.S. South Atlantic coast southern flounder commercial landings by state, 1978–2017. (Source: NOAA Fisheries Annual Commercial Landing Statistics and North Carolina Trip Ticket Program)
*Percentages may not total 100% due to rounding.

Another flounder species, the summer flounder, is also harvested in North Carolina. The commercial fisheries for summer and southern flounder differ in terms of where they operate and the gears they use. For example, summer flounder occur primarily in the ocean from North Carolina to Massachusetts where they are harvested primarily with trawl gear. Commercial fisheries for southern flounder occur almost exclusively in the estuaries where they are harvested with a greater variety of gears, primarily gill nets, pound nets, and gigs.

In North Carolina, landings of southern flounder increased steadily in the mid-1970s, peaking in the mid-1990s before declining to nearly 1.4 million pounds in 2017 (Figure 11). Trends in southern flounder landings were influenced, in part, by management restrictions, including a quota implemented for summer flounder in the mid-1980s to early 1990s and restrictions in the anchored large-mesh gill-net fishery to reduce incidental takes of sea turtles starting in 2000. These restrictions decreased the harvest of summer flounder, which had historically accounted for most of the flounder landings in North Carolina. Concurrently with decreased summer flounder harvest, the southern flounder fishery expanded through growth in the pound net fishery and development of a fall large-mesh gill-net fishery in Pamlico Sound. These changes resulted in southern flounder ranking as the top commercially landed flounder species until 2014, when summer flounder regained the top spot.

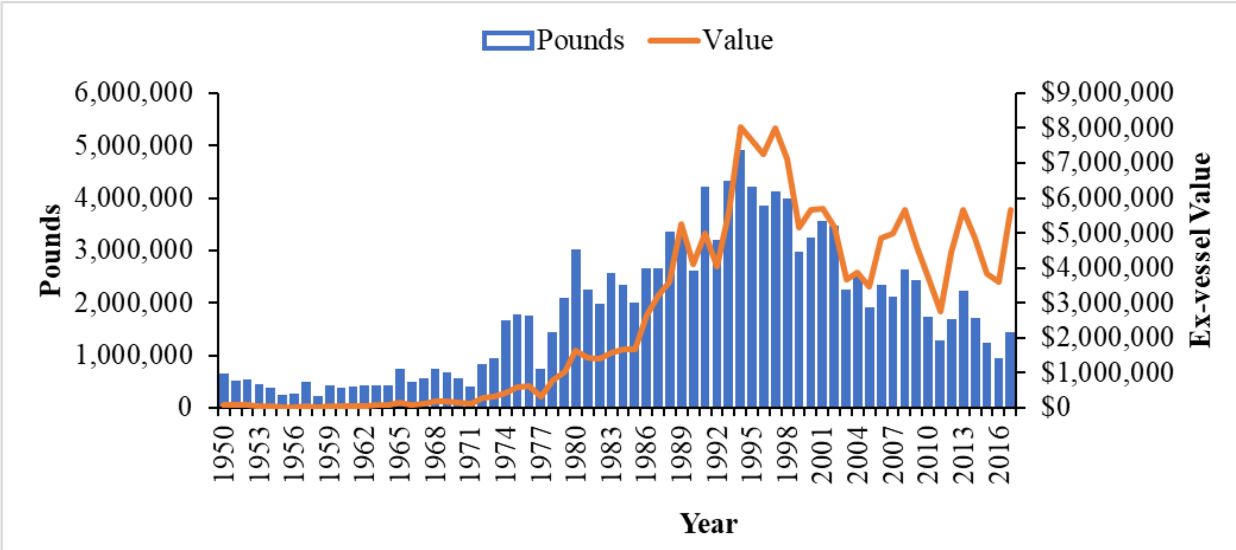

Figure 11. North Carolina annual southern flounder commercial landings and ex-vessel value, 1950–2017. (Source: North Carolina Trip Ticket Program)

Commercial Fishery Data Collection

Data used to describe the commercial fisheries for southern flounder comes from four sources: NMFS, the Atlantic Coast Cooperative Statistics Program (ACCSP), the North Carolina trip ticket program (NCTTP), and the North Carolina fishery-dependent sampling program. The data from NMFS includes historical data prior to 1978 and the data from ACCSP includes landings statistics collected from 1978 to 1993. Data prior to 1994 were collected on a voluntary basis with varying methodologies.

The NCTTP was implemented in 1994 to more accurately monitor commercial landings and fishing effort. Through the NCTTP, the division requires dealers purchasing finfish and/or shellfish from commercial fishermen to submit trip tickets that include information about the catch (e.g., species landed, pounds, gear, waterbody). Commercial fishermen are required to hold a Standard Commercial Fishing License (SCFL) or a Retired Standard Commercial Fishing License (RSCFL) to land southern flounder commercially in North Carolina. For commercial fishermen to sell their catch directly to consumers, they are required to possess a dealer’s license and submit their own trip tickets. The combined number of SCFLs and RSCFLs issued during fiscal years 2008 through 2017 ranged from a low of 6,296 in 2017 to a high of 6,861 in 2008 (NCDMF 2020). The number of seafood dealers reporting landings of southern flounder has ranged from 249 in 2012 to 189 in 2016. Finally, the fishery-dependent sampling program has been ongoing since 1982. This program collects data at fish houses by sampling the catch and recording fishery characteristics, which allows the size and age distribution of southern flounder to be characterized for each of the major gears and fisheries that harvest southern flounder.

Annual Landings and Value

Flounder landings reported through the NCTTP are not tabulated by species. Data from the fishery-dependent sampling program indicate that southern flounder make up less than one percent of the catch from ocean waters, while summer flounder and Gulf flounder account for approximately two percent or less of the flounder harvested from internal waters (NCDMF, unpublished data). Therefore, it is assumed in this analysis that all flounder harvested from estuarine waters are southern flounder, while all flounder taken from the ocean are summer flounder.

Unless otherwise noted, data presented in this section are from the NCTTP from 2008 to 2017. Trends are shown for the dockside (ex-vessel) value; harvest volume is presented in pounds.

Commercial landings of southern flounder were highly variable with a low in the time series in 2016 since the peak in 1994 (Figure 11). Landings have been impacted by environmental conditions, such as hurricanes, and changes in management strategies. Southern flounder may be graded into five market categories: jumbo, large, medium, mixed, and small.

Dockside price per pound of southern flounder is influenced by several factors, including fish size and market. For example, the sushi and sashimi market have had the maximum price per pound in the past. It is important to note that the price-per-pound of southern flounder has increased over time, as average prices have shifted from roughly $2 per pound to $4 per pound across the time series. As the total poundage of southern flounder landings has decreased over time, ex-vessel values have remained relatively consistent, with the exception of 2011 when portions of the pound net fishery was disproportionately impacted by severe weather (Table 2; NCDMF 2020).

Table 2. North Carolina commercial southern flounder landings in pounds and value, 2008–2017. (Source: North Carolina Trip Ticket Program)

Year	Harvest	Reported Dockside Value	Reported Dockside Price Per Pound	Inflation Adjusted Dockside Value	Inflation Adjusted Dockside Price per Pound
2008	2,602,390	$5,650,295	$2.17	$6,500,664	$2.50
2009	2,396,240	$4,609,932	$1.92	$5,350,287	$2.23
2010	1,689,557	$3,695,889	$2.19	$4,086,544	$2.42
2011	1,247,450	$2,753,128	$2.21	$2,832,693	$2.27
2012	1,646,137	$4,451,482	$2.70	$4,600,162	$2.79
2013	2,186,391	$5,673,190	$2.59	$5,921,675	$2.71
2014	1,673,511	$4,839,672	$2.89	$4,833,380	$2.89
2015	1,202,885	$3,823,567	$3.18	$3,908,832	$3.25
2016	897,765	$3,610,533	$4.02	$3,731,125	$4.16
2017	1,394,617	$5,655,751	$4.06	$5,655,751	$4.06
Average	1,693,694	$4,476,344	$2.64	$4,742,111	$2.80

Landings by Gear

Historically, southern flounder were harvested commercially in North Carolina using pound nets, seines, gill nets, and gigs (Chestnut and Davis 1975); all but seines remain as primary gears (Lee et al. 2018). The use of gigs in the southern flounder fishery does not require a specific permit. However, a Pound Net Permit is required to use a pound net, including those used to harvest southern flounder. The average number of issued permits between 2008 and 2017 was 285 [range: 267 (2012) to 304 (2008); Table 3].

Table 3. Number of commercial pound net permits by year of expiration and estuarine gill net permits by license year (July 1 to June 30). (Source: Fisheries Information Network)

Year (Expiration Year or License Year)	Pound Net Permits Issued	Estuarine Gill Net Permits Issued
2008	304	
2009	299	
2010	296	
2011	293	
2012	267	
2013	271	
2014	285	
2015	271	2,674
2016	283	2,897
2017	278	2,672
Average	285	2,748

As of 2015, an Estuarine Gill Net Permit is required to fish with anchored gill-net gear in North Carolina's estuaries. The permits are used to facilitate observer coverage, which is a requirement of ITPs (Section 10(a)(1)(B) of the ESA) for sea turtles and Atlantic sturgeon (NMFS 2013, 2014). The lowest number of permits possessed during a license year was 2,672 in 2017 and the highest was 2,897 in 2016 (Table 3).

Pound nets and gill nets have been the dominant gears, with gill nets leading harvest from the early 1990s through 2013. Recent declines in gill-net landings can most likely be attributed to increased regulations on the large-mesh anchored gill-net fishery. The third most used gear for southern flounder in recent years is the gig, with gig harvest increasing since 2008 (Table 4). Landings from other gears account for approximately two percent of the total landings and include crab and peeler pots, crab and shrimp trawls, hook-and-line, fyke nets, and haul seines (Table 4).

Characterization of Trips

The annual number of commercial trips reporting landings of southern flounder averaged over 20,000 during 2008 to 2017 with a peak in 2009 (Table 5). The predominate gear by number of trips and participants is the anchored large-mesh gill-net fishery, followed by gigs and pound nets, respectively (Table 5). Although large-mesh gill nets account for the largest volume of trips per year, the average landings per trip is 61 pounds, which is less than the average landings per trip for pound nets of 377 pounds.

Table 4. Annual commercial southern flounder landings in pounds by gear type, 2008–2017. Numbers in parentheses are the percent of the total landings for each gear in a given year. (Source: North Carolina Trip Ticket Program)

Year	Gill Net	Pound Net	Gigs	Other	Total
2008	1,770,204 (68%)	685,546 (26%)	82,846 (3%)	63,793 (2%)	2,602,390
2009	1,658,074 (69%)	591,534 (25%)	84,303 (4%)	62,329 (3%)	2,396,240
2010	958,271 (57%)	571,151 (34%)	128,081 (8%)	32,054 (2%)	1,689,557
2011	652,810 (52%)	464,546 (37%)	113,414 (9%)	16,680 (1%)	1,247,450
2012	879,373 (53%)	569,388 (35%)	149,387 (9%)	47,989 (3%)	1,646,137
2013	1,096,060 (50%)	924,887 (42%)	118,489 (5%)	46,955 (2%)	2,186,391
2014	659,394 (39%)	860,216 (51%)	135,273 (8%)	18,628 (1%)	1,673,511
2015	392,339 (33%)	667,847 (56%)	130,277 (11%)	12,422 (1%)	1,202,885
2016	361,570 (40%)	398,258 (44%)	126,983 (14%)	10,953 (1%)	897,765
2017	552,292 (40%)	697,814 (50%)	136,094 (10%)	8,416 (1%)	1,394,617
Average	898,039 (53%)	643,119 (38%)	120,515 (7%)	32,022 (2%)	1,693,694

*Percentages may not total 100% due to rounding.

Table 5. Annual trips, average landings per trip (APT), and number of participants (#PAR) by gear type in the commercial southern flounder fishery, 2008–2017. (Source: North Carolina Trip Ticket Program)

Year	Trips[1] / APT / #PAR[2]	Gill Net Trips/ APT/ #PAR	Pound Net Trips / APT / #PAR	Gig Trips / APT / #PAR	Other Trips / APT / #PAR
2008	28,966 / 90 / 1,235	23,493/ 75 / 924	1,508 / 455 / 83	1,459 / 57 / 140	2,510 / 25 / 413
2009	29,395 / 82 / 1,299	23,691 / 70 / 992	1,746 / 339 / 85	1,450 / 58 / 143	2,510 / 25 / 426
2010	20,408 / 83 / 1,182	15,134 / 63 / 837	1,610 / 355 / 84	2,283 / 56 / 226	1,384 / 23 / 329
2011	15,810 / 79 / 1,039	11,403 / 57 / 759	1,370 / 339 / 63	2,076 / 55 / 212	963 / 17 / 250
2012	20,926 / 79 / 1,202	14,713 / 60 / 855	1,754 / 325 / 84	3,000 / 50 / 288	1,462 / 33 / 291
2013	23,579 / 93/ 1,286	16,968 / 65 / 933	2,111 / 438 / 82	2,408 / 49 / 270	2,094 / 22 / 343
2014	18,121 / 92 / 1,222	11,778 / 56 / 799	1,806 / 476 / 88	2,655 / 51 / 316	1,887 / 10 / 373
2015	13,880 / 87 / 1,029	8,465 / 46 / 674	1,803 / 370 / 81	2,616 / 50 / 307	1,002 / 12 / 249
2016	13,336 / 67 / 945	8,422 / 43 / 591	1,423 / 280 / 77	2,657 / 48 / 323	838 / 13 / 227
2017	17,963 / 78 / 1,048	12,363 / 45 / 713	1,908 / 366 / 88	2,752 / 49 / 310	943 / 9 / 237
Average	20,238 / 84 / 1,149	14,643 / 61 / 808	1,704 / 377/ 82	2,336 / 52 / 254	1,559 / 21 / 314

[1] The number of trips, average landings per trip, and number of participants are from all trips that recorded southern flounder across all gear types including pound nets, gill nets, gigs, and other.
[2] The annual number of participants cannot be summed by gear as many individuals fish multiple gears per trip.

The greater number of participants in the gill-net and gig fisheries may be reflective of the relative lower cost of gear compared to the monetary investment required for pound nets. Effort using other gears has occasionally represented the second highest number of trips in a given year, but the average pounds per trip are low (Table 5). Unlike the major gears, southern flounder catch from other gears is incidental rather than targeted (for further information see below in the *Discards and Bycatch of Southern Flounder* section). The number of trips and participants in the fishery can be dependent on the weather as well as management regulations.

Landings by Season and Waterbody

Commercial southern flounder landings and average dockside value, as well as the average price per pound in North Carolina, vary by season. The southern flounder commercial fishery typically begins with the gig fishery in the early summer in the southern part of the state (Core Sound south) as fish availability is high and good weather allows for increased water clarity necessary for giggers to see flounder when operating at night. During the late summer months, the gill net fishery intercepts the southern flounder that overwintered in the estuaries and have grown to legal size. Gill net harvest typically begins in the western portions of the river systems in Pamlico and Albemarle sounds shifting downstream and eastward as the fish migrate (NCDMF 2019; see the *Achieving Sustainable Harvest* issue paper).

During the fall, flounder migrate into the ocean to spawn, influencing both the harvest in the gill net and pound net fisheries. Although gill nets and gigs are mobile gears that can follow fish, the fall migration coincides with peak harvest for gill nets and pound nets. Pound nets are a passive gear that rely on the migration to be productive. Therefore, the flounder pound net fishery is not active until the fall migration begins. For pound nets, harvest typically begins in Currituck Sound in late August and early September following a north to south migration pattern, with Core Sound harvesting flounder through November after the northern portion of the fishery has ended (NCDMF 2019; see the *Achieving Sustainable Harvest* issue paper).

Data from the NCTTP include the waterbody in which the majority of the catch was caught during each trip. The Albemarle Sound Region (includes Albemarle, Croatan, Roanoke, and Currituck sounds as well as Alligator, Chowan, Pasquotank, Perquimans, and Roanoke rivers, and Back Bay) and the Pamlico Sound Region (includes Pamlico Sound and Neuse, Pamlico, Pungo, and Bay rivers) accounted for 76% of the total southern flounder harvest from 2008 to 2017 (Table 6). During this time period, the average real dockside value was marginally greater in the Pamlico Sound Region. Real prices account for inflation by adjusting all values to a pre-determined base-year, allowing prices across different years to reflect the same monetary value.

Commercial Discards and Bycatch of Southern Flounder

Since 2016, the minimum size limit to harvest southern flounder in the commercial fishery has been 15 inches TL. Management measures, such as yardage restrictions, soak times, minimum mesh size requirements, and pound net escape panels, are used to minimize discards (NCDMF 2019). Any undersized southern flounder that are caught must be immediately returned to the water (regulatory discard). Discards of undersized flounder primarily occur from gill nets, pound nets, gigs, and shrimp trawls. In additional to regulatory discards, some legal-sized fish are discarded because they may not be marketable due to the presence of injuries or sores (unmarketable discards).

Table 6. Commercial southern flounder landings (millions of pounds) and average dockside price per pound by area, 2008–2017. Numbers in parentheses are the percent of the total landings for each area for a given year. (Source: North Carolina Trip Ticket Program)

Year	Albemarle Sound Region	Pamlico Sound Region	Core Sound and South	Statewide
2008	1.2 (44%) / $2.15	0.8 (31%) / $2.23	0.6 (25%) / $2.13	2.7 / $2.17
2009	1.1 (44%) / $1.91	0.9 (37%) / $1.95	0.5 (20%) / $1.90	2.5 / $1.92
2010	0.4 (27%) / $2.14	0.9 (51%) / $2.23	0.4 (23%) / $2.14	1.7 / $2.19
2011	0.1 (7%) / $2.15	0.8 (63%) / $2.20	0.4 (30%) / $2.23	1.3 / $2.21
2012	0.7 (40%) / $2.68	0.6 (37%) / $2.77	0.4 (23%) / $2.64	1.7 / $2.70
2013	0.9 (40%)/ $2.48	0.9 (43%) / $2.69	0.4 (17%) / $2.62	2.2 / $2.59
2014	0.5 (32%) / $2.84	0.8 (48%) / $2.90	0.3 (20%) / $2.97	1.6 / $2.89
2015	0.3 (28%) / $3.15	0.5 (44%) / $3.17	0.3 (28%) / $3.21	1.1 / $3.18
2016	0.2 (20%) / $3.99	0.4 (50%) / $4.04	0.3 (30%) / $4.02	0.9 / $4.02
2017	0.3 (23%) / $4.02	0.7 (50%) / $4.08	0.4 (27%) / $2.23	1.4 / $4.06
Average	0.6 (33%) / $2.75	0.7 (44%) / $2.89	0.4 (23%) / $2.79	1.7 / $2.79

*Percentages may not total 100% due to rounding.

Pound Nets

Data are not available to estimate discards or post-release mortality of southern flounder from commercial pound nets. However, this fishery is known to have discards (unmarketable and regulatory). While the magnitude is unknown, post-release mortality is assumed to be relatively low. Pound nets capture fish by entrapment, as opposed to gilling or entanglement, so southern flounder discards, when culled in a timely and careful manner, can be released with a high likelihood of survival. Additionally, pound nets that are permitted as a "flounder pound net" are required to have escape panels. The escape panels consist of large-mesh [a minimum of 5.75-inch stretch mesh (ISM)] webbing and must be placed in all four bottom corners of the pound. The required minimum mesh size in the panel is adequate to allow a large portion of undersized southern flounder to escape while larger legal sized flounder are retained (Brown 2014; NCDMF 2017).

Gill Nets

Gill-net bycatch of undersized and unmarketable southern flounder commonly occurs in both large-mesh and small-mesh anchored estuarine gill nets. Since January 2016, gill nets landing southern flounder have been required to have a minimum stretched mesh size of six inches to minimize bycatch of sub-legal southern flounder. Commercial gill-net discards are monitored through onboard observers in the estuarine gill-net fishery.

Discard data from the observer program were used to calculate estimates of bycatch, both at-net mortality and post-release mortality, including years prior to the origination of the observer program. These estimates were incorporated into the most recent stock assessment (Flowers et al.

2019). Commercial southern flounder dead discard estimates (fish dead at time net was fished) ranged from a low of just over 4,179 fish in 2017 to over 87,410 fish in 1994 (Figure 12). In addition to the dead discards encountered at the net, post-release or delayed mortality (assumed to be 23% in stock assessment, Lee et al. 2018) associated with the release of live discards ranged from a low of 5,003 fish in 2011 to a high of 40,441 fish in 2008.

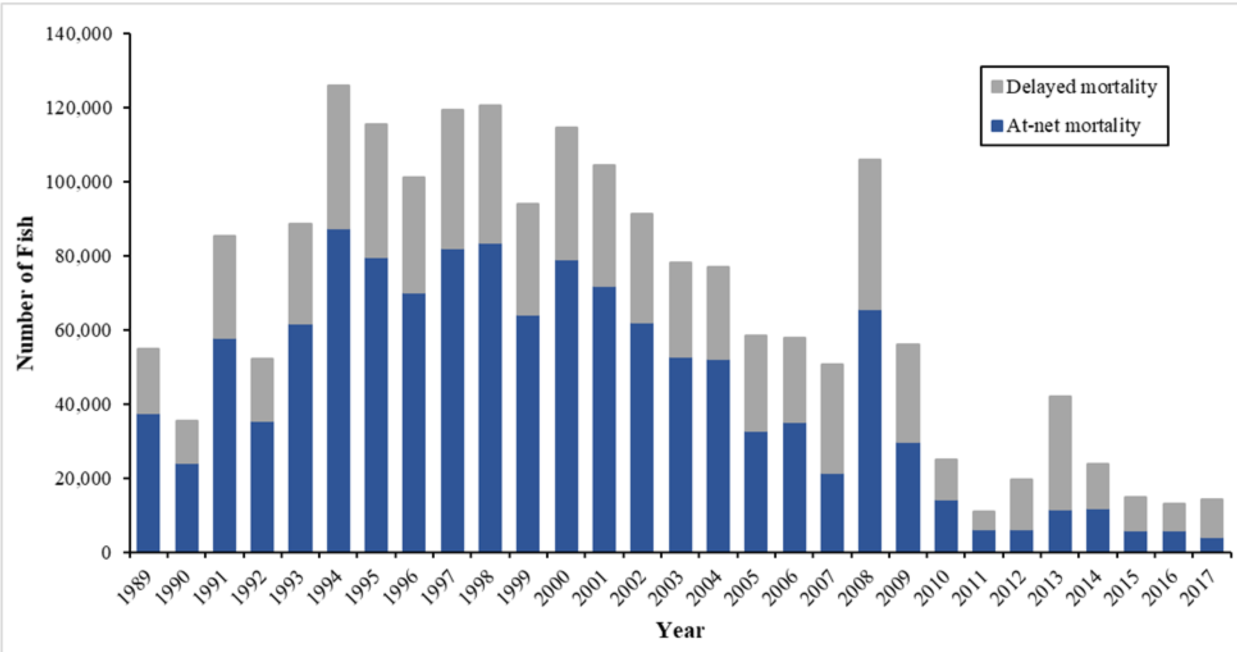

Figure 12. Estimated number of dead discards associated with the North Carolina commercial estuarine gill net fishery, 1989-2017.

Gigs

Due to size limits, regulatory discards in this fishery occur and post-release mortality is assumed to be 100%. Discard estimates in the commercial gig fishery are unknown.

Other Gears (Non-Target)

Marketable legal southern flounder from other gears (e.g., crab and peeler pots, crab and shrimp trawls, channel nets, fyke nets, and haul seines) that are retained (incidental catch) from these gears makes up less than 2% of the total commercial landings and has declined over the last 10 years (Table 7, Figure 13). From 2008 to 2017, approximately 55% of southern flounder harvested as incidental catch came from the crab and shrimp pot fishery, with landings from the shrimp and crab trawl fishery making up the second largest portion of southern flounder sold as bycatch. Since 2014, landings from trawls have been slightly higher than pots.

The portion of bycatch that is returned to the sea (discarded catch) due to economic, legal, or personal considerations is more difficult to quantify. Discard data are not available for many of the non-targeted fisheries that catch southern flounder. However, studies indicate that flounder species are captured as bycatch in the blue crab pot fishery, with a survival rate exceeding 85%

(Doxey 2000; Thorpe et al. 2005). Currently, there are no management measures requiring the use of bycatch reduction devices in crab pots; however, the use of these devices in a tidal marsh creek in Virginia has been shown to be highly effective at excluding fish as bycatch (Morris et al. 2011).

Table 7. Pounds of southern flounder landed as bycatch in commercial non-major ("Other") gears, 2008–2017.

	Gear						
Year	**Pots (crab & shrimp)**	**Trawls (crab & shrimp)**	**Fyke Nets**	**Channel Nets**	**Misc.**	**Total Bycatch Landings**	**Total Commercial Landings**
2008	34,158	21,379	903	463	5,385	62,288	2,602,390
2009	29,091	28,874	654	32	2,046	60,697	2,396,240
2010	17,493	10,073	179	853	1,045	29,643	1,689,557
2011	5,275	8,963	38	162	795	15,232	1,247,450
2012	39,602	4,647	66	783	513	45,611	1,646,137
2013	30,080	13,549	292	395	331	44,646	2,186,391
2014	5,883	9,425	389	309	552	16,556	1,673,511
2015	2,256	3,451	4,538	215	207	10,666	1,202,885
2016	2,265	5,138	1,128	155	441	9,127	897,765
2017	2,492	3,429	80	161	552	6,714	1,394,617
Total	168,595	108,929	8,267	3,525	11,864	301,180	16,936,944
Percentage of Bycatch Only Landings	56	36	3	1	4	100	
Percentage of Total Commercial Landings	1	1	0	0	0	2	100

In North Carolina's shrimp trawl fishery, southern flounder represented 1% to 33% of the regulatory discards in the estuarine otter and skimmer trawls and ocean shrimp trawl fishery (Brown 2009, 2010a, 2010b, 2015, 2016; Brown et al. 2019). In an effort to minimize the discard of sublegal flounder in the shrimp trawl fishery, the 2006 Shrimp FMP initiated management measures limiting the total combined headrope length to 90 ft in the mouths of the Pamlico and Neuse Rivers and all of Bay River, as well as restricting the use of otter and crab trawls above the Highway 172 Bridge in the New River (NCDMF 2015). More recently, the NCMFC voted to require fishermen to use one of four gear combinations in the Pamlico Sound and portions of Pamlico, Bay, and Neuse rivers, which were tested by an industry workgroup and achieved at least a 40% reduction of finfish bycatch (NCDMF 2018; Brown et al. 2019).

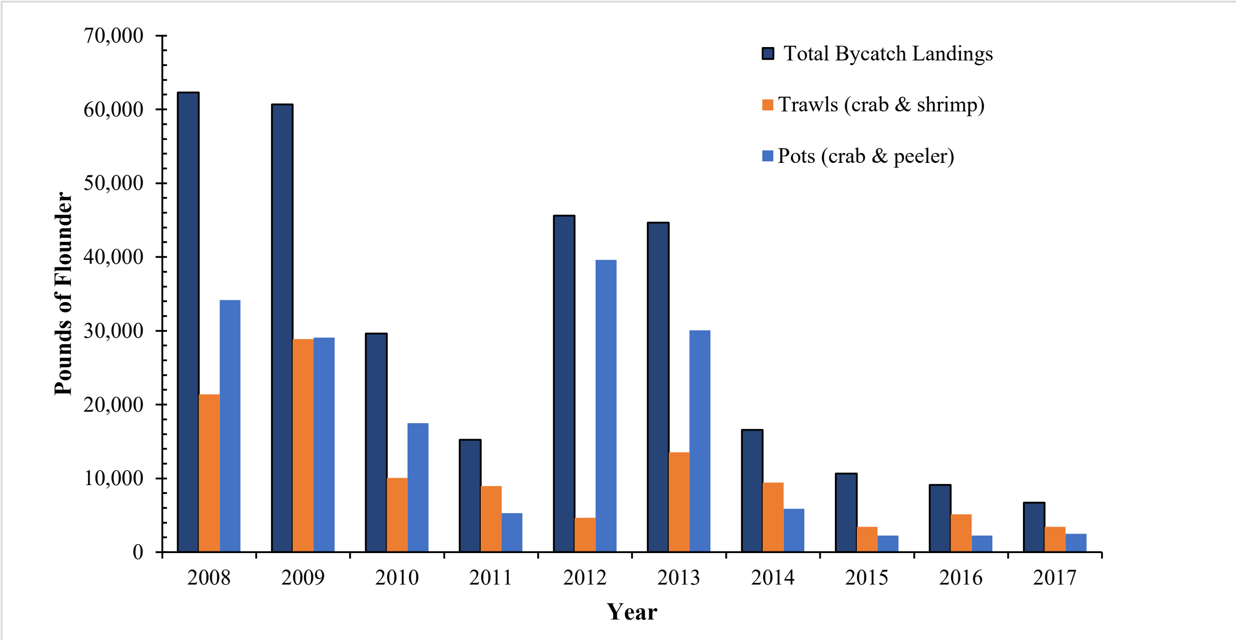

Figure 13. Pounds of southern flounder harvested as bycatch from commercial crab and peeler pots, crab and shrimp trawls, channel nets, fyke nets, and haul seines, 2008–2017. (Source: North Carolina Trip Ticket Program)

Discard data from North Carolina's shrimp trawl observer program were used to help estimate bycatch rates of southern flounder in the U.S. South Atlantic shrimp trawl fishery. Results indicate a general decline in bycatch of southern flounder as well as fishing effort from 1989 to 2017. Discards from the shrimp trawl fishery were found to contribute minimally to the overall catch and were not found to bias the results of the 2019 stock assessment for southern flounder in the South Atlantic (Lee et al. 2018; Flowers et al. 2019).

Summary of Economic Impact of Commercial Fishing

As one of the largest commercial fisheries in the state, the southern flounder fishery is a strong economic driver for the industry. From 2008 to 2017, the average southern flounder fishery consistently included over 1,000 participants except for 2016 (Table 8). Additionally, during this period the ex-vessel value of southern flounder harvest was, on average, 5% of the total value of all commercial seafood landings in the state (NCDMF 2020).

More broadly, an economic impact assessment of the commercial southern flounder fishery helps demonstrate its influence on the state economy. Using IMPLAN modeling software along with expenditure estimates from National Oceanic and Atmospheric Administration's (NOAA) 2016 Fisheries Economics of the U.S. (FEUS) report, the indirect impacts of the southern flounder fishery to the state economy at-large can be estimated (IMPLAN 2013). For a detailed explanation of the methodology used to estimate the economic impacts refer to the division's License and Statistics Section Annual Report (NCDMF 2020).

Table 8. Economic impacts associated with commercial southern flounder fishery in North Carolina,2008–2017. Data below represent the actual effort data from southern flounder harvest, along with the estimated economic impacts to North Carolina using IMPLAN statistical software. Data from the 2016 NOAA Fisheries Economics of the U.S. report, along with internal division survey data, are also used to generate estimates. Note: impact estimates across categories are not additive.

Year	Pounds Landed	Ex-vessel Value	Participants	Estimated Sales Impact	Estimated Income Impacts	Estimated Employment Impact	Estimated Value Added Impact
2008	2,602,390	$5,650,295	1,235	$25,473,137	$10,483,954	1,544	$19,654,727
2009	2,396,240	$4,609,932	1,299	$20,547,716	$8,550,927	1,545	$16,161,407
2010	1,689,557	$3,695,889	1,182	$15,743,327	$6,531,811	1,380	$12,223,365
2011	1,247,450	$2,753,128	1,039	$11,771,643	$4,884,958	1,186	$9,140,235
2012	1,646,137	$4,451,482	1,202	$18,795,084	$7,827,308	1,440	$14,613,360
2013	2,186,391	$5,673,190	1,286	$23,172,478	$9,654,261	1,591	$17,977,144
2014	1,673,511	$4,839,672	1,222	$19,547,618	$8,134,986	1,482	$15,109,459
2015	1,202,885	$3,823,567	1,029	$15,852,258	$6,621,987	1,235	$12,379,619
2016	897,765	$3,610,533	945	$10,724,064	$6,301,409	1,129	$11,716,727
2017	1,394,617	$5,655,751	1,048	$20,489,984	$9,494,322	1,335	$17,676,161
Average	1,693,694	$4,476,342	1,149	$18,211,731	$7,848,592	1,387	$14,665,220

The impact estimates of the commercial southern flounder fishery from 2008 to 2017, taking into account ex-vessel revenues, participants, NOAA FEUS expenditure modifiers, and division socioeconomic survey data are shown in Table 8. Overall, the large economic impact of southern flounder to the state's commercial fishing industry is also reflected in its effect on the state economy. Total impacts vary slightly year-to-year, though these values remain relatively consistent from a state-impact perspective. Additionally, it should be noted that the economic activity generated by commercial southern flounder fishing supports over 1,000 additional full- and part-time jobs in the state.

Lastly, within the direct impacts that effort and production have on the value of the commercial flounder industry, there are several other factors that can dictate the total economic impact of this fishery at any time, both on a broader market level and individual product level. As a popular seafood across the country, the value of flounder in North Carolina is influenced by broader trends of supply and demand. There is a wide range of competitive substitutes for North Carolina flounder, including flounder caught in other states, as well as seafood products with comparatively similar properties, such as halibut (*Hippoglossus spp*.) or sole (*Solea spp*.). Because of this, the value of flounder in North Carolina is not just influenced by the availability of the product in-state, but also the regulations, seasons, and effort for the harvest of flounder and substitute products across the world. However, as flounder is such a popular fish with a number of available substitutes, it is difficult to accurately track how supply of other products directly influences prices in the state.

In addition to the broader dynamics of supply and demand that can influence North Carolina's flounder market, there are also specific factors that can adjust product value on different time scales. Method of catch can often influence prices, as consumers will seek product caught with gears that are perceived as more environmentally friendly, or gears that produce higher-quality flounder (Asche and Guillen 2012). This can lead to increased prices on flounder caught with certain gears.

Additionally, enterprise-level marketing can often impact product value. Both fishermen and dealers have the ability to market their business and product how they wish. When marketing strategies are successful, prices can be raised and value can increase, though this is on an individual level and demonstrates the volatility within the market. Such changes in value can be demonstrated by the positive effects that local product branding and direct-to-consumer strategies have produced in North Carolina (NCREDC 2013; Stoll et al. 2015). While these are just two examples of the variety of factors that can influence the value of North Carolina's flounder industry, they help demonstrate the complicated dynamics at play, as well as the fact that many factors driving the price of flounder are not dictated by fishery managers, but by consumers and producers within the market itself.

RECREATIONAL FISHERY

Southern flounder, or flounder species in general, are one of the most sought-after recreational species in North Carolina. Southern flounder are taken by recreational anglers using hook and line, gigs, and gill nets. Southern flounder are caught year-round, but most southern flounder harvest occurs during the summer and fall. Depending on the season, anglers fish for southern flounder in inland and coastal waters, including the surf, inlets, and nearshore waters of the Atlantic Ocean along live bottom reefs and wrecks. It should be noted that southern, summer, and Gulf flounder are currently managed as an aggregate fishery for the recreational sector. Additional discussion on species-specific management and implications of management as an aggregate can be found in the *Increased Recreational Access* issue paper.

In North Carolina, recreational landings and effort statistics for southern flounder are obtained through three fishery dependent survey programs; the Marine Recreational Information Program (MRIP), the Gig Mail Survey, and the RCGL Survey. A RCGL allows the use of limited amounts of commercial fishing gear in coastal fishing waters for recreational purposes. These surveys produce estimates of effort and catch with an associated measure of variability (proportional standard error; PSE). As with the commercial fishery, southern, summer, and Gulf flounder are all encountered through MRIP, the Gig Mail Survey, and the RCGL Survey.

Recreational Fishery Data Collection

Marine Recreational Information Program (MRIP)

The MRIP is a national program administered through NOAA Fisheries that uses several surveys to obtain catch and effort data at a regional level. The Access Point Angler Intercept Survey (APAIS) provides the catch rates and species composition from anglers fishing in estuarine or marine waters (not freshwater). Anglers who have completed a fishing trip are intercepted and interviewed to gather catch and demographic data, including fishing mode (charter boat, private/rental boat, beach/bank, and man-made structures), area fished, and wave (each two-month sampling period).

The MRIP implemented the Fishing Effort Survey (FES) in 2018, an improved methodology of the prior effort survey (Coastal Household Telephone Survey). The data from the APAIS and FES are combined to provide estimates of the total number of fish caught, released, and harvested. Additionally, information is collected on the weight of the harvest, total number of trips, and the number of people participating in marine recreational fishing. For additional information on MRIP see https://www.fisheries.noaa.gov/topic/recreational-fishing-data.

Flounder landings reported through MRIP are available to the species level through direct observation; however, releases are not observed and therefore are only available at the genus level, which includes southern, summer, and Gulf flounder. To properly estimate species level releases, a ratio of flounder species is obtained from the observed catch through MRIP and applied to the unobserved releases at the corresponding time of year, wave, and fishing area. For further information on species composition and discussion see the *Increased Recreational Access* issue paper.

Mail Surveys: Gig Survey and Recreational Commercial Gear License Survey

Gears other than hook and line, such as flounder gigs and the recreational use of commercial gear, are under-represented within MRIP sampling. The division implemented the RCGL Survey in 2002 and the Coastal Angling Program (CAP) Recreational Gigging Mail Survey in 2010. For additional information on these Gigging Mail Survey see the License and Statistics Annual Report at https://deq.nc.gov/about/divisions/marine-fisheries/science-and-statistics/fisheries-statistics.

The implementation of a mandatory recreational saltwater fishing license in 2007 (Coastal Recreational Fishing License, CRFL) for the harvest of all finfish provides an opportunity to survey participation in gigging at the time of license purchase. The ongoing Gig Mail Survey began in 2010 to collect data on effort and catch. For the gig survey, no observed catch is available, thus harvest is estimated at the genus level and includes all three flounder species. For further information on species composition and discussion see the *Increased Recreational Access* issue paper.

For eight years (2001-2008), two mail surveys of RCGL holders were conducted. Effort information such as seasonal activity, trip number estimates, and monetary expenditures were categorized by gear type and recorded. Additionally, species-specific information such as catch (both harvested and discarded) and target species was also obtained (NCDMF 2009).

Hook-and-Line Fishery

Regulatory measures have strongly influenced the species composition of flounder harvested recreationally in North Carolina. Summer flounder dominated harvest until a size limit change from 13 to 14 inches TL in 2002 redistributed the species composition towards southern flounder. In 2011, a 15-inch TL size limit for the recreational fishery was implemented for all waters within North Carolina, which resulted in a downward trend for both southern and summer flounder (Figure 14). North Carolina represents the second largest proportion of recreationally harvested southern flounder in the U.S. South Atlantic using hook-and-line gear (Figure 15).

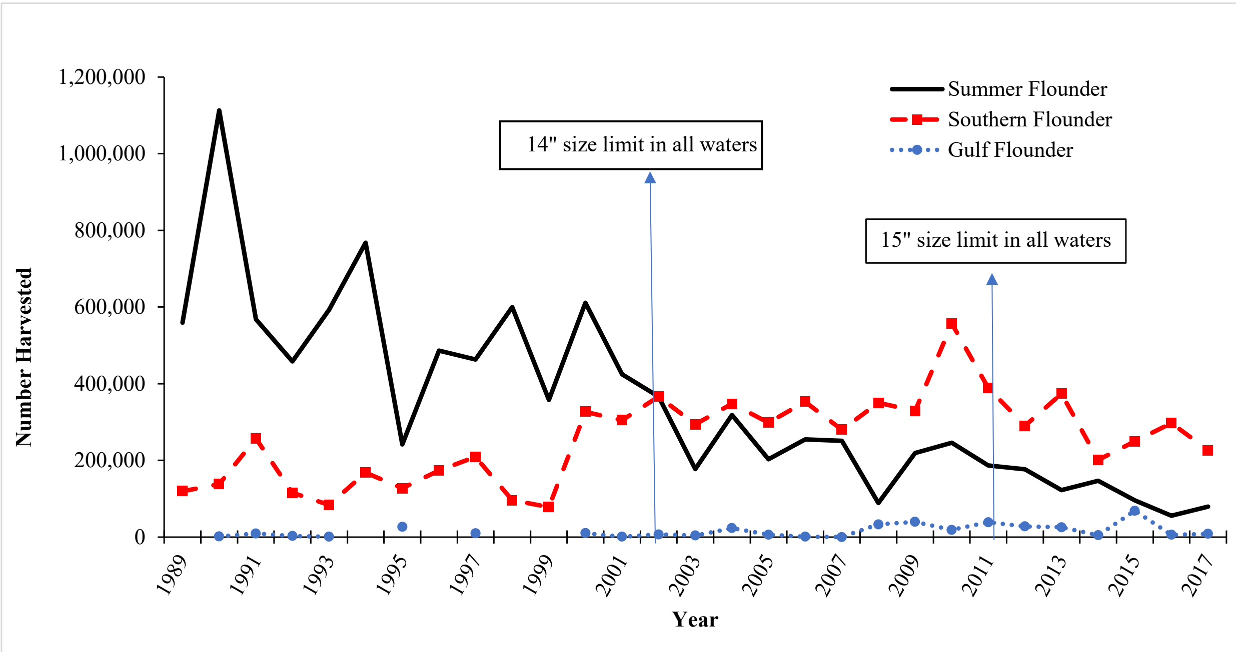

Figure 14. Distribution of flounder species harvested recreationally in North Carolina, 1989–2017. (Source: Marine Recreational Information Program)

In the North Carolina recreational hook-and-line fishery, flounder species have been the most often reported target species in 20 of the last 37 years (Figure 16). Many flounder are also taken during trips when anglers are targeting other species, such as spotted seatrout and red drum. The recreational hook-and-line fishery accounted for 89% of total recreational flounder harvest in 2017.

Anglers catch southern flounder using an array of artificial and natural baits. Preferred artificial baits include soft bodied lures of various colors and shapes fished on the bottom. Bottom fishing using natural live baits (mullet, menhaden, mud minnows, and shrimp) is popular and productive, as well. The recreational harvest of southern flounder exhibits a distinct seasonality that is concentrated between May and October (Figure 17).

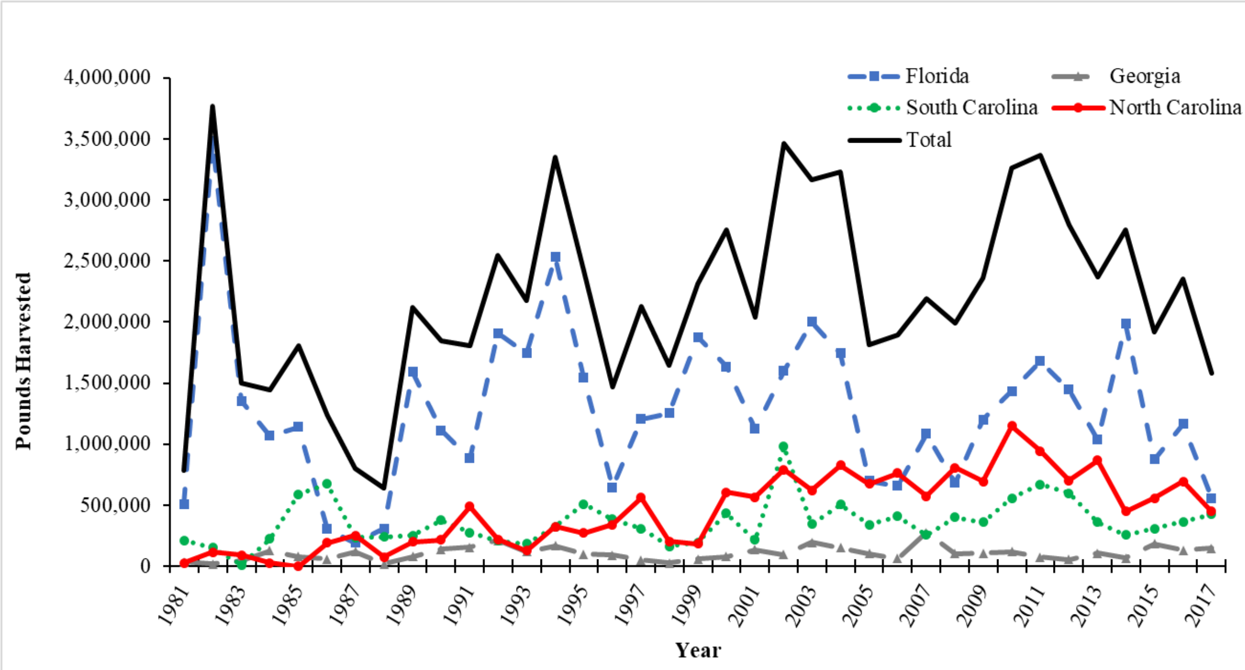

Figure 15. Hook-and-line recreational harvest of southern flounder (in pounds) estimated by MRIP for North Carolina through the east coast of Florida, 1981–2017. (Source: Marine Recreational Information Program)

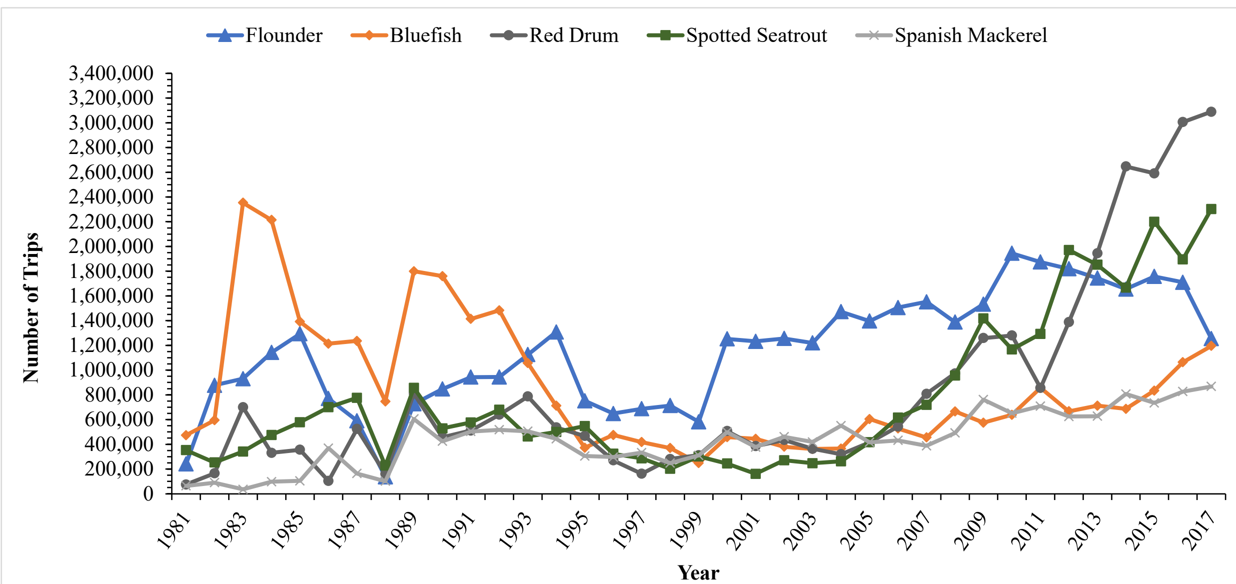

Figure 16. Recreational hook-and-line trips targeting five top species in North Carolina 1981–2017. (Source: Marine Recreational Information Program)

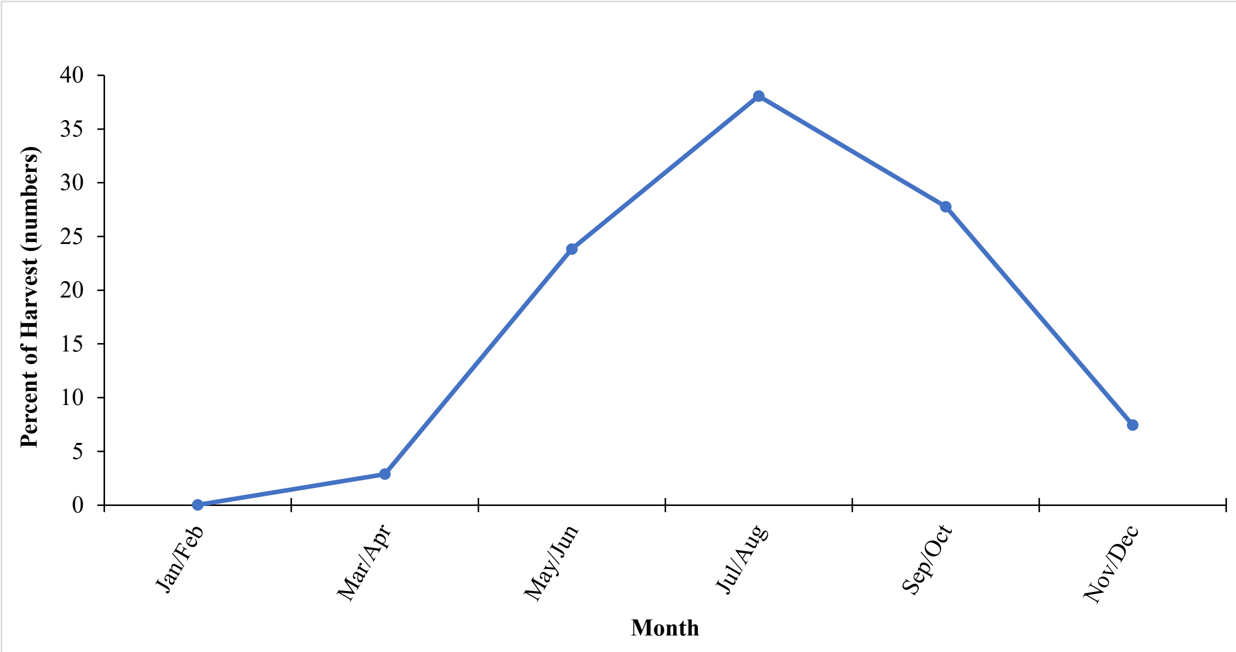

Figure 17. Seasonality of southern flounder recreational harvest in North Carolina, 1981–2017. (Source: Marine Recreational Information Program)

For further information on recreational landings see the *Achieving Sustainable Harvest* and the *Increased Recreational Access* issue papers.

Gig Fishery

The recreational gig fishery accounted for 11% of total recreational flounder harvest in 2017. Effort estimates for 2008 through 2017 ranged from 13,524 to 25,666 trips annually, while harvest estimates ranged from 24,136 to 54,419 fish. Spatially, over 87% of gigging trips originated from Carteret County and south. Like the hook-and-line fishery, an increase in gigging trips was observed from May through October with a peak in harvest in the summer. For a more detailed description of the recreational gig fishery see the License and Statistics Annual Report and the *Achieving Sustainable Harvest* issue paper.

RCGL Fishery

Data on RCGL gears are only available from 2002 to 2008 due to funding being cut for the RCGL survey. Among the allowed gears, large-mesh gill nets comprised 74% of southern flounder harvest, with small-mesh gill nets (21%), crab pots (4%), and shrimp trawls (1%) constituting the remainder (NCDMF 2009). The number of flounder species (southern, summer, and Gulf) harvested between 2002 and 2008 ranged from 18,414 to 53,785 fish or 100,514 pounds in 2002 down to 37,315 pounds in 2008. The number of licensed individuals participating in the RCGL fishery has steadily decreased from approximately 6,000 in 2000 to 1,800 in 2017 (Figure 18). This is the best indicator currently available of declining effort in the RCGL fishery. For additional information on licenses see the License and Statistics Annual

Report or for RCGL survey analysis see the 2009 License and Statistics Annual Report (NCDMF 2009).

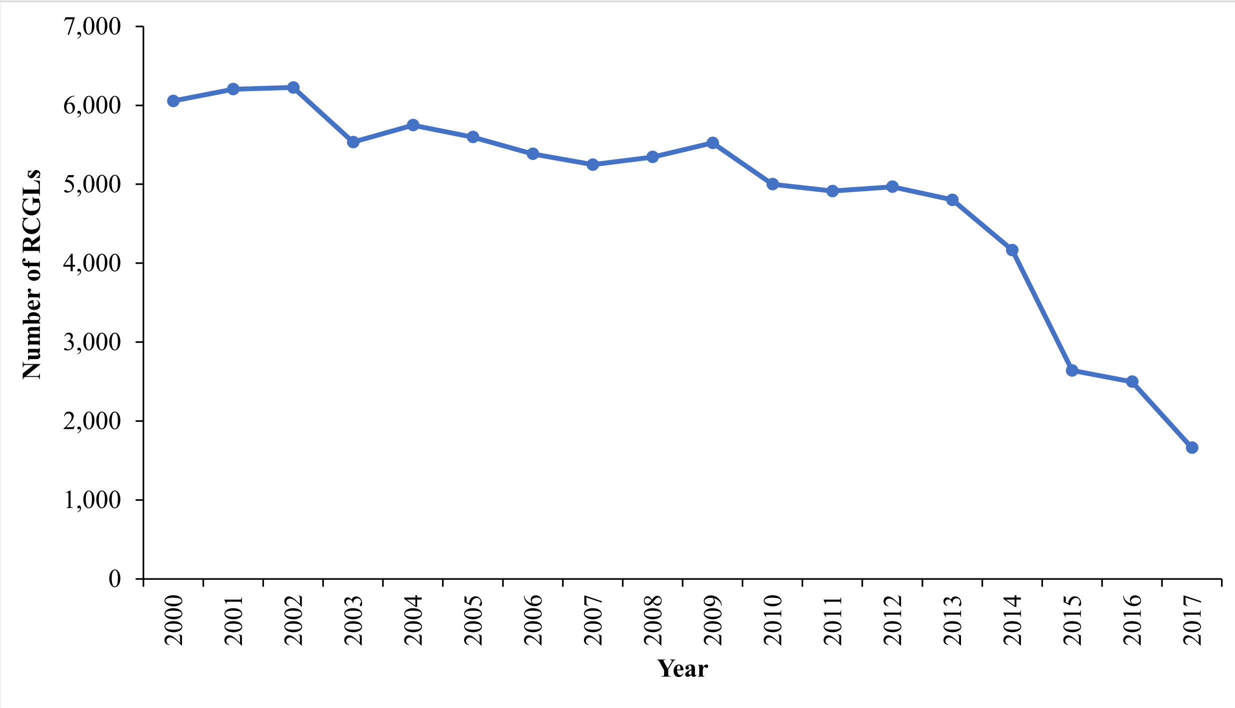

Figure 18. The number of Recreational Commercial Gear Licenses (RCGL) issued 2000–2017. (Source: NCDMF License and Statistics Annual Report)

Recreational Discards and Bycatch of Southern Flounder

The minimum size limit to harvest southern flounder is 15 inches TL. Any southern flounder not legal for harvest must be immediately returned to the water. Primary gears used by recreational fishermen that capture southern flounder include hook-and-line and gigs.

Hook-and-line is the primary gear for taking southern flounder for recreational purposes in North Carolina. North Carolina represents the largest recreational proportion of released flounder in the U.S. South Atlantic (Figure 19). This is driven by the aforementioned regulatory measures. Specifically, the increase in size limit to 15 inches TL in 2011 resulted in a ratio of nine discarded fish for every one fish harvested in North Carolina (Figure 19). In contrast, a 12-inch TL size limit in Florida was allowed prior to March 2021 and the ratio of discard to harvest to was approximately 1:1.

The stock assessment assumes a post-release mortality for hook-and-line released southern flounder of 9% (See Section 2.1.4 in Flowers et al. 2019, https://files.nc.gov/ncdeq/Marine-Fisheries/fisheries-management/southern-flounder/2019-4-sarSouthernFlounder.pdf). The post-release mortality and magnitude of discards in this fishery make these removals a major contributor to the overall fishing mortality being experienced by this stock. In recent years, post-release mortality associated with recreational releases is nearly equal to the number of removals from recreational harvest.

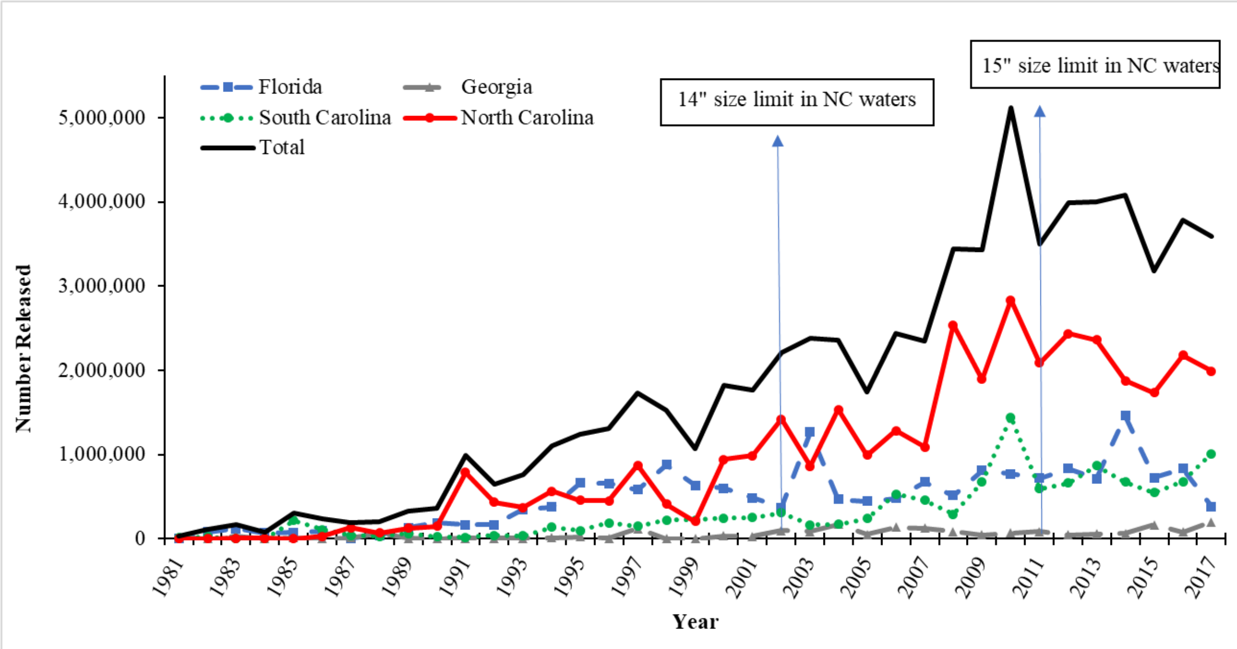

Figure 19. Ratio of the number of southern flounder released compared to harvested in the recreational hook-and-line fishery as estimated through MRIP for North Carolina through the east coast of Florida, 1981–2017. (Source: Marine Recreational Information Program)

In the recreational gig fishery, discard estimates are available from 2010 to 2017 through a division-led mail survey on recreational flounder gigging. This survey estimates the number of trips, as well as southern flounder harvest and discards (See Section 2.1.5 in Flowers et al. 2019, https://files.nc.gov/ncdeq/Marine-Fisheries/fisheries-management/southern-flounder/2019-4-sarSouthernFlounder.pdf). Discard estimates ranged from 655 to 9,726 fish annually and represent only a small portion (less than 1%) of the overall removals from the recreational fishery.

Between 2002 and 2008, the number of discarded flounder species from RCGL gears ranged from approximately 15,000 to 52,000 fish (NCDMF 2009). Large- and small-mesh gill nets contributed 58.9% of discards throughout the time series. Despite making up a small portion of the overall trips (4.8%) and harvest (1.2%), shrimp trawls disproportionately contributed to discards of southern flounder. Flounder discards from shrimp trawls ranged from 15.1 to 51.2% and averaged 31.7% of all flounder discards from RCGL gears for the time series (NCDMF 2009).

Demographic Characteristics

The average angler participating in recreational harvest of southern flounder in North Carolina is a male older than 47 (NCDMF, unpublished data). Anglers targeting or harvesting southern flounder represented all 100 North Carolina counties, all 50 states, and the District of Columbia (Table 9). Anglers harvest southern flounder by three different modes: shore; for-hire boats; and private boats. Private boat anglers harvest the largest volume of southern flounder in the recreational fishery (Figure 20). Due to low sample sizes and high PSE, southern flounder data from the for-hire industry are limited. Data indicate that the for-hire fleet capture flounder at a higher rate than the recreational fishery suggesting that impact on a per angler basis tends to be higher by the for-hire industry.

Table 9. Contribution of North Carolina counties and other states to recreational flounder fisheries according to three sources of data: Access Point Angler Intercept Survey (APAIS), Recreational Commercial Gear License Survey (RCGL), and Gig Mail Survey.

	APAIS		**RCGL**		**Gig Mail Survey**	
Categories	**Counties/States**	**%**	**Counties/States**	**%**	**Counties/States**	**%**
Top 10 Counties	New Hanover	11.3	Craven	9.3	Wake	7.61
	Dare	6.4	Carteret	7.4	New Hanover	6.94
	Brunswick	6.1	New Hanover	6.9	Carteret	5.56
	Carteret	4.5	Beaufort	6.1	Onslow	4.64
	Wake	3.8	Brunswick	5.9	Brunswick	3.98
	Onslow	3.2	Wake	5.2	Johnston	3.08
	Pitt	2.2	Pitt	4.8	Pender	3.07
	Craven	2.1	Onslow	4.3	Craven	2.99
	Pender	2.1	Pamlico	4.1	Guilford	2.63
	Guilford	1.8	Dare	3.7	Dare	2.58
Top 5 Other States	Virginia	10.3	Florida	0.2	Virginia	2.39
	Pennsylvania	2.9	Pennsylvania	0.2	South Carolina	1.06
	Maryland	2.3	Tennessee	0.2	Pennsylvania	0.48
	South Carolina	1.0	California	0.2	Maryland	0.34
	New Jersey	0.9			Georgia	0.20

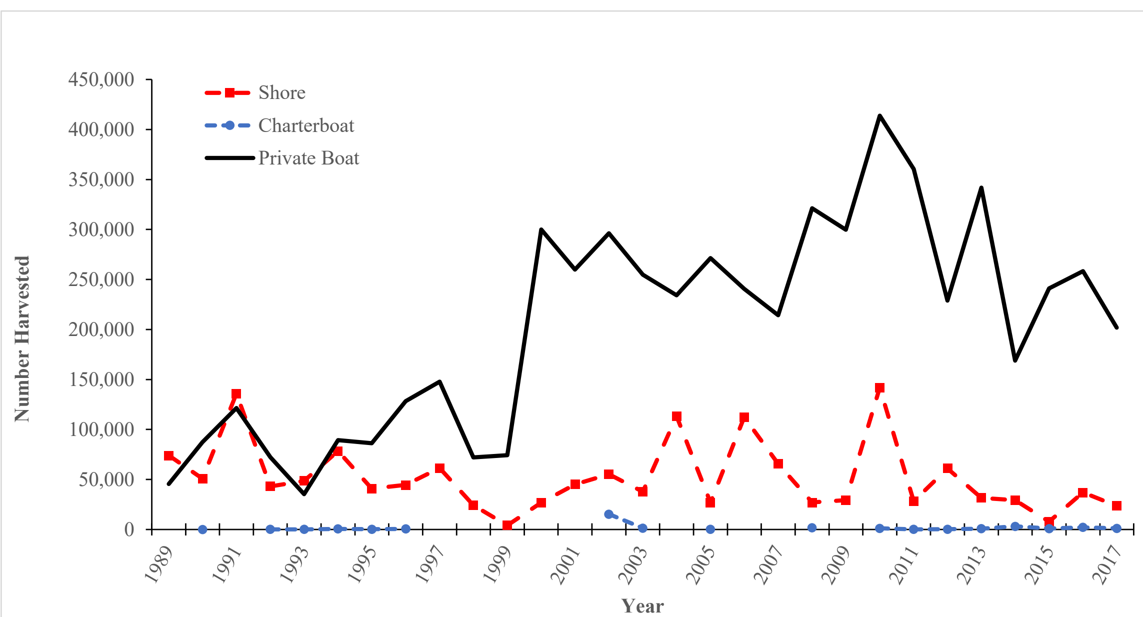

Figure 20. Number of southern flounder harvested in the recreational fishery by MRIP mode, 1989–2017. (Source: Marine Recreational Information Program)

Summary of Economic Impact of Recreational Fishing

The economic impact estimates presented for southern flounder recreational fishing represent the economic activity generated from trip expenditures. These estimates are a product of annual trip estimations originating from the NOAA Fisheries MRIP effort data by area and by mode (i.e., shore, for-hire, private/rental vessel, and man-made), and trip expenditures estimates from the division economics program biennial socioeconomic survey of CRFL license holders (Dumas et al. 2009; Crosson 2010; Hadley 2012; Stemle and Condon 2017). The product of these estimates gives us an annual estimate of trip expenditures made by all licensed anglers for a given year. For this analysis, a recreational flounder trip is defined as a fishing trip for which any flounder was the primary or secondary target species by the angler, or if southern flounder was caught during that trip.

Additionally, these data are used to generate state-level economic impact estimates of recreational flounder fishing in North Carolina. Using IMPLAN statistical software, these direct expenditure estimates from recreational flounder fishing produce indirect output impacts to the state economy across four categories: sales, labor income, value-added impacts, and employment (IMPLAN 2013). Additionally, all imputed expenditure estimates are adjusted for inflation based on 2016 prices, as this was the most recent year of expenditure survey data. For a detailed explanation of the methodology used to estimate the economic impacts please refer to the division's License and Statistics Section Annual Report, which can be found at: https://deq.nc.gov/about/divisions/marine-fisheries/science-and-statistics/fisheries-statistics.

Aside from a spike in 2008 and a dip in 2017, recreational flounder effort is relatively stable over time (Table 10). With this, the economic impact from this fishery is also stable over time, as recreational flounder angling represents a sizeable contribution to the state economy. The top industries impacted by recreational southern flounder fishing in terms of output sales and employment are retail gasoline stores, retail sporting goods stores, retail food and beverage stores, real estate, and wholesale trade businesses.

It should be noted that not included in these estimates, but often presented in the division's overall recreational impacts models, are the durable good impacts from economic activity associated with the consumption of durable goods (e.g., rods and reels, other fishing related equipment, boats, vehicles, and second homes). Durable goods represent goods that have multi-year life spans and are not immediately consumable. Some equipment related to fishing is considered durable goods, however, we cannot estimate the durable goods expense of anglers for a given species. Durable goods expenses and impacts are estimated on an annual basis and serve to supplement angler expenditures outside of trip-based estimates.

Lastly, due to the size and popularity of recreational flounder fishing in North Carolina, changes in access to this fishery may lead to tangible, yet unquantifiable impacts to the value of other sport fisheries (Scheld et al. 2020). Broadly, participants target or catch flounder more than other recreational species due to higher personal satisfaction gained from fishing for this species over others in North Carolina. However, it is unknown whether this benefit from flounder fishing would transfer to other fisheries if effort restrictions were put in place. There is a possibility that when faced with reduced access to flounder fishing, some anglers may choose to not fish at all, rather than seek out new target species. Alternatively, the utility of flounder fishing may not be significantly greater than other species, and anglers would target other species more frequently.

Table 10. Economic impacts associated with recreational southern flounder fishing in North Carolina from 2008–2017. Impacts are generated using IMPLAN statistical software and division recreational survey data. Trips are defined as a fishing trip for which any flounder is the primary or secondary target, or if southern flounder was caught during that trip. All job impacts represent both part- and full-time jobs. Note: impact estimates across categories are not additive.

Year	Estimated Total Flounder Trips	Trip Expenditures	Estimated Sales Impact	Estimated Income Impact	Estimated Employment Impact	Estimated Value-Added Impact
2008	2,701,930	$403,612,123	$376,417,686	$135,957,566	3,292	$205,722,681
2009	1,482,500	$215,695,683	$200,699,372	$72,448,738	1,770	$109,870,023
2010	1,877,504	$280,546,465	$262,481,379	$95,039,325	2,312	$143,569,612
2011	1,796,204	$283,056,149	$250,861,698	$90,609,485	2,212	$137,255,698
2012	1,744,458	$277,772,559	$244,156,371	$88,393,860	2,159	$133,589,470
2013	1,707,904	$273,226,860	$238,202,597	$86,449,024	2,105	$130,332,132
2014	1,639,593	$269,763,604	$229,373,566	$83,466,334	2,027	$125,444,042
2015	1,708,499	$279,669,886	$228,724,518	$83,228,735	2,037	$125,250,995
2016	1,714,200	$279,905,674	$232,116,853	$84,789,195	2,079	$127,093,283
2017	1,250,216	$210,976,279	$171,358,430	$62,652,077	1,532	$93,793,106
Average	1,762,301	$277,422,528	$243,439,247	$88,303,434	2,153	$133,192,104

Through this complicated dynamic, the value and economic impact of other recreational species may increase or decrease based on this concept of per-species utility. However, while it is important to acknowledge how flounder management may economically impact other fisheries, this interaction is not fully understood, and, therefore, it cannot be determined how the value of other recreational species would shift with changes in access to flounder.

SUMMARY OF FISHERIES CONCLUSION

Both the commercial and recreational fisheries combine to create a very dynamic southern flounder fishery in North Carolina with a combined economic value of over 600 million dollars to the state of North Carolina. Effort and harvest in the commercial fishery have continuously declined from nearly 42,475 trips in 1994 to 17,963 trips in 2017 and landings from over 4.8 million pounds in 1994 down to roughly 1.4 million pounds in 2017 (Figure 21).

The recreational sector has seen an increase in both effort and harvest and a major increase in releases since 1994, with trips remaining relatively steady from 1.31 million trips in 1994 to 1.25 million trips in 2017 and harvest increasing from 300,000 pounds in 1994 to 400,000 pounds in 2017 with over one-million pounds harvested in 2010 (Figure 21). Recreational releases have also increased through the years from 209,956 fish in 1999 to over 1.9 million fish released in 2017. Additional information describing discards is in the *Stock Assessment of Southern Flounder (Paralichthys lethostigma) in the U.S. South Atlantic, 1989-2017*, available at https://deq.nc.gov/about/divisions/marine-fisheries/public-information-and-education/managing-fisheries/fmp.

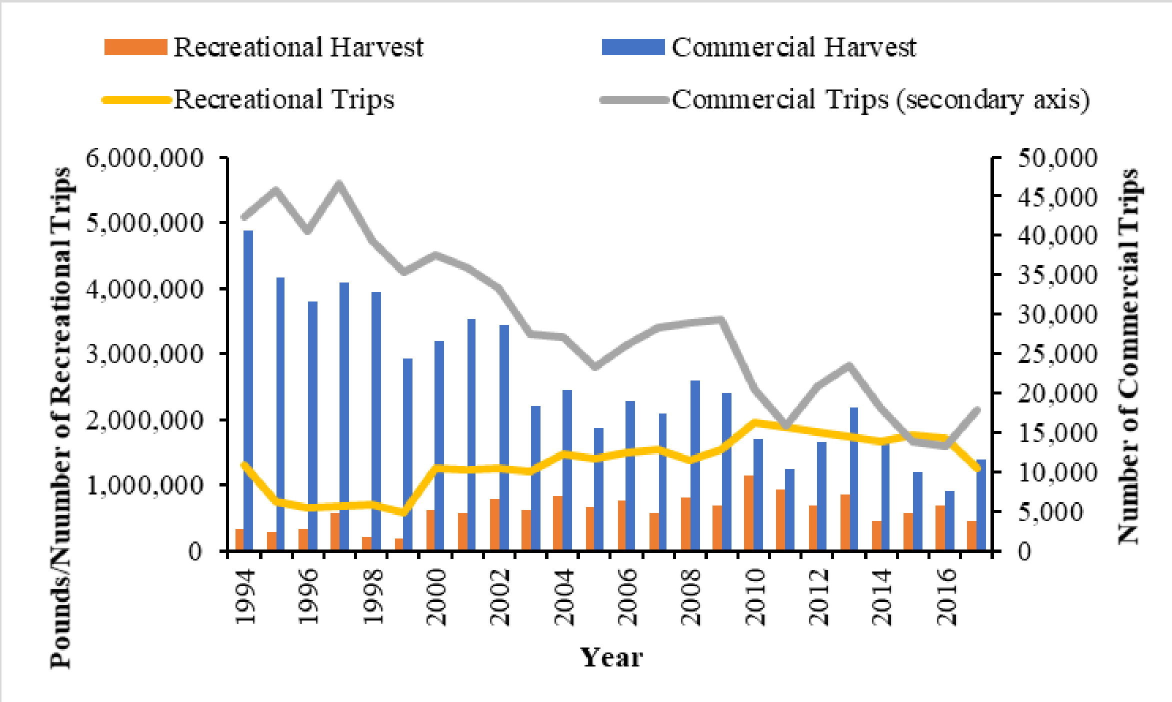

Figure 21. Commercial and recreational harvest (measured in pounds) and effort (measured in trips) from the N.C. Southern Flounder Fishery, 1994–2017. Recreational landings and trips do not include recreational commercial gear or the gig fishery due to data limitations. (Source: North Carolina Trip Ticket Program and Marine Recreational Information Program)

An in-depth analysis and discussion of North Carolina's commercial and recreational southern flounder fisheries can be found in earlier versions of the Southern Flounder FMP (NCDMF 2005, 2013, 2017, 2019); and 2018 and 2019 Southern Flounder Stock Assessments (Lee et al. 2018; Flowers et al. 2019); all documents are available on the division website at: https://deq.nc.gov/about/divisions/marine-fisheries/public-information-and-education/managing-fisheries/fmp, the License and Statistics Annual Report produced by the division which can be found at: https://deq.nc.gov/about/divisions/marine-fisheries/science-and-statistics/fisheries-statistics, or the *Achieving Sustainable Harvest* issue paper included in this FMP.

RESEARCH RECOMMENDATIONS

The research recommendations listed below are offered by the PDT and the stock assessment working group to improve future management strategies and stock assessments of the South Atlantic southern flounder stock. Those recommendations followed by an asterisk (*) were identified as the top five high priority research recommendations and are discussed further below. Otherwise, recommendations within each category, High (H), Medium (M), Low (L), are not listed in order of importance.

Biological/Stock Assessment/Fishery

- H - Conduct studies to quantify fecundity and fecundity-size/age relationships in Atlantic southern flounder. *
- H - Improve estimates of the discard (B2) component (catches, lengths, and ages) for southern flounder from MRIP (underway). *
- H - Expand, improve, or add fisheries-independent surveys of the ocean component of the Stock. *
- H - Determine locations of spawning aggregations of southern flounder (underway). *
- H - Complete an age validation study using known age fish. *
- H - Research and evaluate data on the sub-legal fish in the recreational fishery as it relates to potential future reductions in minimum size limits (underway).
- M - Promote data sharing and research cooperation across the South Atlantic southern flounder range (North Carolina, South Carolina, Georgia, and Florida).
- M - Further research on factors that impact release mortality of southern flounder in the recreational hook-and-line fishery.
- M - Research on deep hooking events of different hook types and sizes on southern flounder.
- M - Coast-wide at-sea observations of the flounder pound net fishery.
- M - Develop a survey that will provide estimates of harvest and discards for the recreational gig fisheries in North Carolina, South Carolina, Georgia, and Florida.
- M - Develop a survey that will provide estimates of harvest and discards from gears used to capture southern flounder for personal consumption.
- M - Collect additional discard data (ages, species ratio, lengths, fates) from other gears (in addition to gill nets) targeting southern flounder (pound net, gigs, hook and line, trawls).
- M - Expand, improve, or add inshore and offshore surveys of southern flounder to develop indices for future stock assessments.
- M - Collect age and maturity data from the fisheries-independent South East Area Monitoring and Assessment Program (SEAMAP) Trawl Survey given its broad spatial scale and potential to characterize offshore fish.
- M - Conduct studies to better understand ocean residency of southern flounder.
- M - Consider the application of areas-as-fleets models in future stock assessments given the potential spatial variation (among states) in fishery selectivity and fleet behavior in the southern flounder fishery.
- M - Consider the application of a spatial model to account for inshore and ocean components of the stock as well as movements among states.

- M - Work to reconcile different state-level/regional surveys to better explain differences in trends.
- M - Evaluate the utility of circle hooks in the southern flounder recreational hook-and-line fishery.
- L - Develop a recreational catch per unit effort (CPUE; e.g., from MRIP intercepts or the Southeast Regional Headboat Survey if sufficient catches are available using a species guild approach to identify trips, from headboat logbooks, etc.) as a complement to the more localized fishery independent indices.
- L - Explore reconstructing historical catch and catch-at-length data prior to 1989 to provide more contrast in the removals data.
- L - Study potential species interactions among Paralichthid flounders to explain differences in population trends where they overlap.
- L - Explore potential impacts stocking may have on the southern flounder population and the costs associated with implementing a stocking program.
- L - Continued otolith microchemistry research to gain a better understanding of ocean residency of southern flounder (underway).
- L - Implement fishery dependent sampling of the commercial spear fishery for flounder in the ocean.
- L - Determine harvest estimates and implement fishery dependent sampling of the recreational spear fishery for flounder in the ocean.
- L - Further research on flatfish escapement devices in crab pots that minimize undersized flounder bycatch and maximize the retention of marketable blue crabs.
- L - Expand tagging study to ocean component of the stock to estimate emigration, immigration, movement rates, and mortality rates throughout the stock's range.
- L - Develop protocol for archiving and sharing data on gonads for microscopic observation of maturity stage of southern flounder for North Carolina, South Carolina, Georgia, and Florida.
- L - Examine the variability of southern flounder maturity across its range and the effects this may have on the assessment model.
- L - Further research on the size distribution of southern flounder retained in pound nets with 5.75-ISM and 6-ISM escape panels.
- L - Research on the species composition and size distribution of fish and crustaceans that escape pound nets through 5.75-ISM and 6-ISM escape panels.
- L - Develop a survey that will estimate harvest and discards from commercial gears used for recreational purposes.
- L - Continue at-sea observations of the large-mesh gill-net fishery including acquiring biological data on harvest and discards (underway).
- L - Develop survey that better represents the for-hire industry.

Ecosystem

- M - Development of alternative gears to catch southern flounder (some research completed, more may be needed).
- L - Continued gear research in the design of gill nets and pound nets to minimize protected

species interactions (some research completed, more may be needed).

- L - Investigate the impacts of warming water temperature on the southern flounder stock.
- L - Develop a study that evaluates inlets and their relationship to southern flounder migration.
- L - Develop studies to investigate the impacts of emerging compounds on southern flounder.

Socio/Economic

- M - Study revenue variability and profitability of commercial southern flounder fishing in North Carolina based on catch characteristics.
- M - Generate a stated preference survey of North Carolina recreational anglers to understand perceived value of targeting southern flounder compared to other estuarine finfish species.

Research Recommendations Summary

The top five research priorities with an (*) identify data needs for continued improvements to the coast-wide stock assessment. Gaining a better understanding of the ocean component of the stock is critical and includes gathering information on the spawning locations, expanding and developing surveys to provide independent abundance trends for the ocean component of the stock, and conducting research to identify fecundity estimates for spawning females by length. Determining the age of fish is critical when estimating maturity and stock structure so verifying the ages of wild fish through an age validation study would provide additional precision. Finally, a large component of removals from this stock is fish released during recreational fishing activities. Many of these fish are not intercepted by port agents during sampling as they are not kept. It is critical that estimates of discards by size and species are available for the various flounder species across the species range.

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APPENDICES

APPENDIX 1. MANAGEMENT ISSUES CONSIDERED BUT NOT DEVELOPED

A scoping period to solicit input on management strategies for the Southern Flounder Fishery Management Plan Amendment 3 was held Dec. 4 through Dec. 18, 2019. During this time, members of the public were encouraged to provide written comments or verbal comments at one of three in-person scoping meetings held within the scoping period. In addition, the NCMFC was provided the opportunity to offer input on management strategies at its February 2020 business meeting. The division received many comments during this scoping period, but few were relevant to potential management strategies. Comments received that were focused on a management strategy included:

- Elimination of specific gear types for the harvest of southern flounder;
- Limiting entry in the flounder pound net fishery;
- Stocking of southern flounder;
- The use of circle hooks in the recreational flounder fishery; and
- Reducing bycatch of southern flounder in the shrimp trawl fishery.

These suggested strategies were reviewed by the division during development of Amendment 3 but are not included as fully developed issue papers. A description of the management strategy and rationale for not developing them are provided for each strategy below.

Elimination of Gears Including Gigs (both sectors), Gill Nets, and RCGL

The possible elimination of specific gears (i.e., gigs for one or both sectors, anchored large-mesh gill nets) for harvesting southern flounder for either the commercial or recreational fishery is statutorily granted to the NCMFC by G.S. 143B-289.52., Marine Fisheries Commission–powers and duties, which states the NCMFC "shall have the power and duty to authorize, license, regulate, prohibit, prescribe, or restrict all forms of marine and estuarine resources in coastal fishing waters with respect to time, place, character, or dimensions of any methods or equipment that may be employed in taking fish." Such actions follow from the NCMFC's charge to "adopt rules to be followed in the management, protection, preservation, and enhancement of the marine and estuarine resources within its jurisdiction…." (G.S. 143B-289.52). The division provides the best available data for a fishery (gear) to meet the mandate for producing a sustainable harvest of the southern flounder stock and to evaluate impacts to habitat. Each allowable gear is similarly presented regardless of its contribution to overall removals from the stock and the division does not presume any NCMFC changes in gear use, unless directed to do so by the NCMFC, which in this case initiated the development of the *Phasing Out Anchored Large-Mesh Gill Nets from the North Carolina Southern Flounder Fishery* issue paper.

Regulations involving the RCGL are found in G.S. 113-173 and Rule 15A NCAC 03O.0302 which authorizes certain commercial fishing gear for recreational use under a valid Recreational Commercial Gear License. A rule change by the NCMFC is required to alter the allowable gears used by RCGL license holders.

Limited Entry in the Pound Net Fishery

G.S. 113-182.1(g) provides narrowly constrained authority to the NCMFC to limit entry into a fishery states the following:

(g) To achieve sustainable harvest under a Fishery Management Plan, the Marine Fisheries Commission may include in the Plan a recommendation that the General Assembly limit the number of fishermen authorized to participate in the fishery. The Commission may recommend that the General Assembly limit participation in a fishery only if the Commission determines that sustainable harvest cannot otherwise be achieved. In determining whether to recommend that the General Assembly limit participation in a fishery, the Commission shall consider all of the following factors:

(1) Current participation in and dependence on the fishery
(2) Past fishing practices in the fishery
(3) Economics of the fishery
(4) Capability of fishing vessels used in the fishery to engage in other fisheries
(5) Cultural and social factors relevant to the fishery and any affected fishing communities
(6) Capacity of the fishery to support biological parameters
(7) Equitable resolution of competing social and economic interests
(8) Any other relevant considerations

Flounder pound nets are a stationary gear that funnel fish along a lead and into a pound (holding area) where they are removed while the fishermen slowly bunt the net. While fish are trapped in the pound, they remain in the water until harvest. This allows fishermen to be selective about fish they harvest or release. Flounder pound nets operate from upper Currituck Sound south through Core Sound. The southern flounder pound net fishery was the dominant gear landing southern flounder into the early 1990s when large-mesh gill nets became the dominate gear. Pound nets again became the top means of southern flounder harvest in 2014. This is likely due to increased regulatory burden on the large-mesh gill-net fishery.

During the last 10 years, the average number of pound net permits issued was 285, ranging from 267 to 304. To obtain a flounder pound net permit, an individual must complete an application package and the selected site goes through a review process including a public comment period. Unlike other gears, pound nets require an extensive monetary investment and many pound net fishermen have been building their stands for multiple generations. Due to the monetary investment, permitting process, and limited productive fishing areas, there has not been a sharp increase in pound net permits. While the possibility does exist that the number of pound net applications may rise in the future, there is no evidence that limited entry is the only way to achieve sustainable harvest, as required by state law in order to pursue.

Sustainable harvest in the southern flounder fishery is predicted to be achievable within 10 years of adoption of Amendment 3 through reductions in total removals for all fisheries and gears. As a result, this statute cannot be employed at this time to pursue limited entry. In addition, Amendment 3 proposes implementing a commercial quota on the harvest of southern flounder, thus the volume of pound nets operating in the fishery will not impact the volume of removals, just the rate at which the quota is harvested. Once the level of harvest has been met, the fishery closes. This closure is not impacted by the number of nets that are set, although the number of pound nets in use may shorten the time in which the quota is reached.

Stocking

Stock enhancement is the stocking of fish to enhance or improve the condition or distribution of a wild stock. North Carolina State University initiated a series of workshops on flounder stock enhancement in North Carolina in the mid-1990s. This effort brought together fish ecologists, culturists, and managers from around the world and was a good forum to discuss successes and failures in aquaculture and stock enhancement. A report of these conversations was developed and outlined several research priorities that should be investigated (Waters 1998), but few if any have been investigated leaving many of the questions unanswered. These unanswered questions leave data gaps that are critical in determining if stocking is appropriate at this time for achieving a self-sustaining southern flounder population.

While management actions for southern flounder have not had the expected response in rebuilding the spawning stock biomass to necessary levels to sustain the stock, not all strategies have been attempted. Amendment 3 will expand on conventional management strategies and employ a quota system for both the commercial and recreational southern flounder fisheries for the first time. Moving forward with Amendment 3 without including stocking as a management strategy does not prohibit researchers from investigating stocking strategies for southern flounder. If more information becomes available about stocking strategies, additional consideration may be warranted during a future review of this FMP.

Use of Circle Hooks in the Southern Flounder Fishery

The use of circle hooks for multiple species was addressed by the division as directed by the NCMFC. At its August 2019 business meeting, the NCMFC directed staff to provide information on the science supporting the use of circle hooks and bent barbed treble hooks and provide input on the efficacy of requiring their use. The NCMFC passed a motion at its May 2020 business meeting directing the division to “develop an issue paper for rulemaking to require the use of barbless non-offset circle hooks when hook size relates to 2/0 or larger while using natural bait. In addition, barbs on treble hooks would be required to be bent down.” The division developed the issue paper and presented management options to the NCMFC at their February 2021 business meeting. The NCMFC voted not to move forward with rule making but instead directed the division to consider circle hook requirements on a species-by-species basis through the fishery management plan process. After a review of available literature of the effect of circle hooks on southern flounder, there is minimal research available at the species level. Inferences could be made from available literature on summer flounder that found no difference in survival rates post-release for fish captured with circle or J-hooks (Malchof and Lucy 1998). Additionally, Stuntz and McKee (2006) concluded that angler education had a greater effect on post-release survival of fish than hook type and bait configuration. Due to the lack of available literature on the effect of circle hook on southern flounder, a research recommendation was added to this FMP (see the *Research Recommendations* section).

Reducing Shrimp Trawl Bycatch

Management strategies to reduce the bycatch of non-target species in the shrimp trawl fishery as well as potential changes to existing shrimp management strategies are being examined as part of the ongoing development of Amendment 2 to the N.C. Shrimp FMP. The division determined that is the most appropriate plan to address shrimp trawl bycatch. Through the original Shrimp FMP (NCDMF 2006) and Amendment 1 (NCDMF 2015), the following were implemented that are having a positive impact on reducing southern flounder bycatch in shrimp trawls.

- Portions of Core Sound (banks side north of Drum Inlet to Wainwright Island), Intracoastal Waterway (Rich Inlet to Carolina Beach), as well as the bays adjacent to the Cape Fear River and Bald Head Island were closed to trawling.
- The use of otter trawls was prohibited upstream of the Highway 172 Bridge in the New River, limiting trawling to skimmer trawls.
- A maximum combined 90 ft. headrope length was implemented in the mouths of the Pamlico and Neuse rivers and all of Bay River to minimize southern flounder bycatch and protect critical habitat used by southern flounder.
- The requirement to use two bycatch reduction devices (BRD) in shrimp trawls and skimmer trawls was implemented.
- A maximum combined headrope length of 220 feet was established in all internal coastal waters where there was no existing maximum combined headrope requirements.
- The requirement to use one of four gear combinations tested by the industry workgroup that achieved at least 40% finfish bycatch was implemented in the Pamlico Sound and portions of Pamlico, Bay, and Neuse rivers (NCMDF 2018).
- Shrimp trawling was prohibited in the Intracoastal Waterway channel from the Sunset Beach Bridge to the South Carolina line, including the Shallotte River, Eastern Channel, and lower Calabash River to protect small shrimp and reduce bycatch (NCDMF 2021).

The division continues to work with commercial fishermen to develop new gear configurations to reduce bycatch in the shrimp trawl fishery as well as to characterize the fishery. While estimates of shrimp trawl bycatch are accounted for in the southern flounder stock assessment (Lee et al. 2018; Flowers et al. 2019) further actions to address bycatch of southern flounder from shrimp trawls is most appropriately handled through the N.C. Shrimp FMP or gear specific management.

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APPENDIX 2. REGULATIONS OF OTHER STATES

Table 2.1. East coast and Gulf of Mexico southern flounder regulations by state as of September 2021.

State	Size Limit	Daily Bag Limit	Commercial Trip Limits	Seasons
North Carolina	15"	4 fish per person per day	None	Recreational: Sep. 1–Sep. 14: Commercial: Northern Sep. 15–Oct 1., Central Oct. 1–19, Southern Oct. 1–Oct. 21
South Carolina	16"	5 per person per day—not to exceed 10 per boat per day	Commercial fishermen are held to recreational limits, trawling and trapping are exempt.	Open all year
Georgia	12"	15 per person per day	Commercial fishermen must abide by season, creel, and size limits.	Open all year
Florida	14"	5 per person per day	Commercial trip and vessel limit 150 fish from Dec. 1–Oct. 14, and 50 fish from Oct 15.–Nov. 30; a federal waters trawl bycatch limit of 150 flounder/trip from Dec. 1–Oct. 14, and 50 fish/trip from Oct. 15–Nov. 30	Oct. 15–Nov. 30 recreational closed season
Alabama	14"	5 per person per day	40 per person or per vessel	Closed Nov. 1–30 for both commercial and recreational
Mississippi	12"	10 per person per day	None; 74,000 pound quota that once reached will close fishery for remainder of year	Open all year
Louisiana	none	10 per person per day	10 fish daily limit for each licensed fisherman; however, commercial shrimping vessels may retain and sell all southern flounder harvested as bycatch	Open all year
Texas	15"	5 per person per day with the exception of Nov. 1–Dec. 14 when it is closed	30 per person per day with the exception of Nov. 1 – Dec. 14 when season is closed. On a shrimp boat the limit is equal to the recreational limit per person with a current shrimp boat captains license and is subject to the 50% bycatch rule.	Open all year with the exception of the gig fishery being closed from Nov. 1–30

APPENDIX 3. NORTH CAROLINA FISHERY MANAGEMENT

The N.C. General Assembly enacts fisheries statutes, or laws, and provides the NCMFC authority to adopt rules to implement those statutes in coastal and joint fishing waters. These rules are found in Chapters 03 and 18 of Title 15A of the N.C. Administrative Code. The following list, while not exhaustive, includes the primary rules used to manage the southern flounder fishery. In inland fishing waters, the N.C. Wildlife Resources Commission rule 15A NCAC 10C .0307 establishes the same recreational seasons, size limits, and bag limits for flounder as those established by NCMFC rules and proclamations issued by the Fisheries Director in adjacent joint and coastal fishing waters. Please refer to the N.C. Administrative Code for the full text of the rules at http://reports.oah.state.nc.us/ncac.asp.

In addition to adopting rules, the NCMFC has the authority to delegate to the Fisheries Director the ability to issue public notices, called proclamations, suspending or implementing particular commission rules that may be affected by variable conditions. The proclamation authority granted to the Fisheries Director in commission rules includes the ability to open and close seasons and fishing areas, set harvest and gear limits, and establish conditions governing various fishing activities. Rules that contain proclamation authority are marked by a diamond symbol ("♦"). Proclamations are not included in this document because they change frequently and are found at https://deq.nc.gov/fisheries-management-proclamations.

- 15A NCAC 03I. 0120 Possession or Transportation Limits Through State Waters; Sale of Native Species
  Sets requirements for possession and transportation of species subject to state season, size, or harvest restrictions. Applies to management across species of flounder (i.e., southern, summer, and Gulf flounder).

- 15A NCAC 03J .0101 Fixed or Stationary Nets
  Establishes where it is unlawful to set fixed or stationary nets.

- 15A NCAC 03J .0102 Nets or Net Stakes
  Establishes where it is unlawful to use nets or net stakes.

- ♦ 15A NCAC 03J .0103 Gill Nets, Seines, Identification, Restrictions
  Establishes requirements for the use of gill nets and seines, including proclamation authority for time, area, means and methods, and seasons.

- ♦ 15A NCAC 03J .0500 Pound Nets
  Establishes requirements for pound net sets, including flounder pound net sets. Limited proclamation authority may be implemented only for escape panel requirements.

- ♦ 15A NCAC 03M .0503 Flounder
  Contains proclamation authority that allows the Fisheries Director, within the bounds of the current Southern Flounder Fishery Management Plan (FMP), to

specify size, season, area, quantity, and means and methods, and the proclamation authority to require submission of statistical and biological data. This rule is the primary management tool to implement management measures, subject to variable conditions, and to implement adaptive management for the southern flounder fisheries ***within the bounds of the current FMP****.*

- ♦ 15A NCAC 03O .0500, Permits
  Establishes procedures and requirements for permits, including eligibility and standard permit conditions such as reporting. Rule 15A NCAC 03O .0506, Special Permit Required for Specific Management Purposes, provides authority to require a new permit for quota monitoring in the southern flounder fishery.

- 15A NCAC 10C .0307, Flounder, Sea Trout, and Red Drum
  Wildlife Resources Commission rule, as described above.

APPENDIX 4. ISSUE PAPERS

APPENDIX 4.1. ACHIEVING SUSTAINABLE HARVEST IN THE NORTH CAROLINA SOUTHERN FLOUNDER FISHERY

I. ISSUE

Implement long-term management measures to achieve sustainable harvest in the North Carolina southern flounder fishery that end overfishing and rebuild the spawning stock.

II. ORIGINATION

The NCMFC adopted Amendment 2 to the Southern Flounder FMP in August 2019. Amendment 2 authorized the development of Amendment 3 to begin immediately in order to implement more comprehensive, long-term management measures. State law requires these management measures to achieve sustainable harvest in the southern flounder fishery (Fisheries Reform Act, G.S. 113-182.1).

III. BACKGROUND

The southern flounder is a demersal species found in the Atlantic Ocean and Gulf of Mexico from northern Mexico to Virginia. The biological unit stock for southern flounder inhabiting U.S. South Atlantic coastal waters includes waters of North Carolina, South Carolina, Georgia, and the east coast of Florida (see the *Introduction* and the *Description of the Stock* sections for more information on the management authority, distribution, and unit stock definition of southern flounder).

To address the coast-wide nature of the southern flounder stock, a comprehensive stock assessment was completed to determine the status of the stock using data from North Carolina through the east coast of Florida from 1989 through 2017 (Flowers et al. 2019). The assessment model indicated the stock was overfished and overfishing was occurring (Figure 3, Figure 5 in the *Description of the Stock* section). Projections were performed to determine the reduction in fishing mortality necessary to end overfishing and to rebuild the spawning stock biomass and end the overfished status.

Fishing mortality was estimated at the target of $F_{35\%}$ as 0.35 and the threshold of $F_{25\%}$ as 0.53. In 2017, F was 0.91, which is higher than the F threshold of 0.53 and indicates overfishing is occurring (Figure 5, in the *Description of the Stock* section). The probability that fishing mortality in 2017 was above the threshold value of 0.53 is 96%, whereas there is a 100% probability fishing mortality in 2017 was above the target value of 0.35.

The spawning stock biomass target ($SSB_{35\%}$) was estimated to be 5,452 metric tons (approximately 12.0 million pounds) and threshold ($SSB_{25\%}$) to be 3,900 metric tons (approximately 8.6 million pounds). In 2017, the estimated SSB was 1,031 metric tons (approximately 2.3 million pounds), which is lower than the SSB threshold of 3,900 metric tons and indicates the stock is overfished (Figure 3 in the *Description of the Stock* section). The probability that SSB in 2017 was below the threshold and target values (3,900 and 5,452 metric tons, respectively) is 100%.

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.

To meet statutory requirements, calculations were made to determine the reductions in total coast-wide removals (all fishery removals from each of the four states) necessary to end overfishing within two years and recover the stock from an overfished status within the 10-year period. Total removals are defined as the total pounds of landed southern flounder plus dead discards. Dead discards are comprised of fish that were dead upon retrieval of gear and not harvested and fish that were released alive that experience delayed mortality. For more information on projections and the resulting removal reductions refer to Amendment 2 or the 2019 updated stock assessment, which includes assumptions and computational details (Flowers et al. 2019; NCDMF 2019).

The projections are based on the conditions and restrictions such as minimum size limits for both the commercial and recreational fishery, current gear requirements, and selected soak time and daytime restrictions in effect at the time that resulted in the annual total removals. These measures, along with recruitment strength, environmental conditions, and fishing effort, influenced the fishery during the 2017 terminal year of the stock assessment which is the base year for reduction calculations. Any changes in these past conditions will have an undetermined impact on the projections and the rebuilding schedule.

As required by North Carolina law, a fishing mortality of 0.34 is needed to reach the SSB threshold by 2028 and end the overfished status (Figure 7 in the *Description of the Stock* section). This will require at a minimum a 52% reduction in total removals coast-wide. To increase the probability of success of rebuilding to the higher SSB target by 2028, fishing mortality would need to be lowered to 0.18 (Figure 8 in the *Description of the Stock* section). This will require a 72% reduction in total removals coast wide. A fishing mortality that falls between the identified target and threshold values meets the statutory requirements (e.g., 62%; Figure 4.1.1). All projections are associated with at least a 50% probability of achieving sustainable harvest for the fishery.

The management measures implemented in North Carolina from the original Southern Flounder FMP (NCDMF 2005), Amendment 1 (NCDMF 2013), and Supplement A to Amendment 1 (NCDMF 2017a) as modified by the Aug. 17, 2017 settlement agreement have not resulted in the necessary increase in SSB to end the stock's overfished status, thus continued reductions are necessary. In developing management measures for Amendment 2 and Amendment 3, the division applied the reductions only to North Carolina's portion of total removals. To account for North Carolina's portion of these reductions in the recreational and commercial fisheries, the identified reduction was applied to both the dead discards and landings, or total removals, for each sector of the North Carolina southern flounder fishery from the terminal year of the assessment (2017).

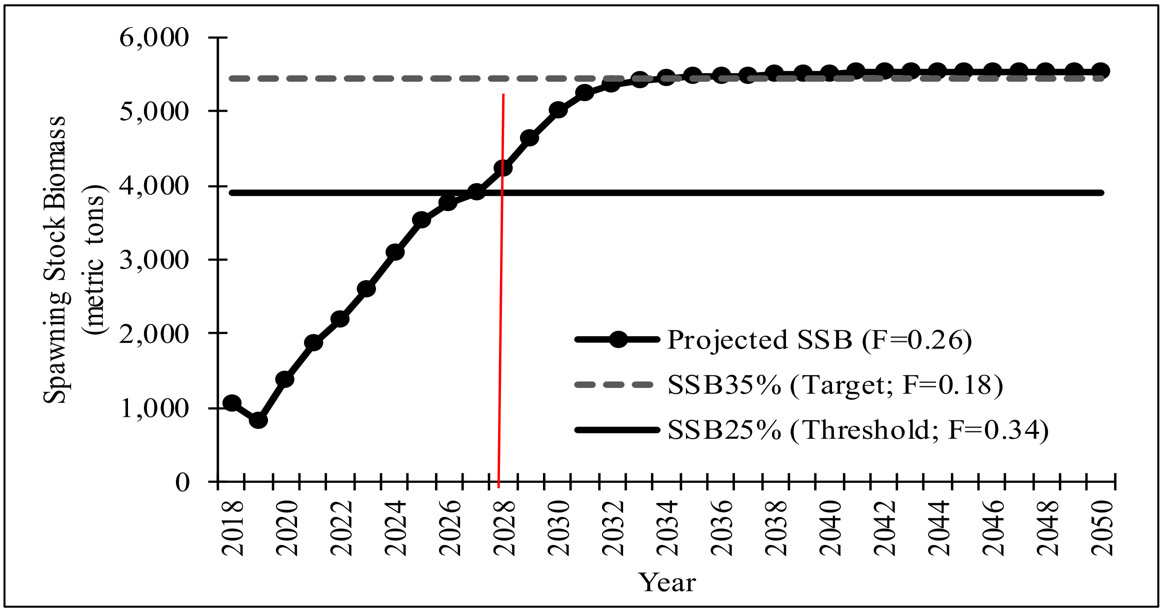

Figure 4.1.1. Predicted future spawning stock biomass (metric tons) assuming the fishing mortality value (*F*=0.26; 62% reduction in total removals) necessary to reach between the SSB_{Target} and $SSB_{Threshold}$ by 2028 (indicated by vertical red line). (Source: Flowers et al. 2019)

In 2017, total removal for all sectors including dead discards was 1,957,264 pounds; the commercial fishery accounted for 72.2% (including 0.9% dead discards) and the recreational fishery (hook-and-line and gigs) accounted for 27.9% (including 2.0% dead discards) of the total North Carolina removals (Figure 4.1.2). Additional options for allocations were requested by the NCMFC at its November 2020 business meeting. These options are presented in the *Recreational and Commercial Sector Allocation* issue paper and NCMFC preferred option was used to develop this *Achieving Sustainable Harvest* issue paper.

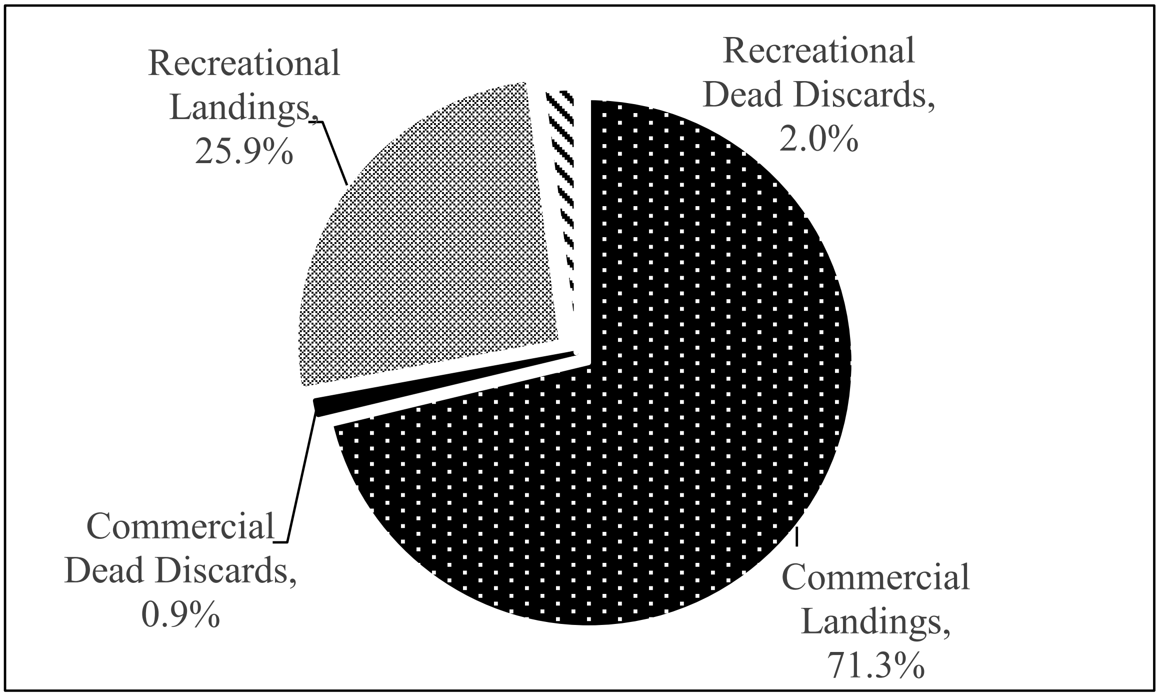

Figure 4.1.2. Contribution of the total removals (observed harvest and dead discards in percent pounds) for the commercial and recreational (hook-and-line and gig) fisheries in North Carolina, 2017. (Source: North Carolina Trip Ticket Program, Marine Recreational Information Program, NCDMF Gig Mail Survey)

In Amendment 3, the management measure proposed to meet sustainable harvest may be changed from a seasonal approach to a quota-based approach. This change does not alter analyses used to calculate reductions but does adjust the terminology used to describe the individual pieces used from Total Allowable Catch (TAC) to Total Allowable Landings (TAL) as landings are the quantifiable mechanism used to manage the quota. Reductions in discards will be accounted for at the end of the fishery as discards are not part of daily quota monitoring and will be added to the annual landings to create total catch and make sure the TAC is not exceeded. This approach differs slightly from Amendment 2. In each amendment, reductions were based on TAC, but as seasons were the selected management measure implemented through Amendment 2, the seasons accounted for estimated reductions in harvest and discards. Based on a fishing mortality that falls between the identified threshold (52% reduction) and target (72% reduction), the range in annual landings of southern flounder that could occur for all sectors is 912,603 pounds to 532,352 pounds, respectively (Table 4.1.1; Figures 4.1.3 and 4.1.4).

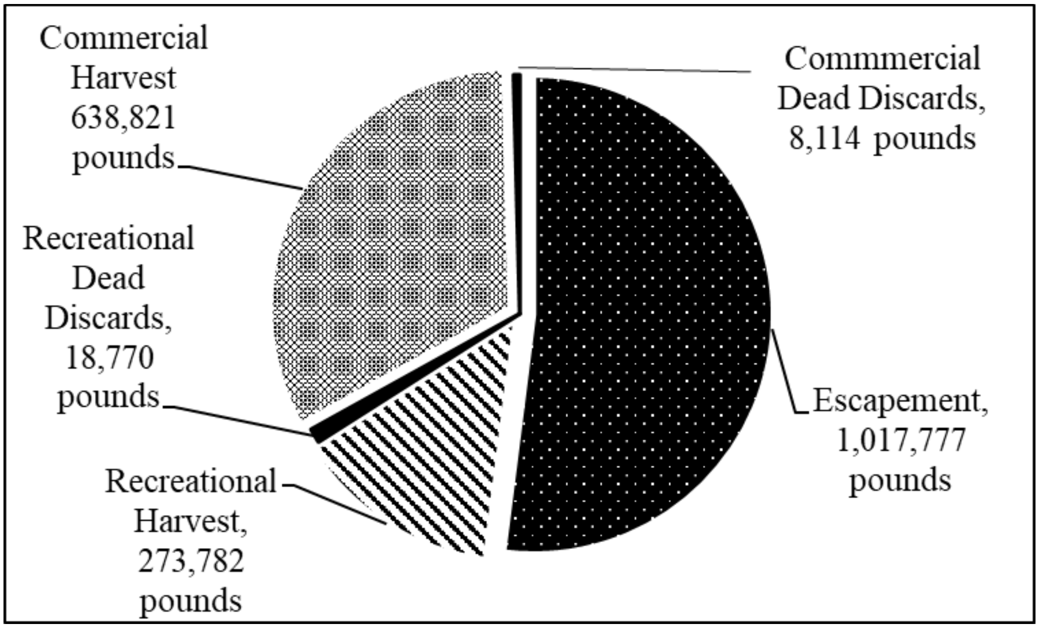

Figure 4.1.3. Estimated escapement of southern flounder (pounds) and contribution of the total removals for the commercial and recreational (hook-and-line and gig) fisheries in North Carolina, 2017, at a 52% reduction and a 70% commercial and 30% recreational allocation. (Source: North Carolina Trip Ticket Program, Marine Recreational Information Program, NCDMF Gig Mail Survey)

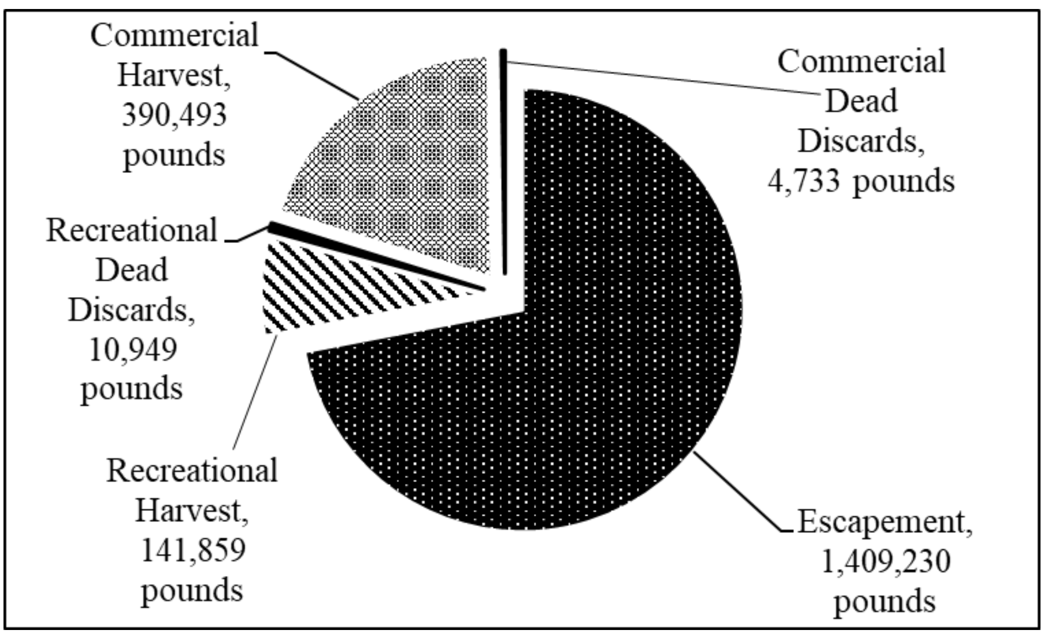

Figure 4.1.4. Estimated escapement of southern flounder (pounds) and contribution of the total removals for the commercial and recreational (hook-and-line and gig) fisheries in North Carolina, 2017, at a 72% reduction and a 70% commercial and 30% recreational allocation. (Source: North Carolina Trip Ticket Program, Marine Recreational Information Program, NCDMF Gig Mail Survey)

Table 4.1.1. Southern flounder total allowable catch (TAC) and total allowable landings (TAL) in pounds needed to meet the necessary reductions for the overfishing threshold and SSB threshold and target of the commercial and recreational fisheries, following the NCMFC selection of a 70/30 allocation.

				Commercial Fisheries			Recreational Fisheries*		
Percent Reduction from 2017 Terminal Year	Total Allowable Catch	Dead Discards	Total Allowable Landings	Total Allowable Commercial Landings	Mobile Gears	Pound Nets	Total Allowable Recreational Landings	Hook and Line	Gigs
2017	1,957,264	56,008	1,901,256	1,330,879	664,957	665,922	570,377	507,877	62,500
52%	939,487	26,884	912,603	638,821	319,179	319,642	273,782	243,782	30,000
62%	743,760	21,283	722,477	505,734	252,684	253,050	216,743	192,993	23,750
72%	548,034	15,682	532,352	372,646	186,188	186,458	159,706	142,206	17,500

*Recreational commercial gear harvest is unknown since 2008 and could not be quantified in the reductions.

Management measures (seasonal closures) implemented in Amendment 2 met the statutory requirements and were critical for reducing removals and initiating the rebuilding of the southern flounder stock. Seasonal closures do not enforce a maximum removal level on the fishery and only limit the time when targeted harvest can occur. Fishing effort can be more concentrated during the open season, potentially altering fishing behaviors from previous years that were used to estimate harvest windows; that is, fishing effort may increase during the open season and lead to higher than predicted removals. Though seasonal flexibility is provided to the NCDMF Fisheries Director by the NCMFC motion approving the adoption of Amendment 2, seasonal closures alone may not result in the needed increase in SSB even if maintained long term (NCDMF 2019). Consequently, the approval of Amendment 2 specified the development of Amendment 3 to begin immediately to implement more comprehensive, long-term management measures to achieve sustainable harvest. Management strategies implemented through Amendment 3 will not restart the time requirements set in Amendment 2 that are necessary to meet the statutory mandates.

Amendment 2 required a 62% reduction in 2019 and a 72% reduction from 2020 onward, both above the minimum 52% reduction that is statutorily required. Preliminary analysis of reductions achieved in 2019 from implementation of Amendment 2 management measures indicate an overall reduction of 35% was achieved or a 43% reduction in total removals for the commercial fishery and a 15% reduction in total removals for the recreational fishery. A level of reduction less than the required 62% was anticipated as the seasons did not begin until Sept. 4, 2019. The fisheries operated three quarters of the calendar year, as compared to estimates that were based on a closure beginning Jan. 1. While Amendment 2 did not meet the 62% reduction in 2019, the 35% reduction achieved was greater than the minimum of 31% to end overfishing. The 2020 landings and preliminary estimates of dead discards indicated a 52% reduction was achieved, exceeding the ending overfishing target and meeting the ending overfished threshold but not the 72% reductions approved under Amendment 2. Harvest exceeded the TAC to meet the 72% reduction for both the commercial and recreational fisheries.

Management measures for Amendment 3 will be selected and implemented from the allowable total removals (landings and dead discards) that are calculated based on the fishing mortality estimates of the terminal year (2017) of the stock assessment (Flowers et al. 2019). Quota-based management accounts for dead discards at the end of each sector's fishing year, therefore quota management is based on total allowable landings. Total allowable catch for the southern flounder fishery was reduced by 72%. Removing dead discards for each corresponding sector results in the estimated total allowable landings that can be removed through the southern flounder fishery. The total allowable landings were allocated 70% commercial and 30% recreational based on the NCMFC decision at the Feb. 2021 business meeting. At a special meeting in March 2021, the NCMFC amended the sector allocations to 70% commercial and 30% recreational in 2021 and 2022, 60% commercial and 40% recreational in 2023, and 50% commercial and 50% recreational in 2024 (see the *Recreational and Commercial Sector Allocations* issue paper for further discussion). While the motion included allocating the southern flounder fishery in 2021, allocations will not take effect until the final approval of Amendment 3; however, to keep consistent with the NCMFC motion 2021 allocations are presented below. The reductions are only applied to North Carolina's portion of total removals. Calculations to predict future harvest reductions depends on environmental parameters, recruitment, and fishing effort remaining similar to previous years, an assumption of the 2019 updated stock assessment. Any changes to these factors will impact the stock's response and whether the statutory requirement of sustainable harvest is achieved.

Building on the seasonal closures in Amendment 2, additional quantifiable and non-quantifiable management measures in Amendment 3 will serve to improve the overall southern flounder stock to reduce total removals and increase likelihood of improved southern flounder SSB and recruitment, while still providing flexibility for fishermen, when possible, in the timing of the harvest for the sectors. This issue paper required assumptions about the fishery to be made as a quota-based management strategy was developed. It evaluates management measures, in addition to seasonal closures, for a long-term approach by constraining harvest in the southern flounder fishery to achieve sustainable harvest in Amendment 3.

IV. AUTHORITY

North Carolina General Statutes

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

North Carolina Marine Fisheries Commission Rules

15A NCAC 03H .0103 PROCLAMATIONS, GENERAL
15A NCAC 03M .0503 FLOUNDER
15A NCAC 03M .0512 COMPLIANCE WITH FISHERY MANAGEMENT PLANS

V. DISCUSSION

The N.C. Department of Environmental Quality and the division recognize the required reductions in the southern flounder fishery are significant but necessary to increase the probability of successfully rebuilding this important recreational and commercial resource. A 72% reduction is used based on the following criteria for the discussion of potential management measures in Amendment 3.

- Amendment 2 required a 72% reduction from 2020 onward until adoption of Amendment 3.
- Projections for rebuilding are based on a minimum of a 50% probability of success. Adopting a reduction greater than the 52% minimum increases the likelihood of achieving the minimum necessary for rebuilding.
- The projections were made with the assumption that each state that participated in the coast-wide stock assessment would implement measures for the necessary reductions required to rebuild SSB. There are uncertainties surrounding the other states with implementing cooperative management and the timing of regulations if implemented. The reductions in Amendment 3 are only to North Carolina's portion of total removals through the time series of the assessment.
- The management measures implemented in North Carolina from the original Southern Flounder FMP (NCDMF 2005), Amendment 1 (NCDMF 2013), and Supplement A to Amendment 1 (NCDMF 2017a) as modified by the Aug. 17, 2017 settlement agreement has not resulted in the necessary increase in SSB to end the stock's overfished status, thus further reductions are necessary.

A fishing mortality that falls between the identified threshold (52% reduction; Figure 7 in the *Description of the Stock* section) and target (72% reduction; Figure 8 in the *Description of the Stock* section) meets the statutory requirements (Figure 4.1.1).

As the potential management measures for Amendment 3 are presented there are several assumptions and limitations provided in the background section of this paper that are important to take into consideration.

- To account for North Carolina's portion of these reductions in the recreational and commercial fisheries, the identified reduction was applied to both the dead discards and landings, or total removals, for each sector (commercial and recreational) of the North Carolina southern flounder fishery from the terminal year of the assessment (2017; Figure 4.1.2).
- Dead discards will be accounted for at the end of the fishery as dead discards are not part of daily quota monitoring and will be added to the landings to adjust the value to make sure the TAC is not exceeded. This approach differs slightly from Amendment 2, in each amendment reductions were based on TAC, but as seasons were the selected management measure implemented through Amendment 2, the seasons accounted for estimated reductions in harvest and dead discards.
- The projections for rebuilding necessary to end overfishing and the overfished status included the minimum size limits for both the commercial and recreational fishery, the current gear requirements, and selected soak time and daytime restrictions. These measures influenced the fishery during the terminal year of the stock assessment and any consideration of changes to those values should be viewed with caution as they will have an undetermined impact on the projections and the rebuilding schedule.
- The approval of Amendment 2 specified the development of Amendment 3 to begin immediately to implement comprehensive, long-term management measures to achieve

sustainable harvest. Management measures for Amendment 3 will be selected and implemented from the allowable total removals (landings and dead discards) that are calculated based on the fishing mortality estimates of the terminal year (2017) of the stock assessment.

- Additional quantifiable and non-quantifiable management measures to augment the seasonal closures will serve to improve the overall southern flounder stock to ensure total removals are reduced and southern flounder SSB and recruitment increase, while still providing flexibility for fishermen, when possible, in the timing of the harvest for the sectors. Quantifiable measures are calculable and count towards the requirements to end overfishing and rebuild the stock, while non-quantifiable measures serve as a buffer and help to prevent the expansion of harvest as the stock rebuilds.

MANAGEMENT CARRIED FORWARD

There are several management measures from Amendment 2 to carry forward into Amendment 3 to serve the purpose of addressing fishing behavior and potential changes in effort to minimize the possibility of catching southern flounder in a greater volume than predicted.

Management measures from the Southern Flounder FMP Amendment 2 that will be clarified and carried forward in Amendment 3 are:

- A minimum distance (area dependent) between gill-net and pound net sets, per NCMFC Rule 15A NCAC 03J .0103 (d);
- No greater than a recreational fishery four fish bag limit;
- A recreational minimum size limit of 15 inches TL;
- A commercial minimum size limit of 15 inches TL;
- A minimum mesh size of 6.0-ISM for anchored large-mesh gill nets used in the taking of flounder;
- A minimum mesh size of 5.75-ISM for pound net escape panels;
- Reduced commercial anchored large-mesh gill-net soak times to single overnight soaks where nets may be set no sooner than one hour before sunset and must be retrieved no later than one hour after sunrise the next morning;
- For anchored large-mesh gill nets with a stretched mesh length of 4.0 inches through 6.5 inches, maintain a maximum of 1,500-yards in Management Units A, B, and C and a maximum of 750-yards in Management Units D and E unless more restrictive yardage is specified through adaptive management or through the sea turtle or sturgeon ITPs;
- Removal of all commercial gears targeting southern flounder from the water (e.g., commercial and RCGL anchored large-mesh gill nets and gigs) or make them inoperable (flounder pound nets) in areas and during times outside of an open season with exceptions for commercial large-mesh gill-net fisheries that target American (*Alosa sappidissima*) and hickory shad (*A. mediocris*) and catfish species if these fisheries are only allowed to operate during times of the year and locations where bycatch of southern flounder is unlikely;
- Unlawful to use any method of retrieving live flounder from pound nets that cause injury to released fish (e.g., picks, gigs, spears, etc.); and

- Unlawful for the commercial fishery to possess any species of flounder harvested from the internal waters of the state during the closed southern flounder season.

QUANTIFIABLE AND NON-QUANTIFIABLE MANAGEMENT MEASURES

Both quantifiable and non-quantifiable management measures are presented to meet the North Carolina harvest reduction for southern flounder based on the terminal year of the stock assessment (2017). Quantifiable management measures include a quota for the commercial fishery, which relies on daily quota monitoring, and a quota implemented by seasons for the recreational fishery, which serves to constrain the recreational fishery within a quota; these measures relate specifically to the stock assessment total removals and are calculable.

Additional types of management measures that are non-quantifiable are likely to be effective in reducing mortality, but the resulting reduction cannot be determined using existing data sources. Examples of non-quantifiable measures explored in this paper include certain management measures carried forward from Amendment 2 as described above, as well as changes to trip limits in the commercial fisheries, changes to bag limits in the recreational fisheries, and a RCGL season. Additionally, a discussion of slot limits as a non-quantifiable management measure can be found in the *Implementing a Slot Limit in the Southern Flounder Fishery* issue paper. Such non-quantifiable measures are needed to prevent the expansion of harvest as the stock rebuilds, increasing the likelihood of rebuilding success; however, the magnitude of these management measures, as well as the possible response of the stock, is unknown.

QUANTIFIABLE MANAGEMENT MEASURES: QUOTA

For Amendment 3, a quota will be set so the TAL that establishes maximum fishing limits (in pounds) in a year for all participants does not exceed a pre-determined amount. A quota is a specified numerical harvest objective, the attainment of which causes closure of the fishery for that species (Blackhart et al. 2005). For the North Carolina southern flounder fisheries, the quota is measured in pounds of fish. The quota that meets the required reductions and the NCMFC allocation motion is a 548,034 pounds TAC which results in 532,352 pounds of TAL for management. This TAL will be further divided into commercial and recreational allocations based on a motion approved by the NCMFC in March 2021, which was further refined in February 2022. The allocations will be 70% commercial and 30% recreational for 2021 through 2024, 60% commercial and 40% recreational in 2025, and 50% commercial and 50% recreational beginning in 2026. The TAL for each sector can be found in Table 4.1.2 and additional information on allocations can be found in the *Recreational and Commercial Sector Allocation* issue paper.

Table 4.1.2. Allocations for commercial and recreational fisheries and associated sub-allocations for each sector for the North Carolina Southern Flounder Fishery that maintains overall reductions of 72%.

					Commercial Fisheries	Recreational Fisheries*
Year	**Allocation**	**Total Allowable Catch**	**Dead Discards**	**Total Allowable Landings**	**Total Allowable Commercial Landings**	**Total Allowable Recreational Landings**
2021	70/30	548,034	15,682	532,352	372,646	159,706
2022	70/30	548,034	15,682	532,352	372,646	159,706
2023	70/30	548,034	15,682	532,352	372,646	159,706
2024	70/30	548,034	15,682	532,352	372,646	159,706
2025	60/40	548,034	15,682	532,352	319,411	212,941
2026	50/50	548,034	15,682	532,352	266,176	266,176

*RCGL gear removals not included in the Total Allowable Landings

When using a quota to manage a fishery, decisions need to be made on how to split or allocate the resource within each of the sectors and determine whether rollover of unused quota, payback of exceeded quota, or both will occur. Accountability measures implemented provide a means to manage the quota. A conservative approach benefits the resource by protecting any unharvested fish and not exceeding the TAC. This benefits the resource but may have consequences to user groups by shortening seasons or limiting access in some areas during subsequent years. A more liberal approach to accountability measures benefits the user groups by allowing harvest of any remaining allocation during subsequent years and not requiring paybacks for any harvest over an allocation but may have consequences to the resource.

Commercial Fisheries

For all commercial fisheries combined, the total allowable landings are 372,646 pounds of southern flounder for 2021 through 2024, 319,411 pounds in 2025, and 266,176 pounds beginning in 2026 (Table 4.1.2). This is the commercial allocation of the overall quota. To ensure the commercial allocation is not exceeded and provides all sectors continued access to the resource under these restrictions, further refinement maybe necessary to allow an annual harvest, to manage by areas, gears and opening dates. The division analyzed data to determine individual gear allocations for different areas and opening time frames, as well as data that combined some gears into one allocation for a given area. This analysis was undertaken with the understanding that increasing the complexity of management also increases the complexity of monitoring the quota, reducing the ability to effectively meet the targets to achieve sustainable harvest.

Commercial Gear Allocation

Given the large reduction needed to achieve sustainable harvest and the importance of each allocation staying within its allowed landings, it is most practical to separate the gears into two categories: pound nets and mobile gears (including gears that target southern flounder, primarily gigs and gill nets, and “other” gears that do not target southern flounder such as shrimp trawls, crab pots, and fyke nets). Using these two categories of mobile gears and pound nets also provides flexibility by allowing fishermen to use multiple gears in a trip without having to separate catches unless a pound net is involved. Combining mobile gears into a single category prevents users from switching between the two categories or altering their behavior that may increase harvest. For example, if there is a closure for gill nets due to protected species interactions, the remaining allocation would be available for harvest using non-gill net gears within the mobile gear category. In addition, the NCMFC has requested the division evaluate phasing out large-mesh gill nets in the southern flounder fishery by the terminal year of the current sea turtle ITP, August 2023. If the NCMFC selects this as a management measure it may impact the sub-allocations for each gear category. More information can be found in the *Phasing out Large-Mesh Gill Nets in the North Carolina Southern Flounder Fishery* issue paper in Appendix 4.7.

All mobile gears have the capability to harvest southern flounder throughout the year, although there is variability in their use among the individual gears. Combining mobile gears into one allocation makes monitoring the daily harvest more efficient with less risk of exceeding the annual allocation. Based on the seasonality and movement of southern flounder, commercial gigs and “other” gears would likely benefit from opening in the late spring or early summer to maximize the economic benefit of the market at that time. The gig fishery could open in early summer and any remaining allocation would be available for harvest by gill nets and other gears at a specific opening date later in the fall. Consequences of the southern flounder gill-net fishery operating in the early spring or summer include at-net mortality, discards of non-marketable fish, as well as post-release mortality of undersized flounder.

The commercial southern flounder pound net fishery only has the capability to operate during the fall months, beginning in late August in Albemarle Sound and ending in late November in Core Sound. Allocating harvest to the pound net fishery outside of the fall migration would not be appropriate. Flounder pound nets are stationary gears and are only actively fishing when southern flounder are migrating to the ocean. The pound net gear is most susceptible to changes in average price per pound, as the market typically drops in value in October due to the opening of the summer flounder winter trawl fishery.

Commercial Gear Sub-Allocations

Due to the shift in allocation based on the March 2021 and February 2022 NCMFC motions, it is prudent to evaluate the sub-allocations for the commercial fishery. Presented below are three potential scenarios that account for the NCMFC approved allocation changes as well as changes to the sub-allocations for the commercial fishery sectors. The first scenario is showing the TAL by year for each sector based on historical landings and can be found in Table 4.1.3. A second scenario is to meet the NCMFC approved allocation and adjust the commercial sub-allocations so the pound net fishery maintains their current harvest estimate of 186,458 pounds. This scenario provides a level of harvest that maintains the fishery at a reduced level but accounts for the increased monetary investment of operating and maintaining the pound net gear. Sub-allocations for this scenario can be found in Table 4.1.4. A final scenario considered is to adjust the allocation and phase out large-mesh gill nets in the southern flounder fishery at the end of the current ITP in 2023 as proposed by the NCMFC. Under this scenario the sub-allocations remain consistent with the first scenario for 2021 and 2022 but beginning in 2023 half of the gill net landings are transferred to the pound net gear category and the other half remaining with the mobile gear category (Table 4.1.5). This 50/50 transfer of gill net allocation is just one example and can be altered based on NCMFC, Advisory Committee, or public input.

Table 4.1.3. Allocations for the North Carolina Southern Flounder commercial and recreational fisheries and associated sub-allocations for each sector for the North Carolina Southern Flounder Fishery that maintains overall reductions of 72% and historical sub-allocations.

					Commercial Fisheries			Recreational Fisheries*		
Year	**Allocation**	**Total Allowable Catch**	**Dead Discards**	**Total Allowable Landings**	**Total Allowable Commercial Landings**	**Mobile Gears**	**Pound Nets**	**Total Allowable Recreational Landings**	**Hook and Line**	**Gigs**
2021	70/30	548,034	15,682	532,352	372,646	186,188	186,458	159,706	142,206	17,500
2022	70/30	548,034	15,682	532,352	372,646	186,188	186,458	159,706	142,206	17,500
2023	70/30	548,034	15,682	532,352	372,646	186,188	186,458	159,706	142,206	17,500
2024	70/30	548,034	15,682	532,352	372,646	186,188	186,458	159,706	142,206	17,500
2025	60/40	548,034	15,682	532,352	319,411	159,590	159,821	212,941	189,608	23,333
2026	50/50	548,034	15,682	532,352	266,176	132,992	133,184	266,176	237,010	29,166

*RCGL gear removals not included in the Total Allowable Landings

Table 4.1.4. Allocations for the North Carolina Southern Flounder commercial and recreational fisheries and associated sub-allocations for each sector that maintains overall reductions of 72% but maintains the current level of sub-allocation for the pound net fishery.

					Commercial Fisheries			Recreational Fisheries*		
Year	**Allocation**	**Total Allowable Catch**	**Dead Discards**	**Total Allowable Landings**	**Total Allowable Commercial Landings**	**Mobile Gears**	**Pound Nets**	**Total Allowable Recreational Landings**	**Hook and Line**	**Gigs**
2021	70/30	548,034	15,682	532,352	372,646	186,188	186,458	159,706	142,206	17,500
2022	70/30	548,034	15,682	532,352	372,646	186,188	186,458	159,706	142,206	17,500
2023	70/30	548,034	15,682	532,352	372,646	186,188	186,458	159,706	142,206	17,500
2024	70/30	548,034	15,682	532,352	372,646	186,188	186,458	159,706	142,206	17,500
2025	60/40	548,034	15,682	532,352	319,411	132,953	186,458	212,941	189,608	23,333
2026	50/50	548,034	15,682	532,352	266,176	79,718	186,458	266,176	237,010	29,166

*RCGL gear removals not included in the Total Allowable Landings

Table 4.1.5. Allocations for the North Carolina Southern Flounder commercial and recreational fisheries and associated sub-allocations for each sector that maintains overall reductions of 72% but redistributes the gill net allocation equally between mobile and pound net gears.

					Commercial Fisheries			Recreational Fisheries*		
Year	Allocation	Total Allowable Catch	Dead Discards	Total Allowable Landings	Total Allowable Commercial Landings	Mobile Gears	Pound Nets	Total Allowable Recreational Landings	Hook and Line	Gigs
2021	70/30	548,034	15,682	532,352	372,646	186,188	186,458	159,706	142,206	17,500
2022	70/30	548,034	15,682	532,352	372,646	186,188	186,458	159,706	142,206	17,500
2023	70/30	548,034	15,682	532,352	372,646	186,188	186,458	159,706	142,206	17,500
2024	70/30	548,034	15,682	532,352	372,646	186,188	186,458	159,706	142,206	17,500
2025	60/40	548,034	15,682	532,352	319,411	99,102	220,309	212,941	189,608	23,333
2026	50/50	548,034	15,682	532,352	266,176	85,803	180,373	266,176	237,010	29,166

*RCGL gear removals not included in the Total Allowable Landings

Commercial Areas and Seasons Allocation

Because of the migratory nature of southern flounder, areas were investigated by the NCTTP waterbody locations to allow more equitable access by fishermen across the state with seasonal openings varying by area. As the weather begins to change during the fall, southern flounder migrate to estuarine waters in the south and east before moving into the ocean (Craig et al. 2015). The migration begins in the northern and western sounds and tributaries before it begins in the southern areas. As previously stated, increasing the complexity of management also increases the complexity of monitoring the quota, reducing the ability to effectively meet the targets; however, the benefit of this type of flexibility is the potential for staggered opening dates that will be determined by the Fisheries Director after consultation with user groups (more information on how the division will determine opening dates is available in the *Adaptive Management* issue paper). Staggering opening dates minimizes the chances of a "derby fishery," which forces all participants to fish at the same time ultimately leading to a flooded market and lower prices. Altering opening dates allows for specific areas and gears to target southern flounder when they are accessible and most valuable to fishermen with the expectation that harvest is tracked daily so the total allowable landings are not exceeded.

Analysis indicates that gear and area combinations with no more than three areas statewide would provide the best chance of success of achieving sustainable harvest through daily quota monitoring. For some gear and area combinations, two areas would allow some flexibility to the sectors and make accountability more manageable.

Landings data for the southern flounder commercial fishery were reviewed using waterbody locations and gear type identified by the NCTTP to determine if natural breaks by area and gear occurred (NCDMF 2017b). Identification of natural breaks by waterbody and gear determines how finely the areas can be managed within each gear category. A natural break in commercial effort and landings occurs in several areas across the state, but for ease of enforcement and knowledge of existing areas by fishermen, it is beneficial to use regulatory boundaries already in place.

Dividing mobile gears into two areas using current boundaries would result in a northern area from the North Carolina/Virginia border south to the B-D ITP boundary line in Core Sound (34° 48.2700’ N latitude which runs approximately from the Club House on Core Banks westerly to a point on the shore at Davis near Marker “1”) and a southern area from the 34° 48.2700’ N latitude south to the North Carolina/South Carolina Border (Figure 4.1.5). Splitting mobile gears into three areas may best be approached with a northern area encompassing the Albemarle Sound and its tributaries including the Croatan and Roanoke sounds, a central area encompassing the Pamlico Sound and its tributaries, and a southern area encompassing all waters from Core Sound south (Figure 4.1.5).

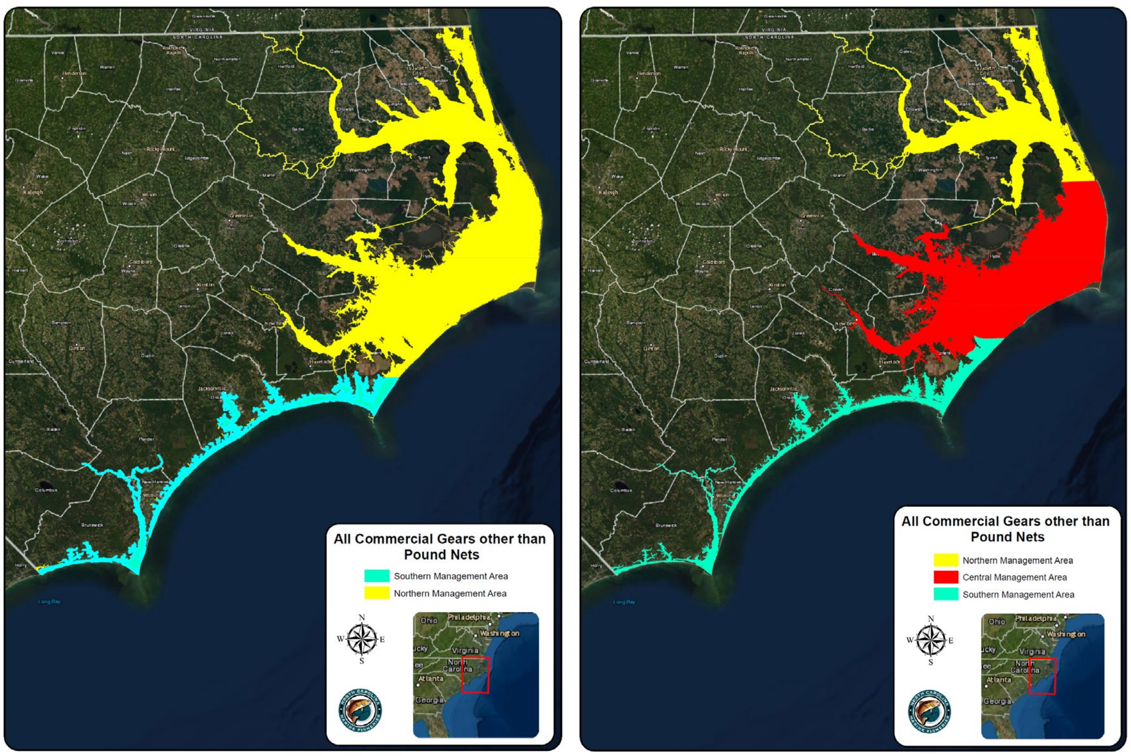

Figure 4.1.5. Boundary descriptions for two (left) and three (right) areas to consider for mobile gears. The three area boundaries are identical as seen for pound nets.

If the NCMFC selects to phase out large-mesh gill nets the boundary line for mobile gears can be re-evaluated or removed all together and create a single statewide fishery for mobile gears (Table 4.1.6). The ITP B-D boundary line was selected due to the inclusion of large-mesh gill nets under the mobile gear category to remain consistent with ITP boundary areas.

Dividing the state’s pound net fishery into two areas may best be approached with a northern area from the North Carolina/Virginia border south to the 35° 46.3000’ N latitude which runs approximately from the north end of Pea Island (old Coast Guard station) westerly to a point on the shore at Point Peter Canal and a southern area from 35° 46.3000’ N latitude south to the

North Carolina-South Carolina border (Figure 4.1.6). Three areas for the pound net fishery would be consistent with areas already in place under Amendment 2 for this fishery and would be the same boundaries described for mobile gears (Figure 4.1.6).

Based on the NCMFC allocations, the annual commercial TAL allocation in 2021 through 2024 is 372,646 pounds (Table 4.1.1). This allocation will be reduced in 2025 to 60% (319,411 lb) and again in 2026 to 50% (266,176 lb) to meet the requirements outlined by the NCMFC (Table 4.1.2). Three options presenting associated pounds of available allocation by area and gear can be found in Tables 4.1.6, 4.1.7, and 4.1.8. Commercial landings for mobile gears were combined and allocated by waterbody, with the exception of landings from Core Sound. Due to Core Sound being split in two areas, 50% of the landings from Core Sound were counted towards the northern area and 50% were counted towards the southern area (Table 4.1.2; Tables 4.1.6-4.1.8). Commercial pound net landings were allocated to each waterbody within the areas.

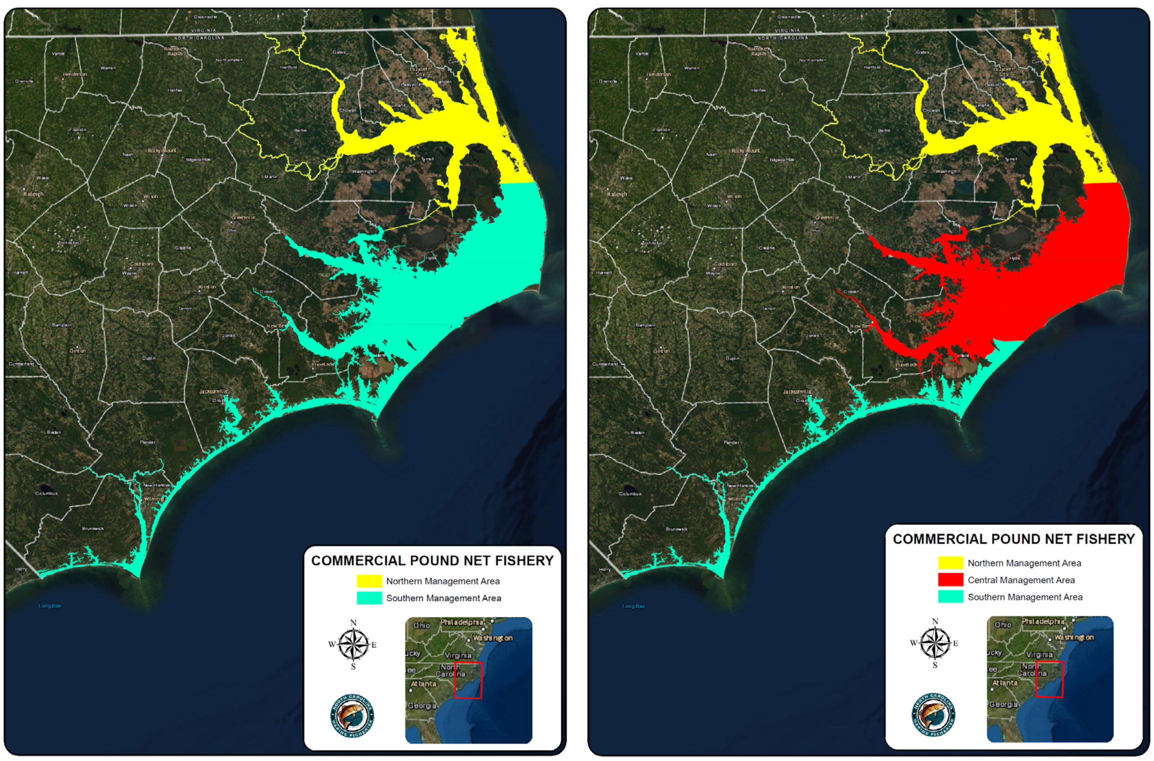

Figure 4.1.6. Boundary descriptions for two (left) and three (right) areas to consider for the pound net fishery. The three area boundaries are the same as mobile gears.

Table 4.1.6. Allocation for the North Carolina Southern Flounder commercial fishery and associated sub-allocations for each sector that maintains overall reductions of 72% and historical sub-allocations.

Commercial Gear	Allocation %	Area/Allocation (lb)			Total Allocation (lb)	Option
Mobile gears	70	Statewide 186,188			186,188	1.1B
	70	Northern 123,879	Southern 62,309		186,188	1.1A
	70	Northern 47,082	Central 65,355	Southern 73,751	186,188	1.1C
	60	Statewide 159,590			159,590	1.1B
	60	Northern 106,182	Southern 53,408		159,590	1.1A
	60	Northern 40,356	Central 56,018	Southern 63,216	159,590	1.1C
	50	Statewide 132,992			132,992	1.1B
	50	Northern 88,486	Southern 44,506		132,992	1.1A
	50	Northern 33,360	Central 46,682	Southern 52,680	132,992	1.1C
Pound nets	70	Statewide 186,458			186,458	1.2B
	70	Northern 37,900	Southern 146,758		186,458	1.2C
	70	Northern 39,700	Central 121,756	Southern 25,002	186,458	1.2A
	60	Statewide 159,821			159,821	1.2B
	60	Northern 34,028	Southern 125,793		159,821	1.2C
	60	Northern 34,028	Central 104,363	Southern 21,430	159,821	1.2A
	50	Statewide 133,184			133,184	1.2B
	50	Northern 28,357	Southern 104,827		133,184	1.2C
	50	Northern 28,357	Central 86,969	Southern 17,858	133,184	1.2A

Table 4.1.7. Allocation for the North Carolina Southern Flounder commercial fishery and associated sub-allocations for each sector that maintains overall reductions of 72% but maintains the current level of sub-allocation for the pound net fishery.

Commercial Gear	Allocation %	Area/Allocation (lb)			Total Allocation (lb)	Option
Mobile gears	70	Statewide 186,188			186,188	1.1B
	70	Northern 123,879	Southern 62,309		186,188	1.1A
	70	Northern 47,082	Central 65,355	Southern 73,751	186,188	1.1C
	60	Statewide 132,593			132,953	1.1B
	60	Northern 88,460	Southern 44,493		132,953	1.1A
	60	Northern 33,621	Central 46,668	Southern 52,664	132,953	1.1C
	50	Statewide 79,718			79,718	1.1B
	50	Northern 53,040	Southern 26,678		79,718	1.1A
	50	Northern 20,159	Central 27,982	Southern 31,577	79,718	1.1C
Pound nets	70	Statewide 186,458			186,458	1.2B
	70	Northern 37,900	Southern 146,758		186,458	1.2C
	70	Northern 39,700	Central 121,756	Southern 25,002	186,458	1.2A
	60	Statewide 186,458			186,458	1.2B
	60	Northern 37,900	Southern 146,758		186,458	1.2C
	60	Northern 39,700	Central 121,756	Southern 25,002	186,458	1.2A
	50	Statewide 186,458			186,458	1.2B
	50	Northern 37,900	Southern 146,758		186,458	1.2C
	50	Northern 39,700	Central 121,756	Southern 25,002	186,458	1.2A

Table 4.1.8. Allocation for the North Carolina Southern Flounder commercial fishery and associated sub-allocations for each sector that maintains overall reductions of 72% but redistributes the gill net allocation equally between mobile and pound net gears beginning in 2023 (shown in the 60% and 50% allocations).

Commercial Gear	Allocation %	Area/Allocation (lb)			Total Allocation (lb)	Option
Mobile gears	70	Statewide 186,188			186,188	1.1B
	70	Northern 186,188	Southern 186,458		186,188	1.1A
	70	Northern 47,082	Central 65,355	Southern 73,751	186,188	1.1C
	60	Statewide 99,102			99,102	1.1B
	60	Northern 65,937	Southern 33,165		99,102	1.1A
	60	Northern 25,060	Central 34,786	Southern 39,255	99,102	1.1C
	50	Statewide 85,803			85,803	1.1B
	50	Northern 57,089	Southern 28,714		85,803	1.1A
	50	Northern 21,697	Central 30,118	Southern 33,988	85,803	1.1C
Pound nets	70	Statewide 186,458			186,458	1.2B
	70	Northern 37,900	Southern 146,758		186,458	1.2C
	70	Northern 39,700	Central 121,756	Southern 25,002	186,458	1.2A
	60	Statewide 220,309			220,309	1.2B
	60	Northern 46,907	Southern 173,402		220,309	1.2C
	60	Northern 46,907	Central 143,861	Southern 29,541	220,309	1.2A
	50	Statewide 180,373			180,373	1.2B
	50	Northern 38,404	Southern 141,969		180,373	1.2C
	50	Northern 38,404	Central 117,783	Southern 24,186	180,373	1.2A

Landings data for the southern flounder commercial fisheries were evaluated to determine how landings and price per pound fluctuated during the year. This helped to identify what time frames would allow for the most productive fishery while minimizing discard mortality and meeting the necessary reductions. Commercial landings remain low through the majority of the first half of the year and begin to increase in late summer and peak in October and early November (Figure 4.1.7).

Southern flounder landings vary by location, month, and gear but typically increase in the Albemarle Sound area (northern) in early September, Pamlico Sound (central) in mid-to-late September, and Core Sound and south (southern) by October. Due to these variations in seasonal landings by gear and area, landings were analyzed to show the weekly rate of harvest as a percent of the total average landings from 2008 to 2017 (Figures 4.1.8 and 4.1.9). This analysis shows harvest rates through the year for each gear category statewide and by area as identified in Figures 4.1.5 and 4.1.6. One exception is in the southern portion of the state where the commercial gig fishery harvests flounder beginning in early summer and drives the harvest in the summer for the southern area (Figure 4.1.8).

Combining all mobile gears into a single group would allow for flexibility in determining opening dates for gears within the larger category, possibly allowing a gig fishery to operate during these summer months when the fish are available. For example, a sub-allocation of 38,614 pounds of the mobile gear allocation can be set aside for gigs and other gears, excluding gill nets, for harvest beginning May 1 and operating until this sub-allocation is harvested. This sub-allocation is based on the commercial gig fishery portion of the mobile gears category but could change if the NCMFC selects to phase out large-mesh gill nets in the southern flounder fishery. Once this sub-allocation is met, the remaining harvest would be available for harvest during the fall fishery where all gears, excluding pound nets, would be able to harvest the remainder of the available allocation for mobile gears. It is important to note that this summer sub-allocation is not independent of the mobile gear allocation. All reporting from dealers during this period will be accounted to the mobile gear allocation. In addition to seasonal information, effort data, environmental changes, ITP constraints, and quota monitoring requirements all provided information for the division to select management areas, opening dates, and gear combinations.

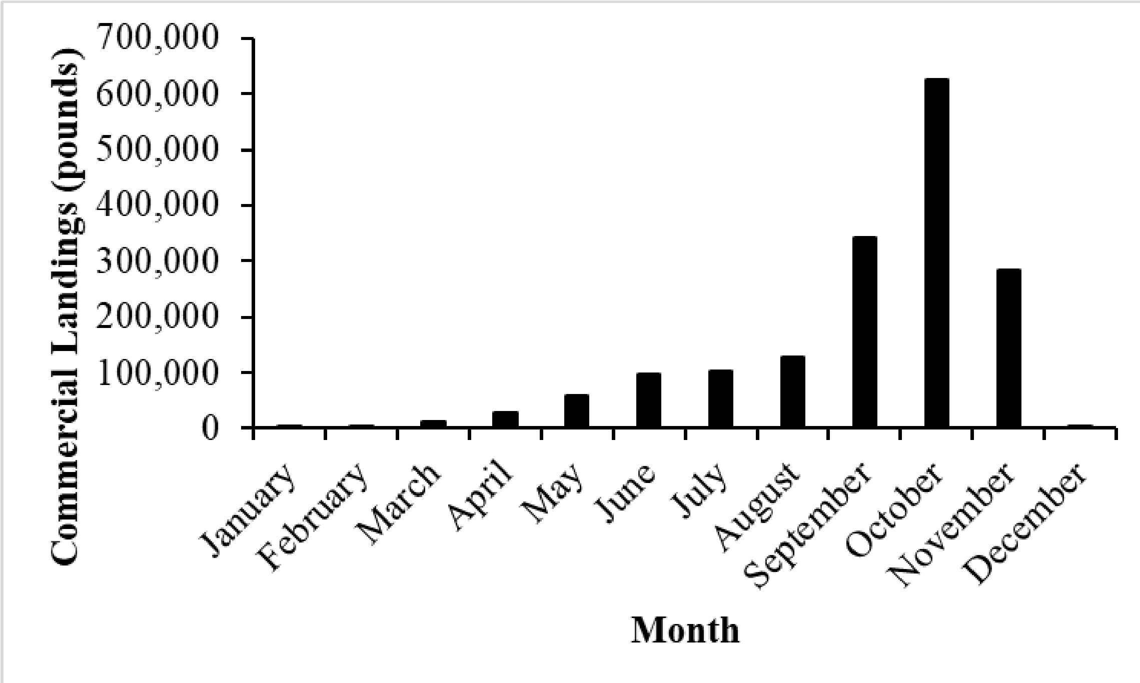

Figure 4.1.7. Average commercial southern flounder landings (pounds) by month in North Carolina, 2008-2017. (Source: North Carolina Trip Ticket Program)

Combining all mobile commercial gears into one category split between two areas of the state, with each area having its own mobile gear allocation, will provide the most flexibility to accommodate opening dates within an area based on southern flounder movements. Dividing the pound net fishery into three areas will allow the timing of the openings for this gear to be more relevant to their geographic locations. Because pound nets are stationary gear, areas to further split the allocation will accommodate some flexibility on opening dates based on southern flounder movements; however, there will be consequences of disproportionate impacts to individual areas and gears that should be noted within these added layers to the quota allocation.

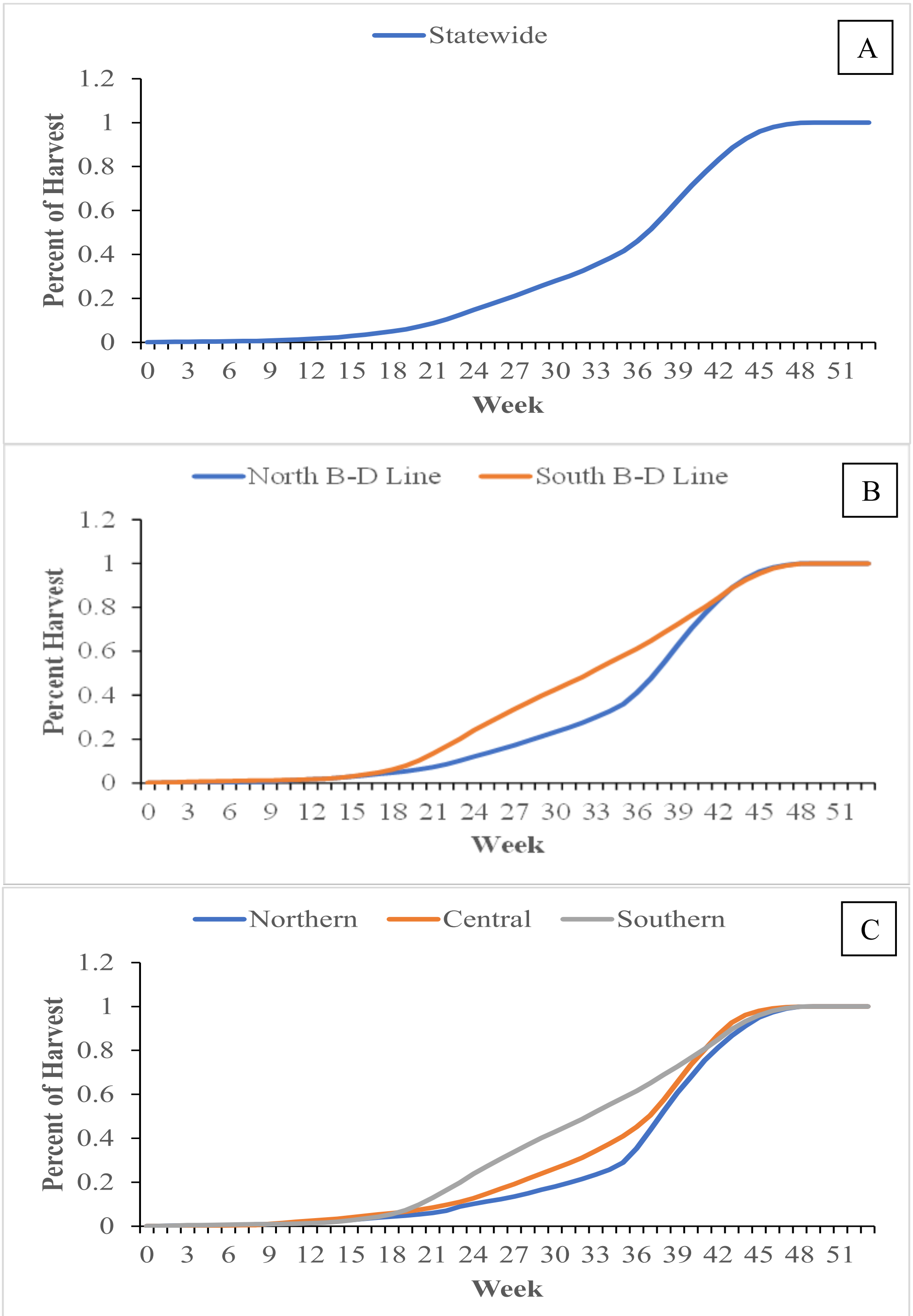

Figure 4.1.8. Average weekly harvest (in percent, 2008–2017) through the year from mobile gears statewide (A) and for two (B) and three (C) areas management scenarios as identified in Figure 4.1.5.

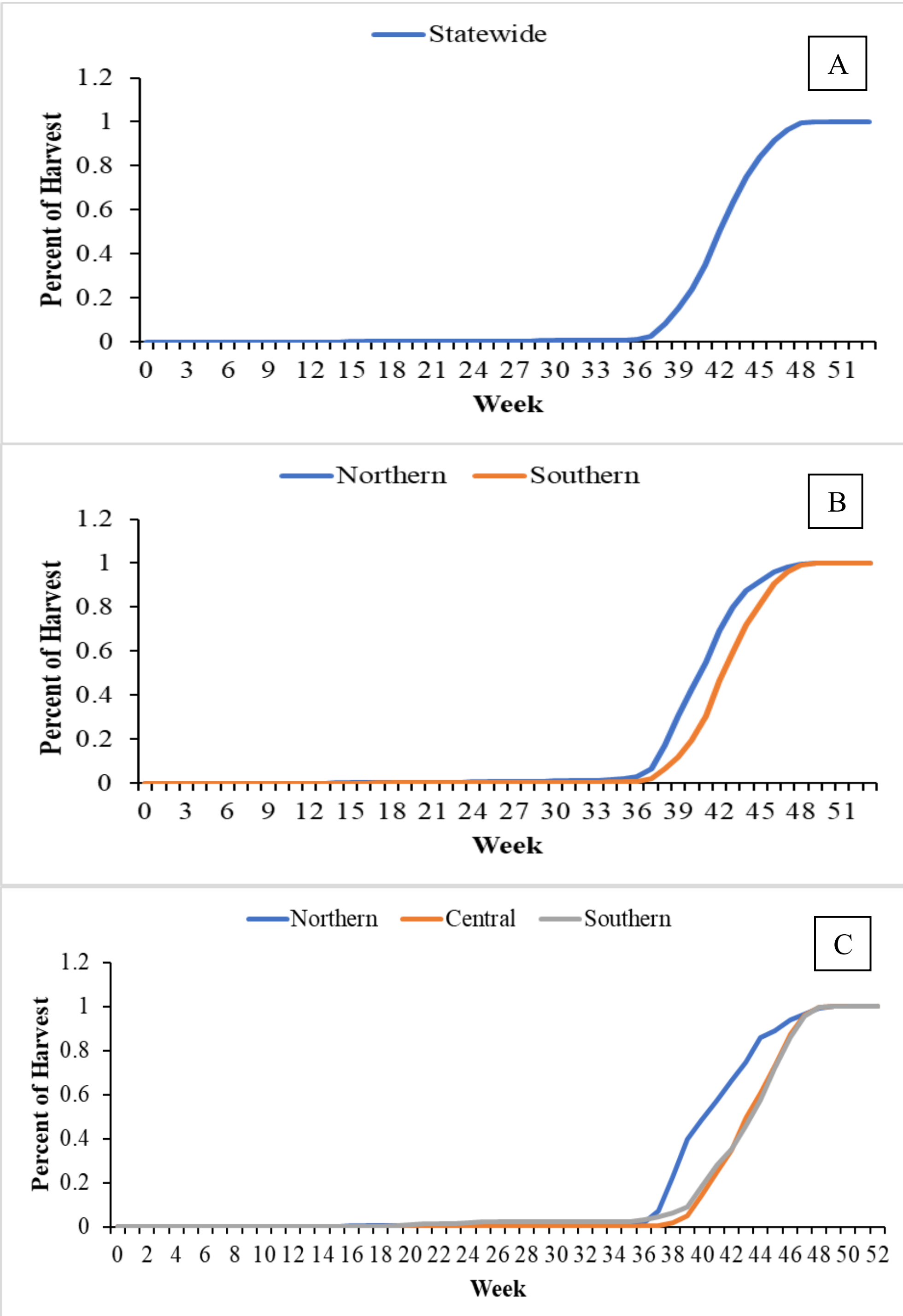

Figure 4.1.9. Average weekly harvest (in percent, 2008–2017) from the commercial pound net fishery statewide (A) and for two (B) and three (C) areas management scenarios as identified in Figure 4.1.6.

Commercial Accountability Measures

For the commercial fishery, if the combined TAL for all gear and area combinations are not exceeded at the end of a fishing year, accountability measures will not be applied. If the combined TAL are exceeded, paybacks due to overages of an allocation for a particular year from landings and dead discards would be applied to the responsible gear and area combination, meaning overages would be subtracted from the following year's allocation for that gear and area combination. These overages will be applied on a pound for pound basis. Any unused allocation or rollover would not be added to the subsequent year's allocation and would serve as a benefit to the resource and potentially decrease the time for rebuilding. The final total of pounds landed (including estimates of dead discards for the gill net fishery) from a year's harvest will be determined through verification of the quota monitoring forms and NCTTP landings data. It is important to restate that it is not the individual gear and area allocations that are driving management, rather it is the overall quota. The NCDMF will do what is necessary to maintain landings to meet the needs of rebuilding of the stock. Flexibility in managing each gear and area combination is necessary for the overall success of a quota system; see the *Adaptive Management* issue paper for further flexibility in developing long-term management measures.

Division staff will monitor the quota on a daily basis in order to prevent landings from becoming so large that the quota will be exceeded and the stock will continue to be overfished. When the sum of the daily reporting for an area and gear combination approaches approximately 80% of the allocated landings, the division will issue a proclamation immediately to close the gear and area combination to the harvest of southern flounder. The mechanism for closing the southern flounder commercial fishery is through G.S. 113-221.1 (b) and Rule 15A NCAC 03M .0503 that provide the Fisheries Director proclamation authority to immediately close a fishery that is monitored by a quota. Closure under this rule does not require a 48-hour notice and can be issued effective immediately. This may be necessary to prevent additional overfishing as certain gear-area combinations can harvest a large percentage of the commercial quota if left unchecked.

Daily quota monitoring of the commercial fisheries will be key in achieving a long-term sustainable harvest of the southern flounder stock. A quota in combination with area, season openings, and trip limits for some gears will also provide access to the fish as they migrate through the sounds and into the ocean and maintain some buffer to reduce the potential for overages in the quota.

If remaining allocation is available, the division may reopen the gear and area combination for a short window to provide opportunity to harvest the remaining allocation; however, if the remaining allocation is not practical to manage while ensuring an overage will not occur, the fishery in question will not be reopened. This reopening may include trip limits for gears where this type of management would not increase dead discards as an additional regulation to prevent any overage of the allocation.

For gears where trip limits are not a viable option, like gill nets, the division may open the fishery daily. Daily openings may prove futile in keeping landings within an allocation and may not be a good option to use; the remaining allocation could be made available for other gears within the mobile gears category in this case; however, if the remaining allocation is not practical to manage while ensuring an overage will not occur, the fishery in question will not be reopened.

Recreational Fisheries

The recreational fisheries, hook and line and gigs, TAL will change from 159,706 pounds in 2021 through 2024, 212,941 pounds in 2025and from 2026 onward the TAL will be 266,176 pounds (Table 4.1.9). These are the recreational allocations of the overall quota as determined by the NCMFC. To ensure the recreational allocation is not exceeded but provides continued access to the resource under these restrictions, the allocation will be further refined to allow an annual harvest of 89% of the recreational TAL for the hook-and-line fishery and 11% of the recreational TAL for the recreational gig fishery. The associated pounds can be found in Table 4.1.9. The ability to monitor a recreational quota in real time is possible with a well-designed creel survey specific to the species and covering the geographic range of harvest and gears. The division relies on the MRIP, in which southern flounder is a species encountered regularly in the hook-and-line recreational fishery. The survey design of MRIP does not allow for results on a daily or weekly basis. Instead, results are available by two-month waves, several months after the data are collected. As a result, historical catch data must be used to predict future catch rates. Once the level of harvest for each reduction value was identified, catch from the MRIP was analyzed by two-week increments (the finest level of detail available) and summed to determine seasonal dates the fishery could operate while meeting the necessary reduction (Table 4.1.10). Seasons may vary as the TAL increases from 30% in 2021 until 50% parity is reached in 2026. This will be determined through Adaptive Management, see the *Adaptive Management* issue paper.

Although the recreational hook-and-line fishery is monitored through the MRIP, this program does not collect necessary information to provide estimates for the recreational gig fishery. As a result, the division conducts an annual mail survey for gig fishery effort and harvest estimates (see the *Description of the Fisheries* section for additional details on MRIP and the Recreational Gig survey).

Recreational use of limited commercial fishing gears is allowed in North Carolina and is subject to the same reductions as the other recreational and commercial fisheries. RCGL holders primarily use large-mesh gill nets to harvest southern flounder but may occasionally harvest southern flounder from shrimp trawls and crab pots. The collection of RCGL harvest data has not occurred since 2008 and is not reliable for estimating reductions due to multiple management changes since the survey ended. See the section on the *Description of the Fisheries* for trends in the RCGL fishery.

Table 4.1.9. Southern flounder recreational fishery total allowable landings allocations in pounds by gear and total recreational allocation percentage.

		Recreational Gear		
Year	**Allocation %**	**Hook-and-Line**	**Gig**	**Total**
2021-2024	30	142,206	17,500	159,706
2025	40	189,608	23,333	212,941
2026	50	237,010	29,166	266,176

Table 4.1.10. Seasons identified to reach the TAL (142,206 pounds in 2021 through 2024, 189,608 pounds in 2025, and 237,010 pounds beginning in 2026) of the NC recreational hook-and-line fishery quota in pounds at the current four fish bag limit based on average landings from 2008–2017. Seasons may vary as the TAL increases until 50% parity is reached and will be determined through Adaptive Management. (2020 landings for the recreational hook and line fishery for the Aug 16 – Sep. 30 season with a four-fish bag limit was 362,119 pounds).

	Landings (lb)			
Season	**4-Fish Bag Limit**	**3-Fish Bag Limit**	**2-Fish Bag Limit**	**1-Fish Bag Limit**
No closure	451,126	428,594	400,502	332,075
Apr 16–Jun 30	109,157	107,657	105,569	100,911
May 1–Jun 30	102,622	102,622	99,249	94,985
Jun 1–Jul 15	110,702	109,102	106,836	102,184
Aug 1–Sep 30	179,895	175,782	171,480	161,015
Aug 16–Sep 30	127,706	125,359	123,267	118,071
July 16–Sep. 30	222,360	216,583	210,150	194,024
June 16–Sep. 15	272,287	263,508	252,502	226,790
Aug 16-Oct 15	156,040	152,524	149,254	*141,382
Aug-16-Oct 30	177,680	173,505	169,590	159,554

*This season and bag limit does meet the harvest level of TAL but exceeds estimates at the TAC level.

The use of RCGL gear is only allowed when both the recreational and commercial fisheries are open for the particular gear, and the user can only harvest recreational limits. Due to these requirements, the only options available to regulate the harvest of flounder using a RCGL is to allow harvest during a period of time when the commercial and recreational fisheries are open simultaneously or prohibit the harvest of flounder using a RCGL.

The limitations in monitoring for the recreational southern flounder fisheries allows for less flexibility in management measures to ensure the recreational allocation is not exceeded. Final estimates of recreational harvest are not available until the season ends, so real time accounting of catch cannot be determined for underage or overage to the sector allocation. To complement a seasonal approach to the allocations, further non-quantifiable measures such as bag limits and allowable RCGL harvest are considered, as maintaining the four-fish daily bag limit allows for harvest just above the maximum required within the current season. These additional management tools are needed to increase the likelihood of meeting required reductions in the recreational fisheries and are discussed below.

Further discussion on species-specific management measures is considered and presented in the *Increased Recreational Access* issue paper.

Recreational Season Allocation

The recreational hook-and-line fishery is allocated an increasing volume from 142,206 pounds in 2021 up to 237,010 pounds of southern flounder beginning in 2026 (Tables 4.1.1 and 4.1.9). With the current four-fish bag limit, the identified season of Aug. 16 through Sept. 30 meets the reductions when combined with the inability to provide estimates of gig harvest and discards at reduced bag levels and the potential additional harvest from an ocellated flounder season (see the *Increased Recreational Access* issue paper). While this seasonal approach does meet the reductions, changes to bag limits are discussed in detail later due the potential for increased angler success. Seasonal allocation results in a quota that is validated using MRIP landings only after the season has closed. In North Carolina, the previous years' MRIP landings are available by mid-April of the following year.

The recreational gig fishery is allocated an increasing volume from 17,500 pounds in 2021 up to 29,166 pounds of southern flounder beginning in 2026 (Table 4.1.9). It is necessary to maintain concurrent seasons for the recreational hook-and-line and gig fisheries to keep from undermining the success of achieving necessary reductions (Table 4.1.11). Allowing a gig fishery to operate longer than the recreational hook-and-line fishery would allow excess harvest from the gig fishery that would exceed the gig allocation. In addition, if the gig fishery and the hook-and-line fishery operated during independent seasons, anglers could alter their current behavior by participating in each of the seasons, increasing effort and harvest on an already limited allocation.

Table 4.1.11. Seasons identified to reach the initial TAL (17,500 lb in 2021 through 2024, 23,333 lb in 2025, and 29,166 lb beginning in 2026) of the N.C. recreational gig fishery landings (observed harvest) at the current four-fish bag limit based on average landings from 2010–2017. Seasons may vary as the TAL increases until 50% parity is reached and will be determined through Adaptive Management. (2020 landings for the recreational gig fishery for the Aug 16 – Sep. 30 season with a four-fish bag limit was 26,475 pounds).

Season	Landings (lb)
No closure	85,688
Jul 1–Sep 30	33,532
Jul 16–Sep 30	28,060
Jul 1–Sep 15	27,711
Aug 1–Sep 30	22,587
Aug 16–Sep 30	17,115

When the recreational fishery is closed, recreational harvest of flounder in both internal and ocean waters will be unlawful as all flounder species (southern, summer, Gulf) are managed collectively in North Carolina. Other measures may be available to allow for species-specific management (see the *Increased Recreational Access* issue paper*)*.

Recreational Accountability Measures

Accountability measures will also be necessary for the recreational hook-and-line and gig fisheries. The final recreational total catch will be determined by adding the total landings from the MRIP and gig surveys to the estimates of dead discards. To account for overages from landings and dead discards, the following year's recreational quota and season will be adjusted based on the results of the MRIP and gig mail surveys from the previous year. If the TAL for the recreational sector combined is not exceeded, then accountability measures will not be applied. If the TAL are exceeded, any overages to the TAL will be applied to the subsequent season (which includes both hook-and-line and gig gears). Using the conservative approach described in the commercial accountability measures, any remaining allocation will not be rolled over to subsequent years. These data are typically available by mid-April for the previous calendar year, can be calculated quickly, and are expected to be finalized prior the usual recreational season, assuming the season does not open prior to June 1. For the recreational fishery, final total of pounds harvested from a year's harvest, discard estimates, and estimates of number of trips will be determined through verification of the final MRIP and Gig Mail Survey.

An annual quota is the most appropriate tool for the recreational fisheries to maintain sustainable harvest, but it is more challenging to track every trip because harvest data are only available in two-month intervals with delays in verification. Instead, a season for the recreational fisheries that will maintain the allocation within its bounds may be the most reasonable approach. Due to a high level of discards in the recreational hook-and-line fishery, there is concern that the volume of discards can have a large direct impact on subsequent seasons if anglers continue to target and release southern flounder during closed seasons. Recreational hook-and-line discards are not monitored through a quota and are not available until after the season is complete. It is important to restate that it is not the individual gear allocations that are driving management, rather it is the overall quota. Additional measures can be implemented in concert to further refine harvest management to limit impacts due to overages while the fishery is recovering. This approach does limit angler access during periods of no harvest, but it does not stop the unintended consequences of large volumes of discards through indirect hooking while targeting other species or intentional catch and release discards. Unintended discards are a major source of removals in the southern flounder recreational fishery (Flowers et al. 2019; NCDMF 2019).

OTHER NON-QUANTIFIABLE MANAGEMENT MEASURES

Non-quantifiable measures are those that are not directly part of the stock assessment model and there is no way to measure the impact on the modeled fishing mortality. This does not mean that these non-quantifiable measures are not important to consider in management, they merely are not able to be included in the percent reduction needed to end overfishing/overfished status as statutorily required. If non-quantifiable measures are implemented, future stock assessments will indirectly reflect their effect on the fishery status. The non-quantifiable management measures under consideration to control effort in the fishery include trip limits in the commercial fisheries and bag limits in the recreational fisheries. Because specific impacts on recruitment and overfishing cannot be calculated, relevant empirical data for the various measures are presented herein. Earlier in the discussion section, the management carried forward was described. In addition to those non-quantifiable management measures carried forward, there are other non-quantifiable management measures to consider.

<u>Commercial Fisheries Trip Limits</u>

In the southern flounder commercial fishery, the use of a trip limit may be useful to maintain the quota allocation in the gig and pound net fisheries but is not ideal for the gill-net fishery due to the potential for increased dead discards. Unlike gigs or pound nets where commercial fishermen can selectively harvest flounder or release captured flounder with a high rate of survival, gill nets, although selective for fish size, cannot select for volume of fish entangled. As a result, any fish entangled in a gill net that is over a trip limit would be released with a higher rate of discard mortality, increasing the pounds of removals and impacting the overall quota.

To calculate trip limits for the gig and pound net fisheries, average landings for the past 10 years by proposed areas were reviewed in conjunction with the numbers of trips with landings in varying poundage increments for each area based on the 10-year average for that fishery. For the gig fishery, a trip limit in numbers of fish, not pounds, is needed for the trip limit to be enforceable. To calculate this, the pounds harvested were converted to numbers of fish based on an average of 2.56 pounds per gigged fish as determined from commercial fish house sampling.

Trip limits for the commercial pound net and gig fisheries cannot be determined at this time because trip limits may change depending on the fishery and how many pounds are available to harvest. The Fisheries Director will determine the trip limit amounts dependent upon how close the fishery is to their allocation and what overall daily harvest amounts have already occurred in the season. Information is available to identify the volume of trips that remove southern flounder based on various intervals to provide some guidance (Tables 4.1.12 and 4.1.13). There are concerns with a trip limit for the pound net fishery, particularly if set too low. Because southern flounder can be held in pound nets, it is possible for fishermen to hold southern flounder until they can be landed. Multiple people can harvest from a single operation in order to land the fish available. If the pound net trip limit is set too low, safety becomes a consideration as well and fishermen may be forced to fish their sets in unfavorable weather conditions; currently, sets are fished on good weather days, not every day. Understanding these shortcomings in the pound net fishery, a trip limit would allow harvest of southern flounder while minimizing dead discards as discards from pound nets are assumed to have a high survival rate. Allowing the gig fishery additional landings within the allocation using trip limits on the remaining quota will allow harvest and minimize discards as the gig fisherman can stop harvesting fish when the daily limit is reached. A trip limit for the gill-net fishery creates additional discards, once their trip limit has been reached remaining gear soaking will capture fish in excess of the specified trip limit and be released with an estimated mortality of 23% (Lee et al. 2018). Additional information on trip limits can be found in the *Adaptive Management* issue paper.

Recreational Fisheries Bag Limits

Potential changes to bag limits for all recreational gear were evaluated. Reductions in recreational bag limits may increase the likelihood of meeting required reductions as the stock rebuilds. The current daily bag limit for flounder is set at four fish; the average angler success rate for a single trip is one harvestable southern flounder (Figures 4.1.10 and 4.1.11). During 2017, recreational anglers released nine southern flounder for every one southern flounder that was harvested (Figure 19 in the *Description of the Fisheries* section). Angler success rates are tied to stock size (fish availability) and minimum size limits. As stock abundance increases during the rebuilding period, it is likely angler success will increase as well. If angler success improves, any gains achieved through limited open seasons will be lessened, limiting the actual recovery of the species. Harvest should be constrained using multiple measures in the recreational fisheries while rebuilding occurs.

Reducing the southern flounder bag limit would minimize the impacts of increased angler success on the rebuilding stock. Current data show that recreational anglers harvest 93% of the southern flounder total landings during trips where only one fish is harvested in a daily trip, although there is a four-fish daily bag limit in addition to the minimum size limit (Table 4.1.14). A reduction from four fish to three fish or from four fish to two fish daily bag limit does not curtail actual harvest (Table 4.1.14). Dropping the recreational bag limit for southern flounder to zero fish still results in dead discards of over 50,000 pounds for all identified potential season dates by anglers who are not targeting southern flounder and happen to catch and release some.

If angler success increases during the rebuilding time period, the volume of removals could increase relative to the original reduction calculations (Figure 4.1.11). If angler success doubles, which would be a two-fish daily harvest limit, paybacks from overharvest have the potential to severely curtail continued recreational angling opportunities as the stock recovers (Figure 4.1.12). Preliminary analyses of 2020 MRIP data indicate that angler success increased during the 2020 recreational season, when compared to 2015-2019, with the most notable increase with the number of anglers catching a single southern flounder. Limiting the potential future harvest during times of increased abundance will allow the stock to rebuild, making further bag limits necessary to constrain recreational harvest to meet the required reductions.

Table 4.1.12. Commercial southern flounder pound net trip limit scenarios (in pounds), including the number and cumulative of % trips, and % harvest within each trip limit bounds, September through November, 2008–2017. Note: Rounding of values may cause cumulative percentages to differ slightly.

	Management Area									
	Northern					Central				
Pounds Per Trip	Number of Trips	% of Trips	Cumulative Trip %	% of Harvest	Cumulative Harvest %	Number of Trips	% of Trips	Cumulative Trip %	% of Harvest	Cumulative Harvest %
<251	1,633	65	65	8	8	4,173	51	51	11	11
251-500	291	12	77	8	16	1,533	19	70	14	24
501-750	159	6	83	7	24	794	10	80	12	36
751-1,000	86	3	87	6	29	518	6	86	11	47
1,001-1,250	63	3	89	5	34	315	4	90	9	56
1,251-1,500	43	2	91	5	39	212	3	93	7	63
1,501-2,000	66	3	93	8	47	252	3	96	11	74
2,001-3,000	63	3	96	11	59	209	3	98	12	86
3,001-4,000	36	1	97	10	68	76	1	99	6	92
4,001+	66	3	100	32	100	59	1	100	8	100
Average Pounds Per Trip	539					503				

	Management Area									
	Southern					Statewide				
Pounds Per Trip	Number of Trips	% of Trips	Cumulative Trip %	% of Harvest	Cumulative Harvest %	Number of Trips	% of Trips	Cumulative Trip %	% of Harvest	Cumulative Harvest %
<251	1,850	66	66	18	18	7,656	57	57	11	11
251-500	420	15	81	15	33	2,244	17	74	13	24
501-750	197	7	88	13	46	1,150	9	82	11	35
751-1,000	123	4	92	12	57	727	5	88	10	45
1,001-1,250	63	2	94	7	64	441	3	91	8	52
1,251-1,500	40	1	96	6	70	295	2	93	6	59
1,501-2,000	48	2	98	9	78	366	3	96	10	69
2,001-3,000	40	1	99	10	89	312	2	98	12	81
3,001-4,000	20	1	100	7	96	132	1.0	99	7	88
4,001+	9	0	100	4	100	134	1.0	100	12	100
Average Pounds Per Trip	344					475				

Table 4.1.13. Commercial southern flounder gig fishery trip limit scenarios (in number of fish), including the number and cumulative % of trips, and % of harvest within each trip scenario, 2008–2017. Note: Rounding of values may cause cumulative percentages to differ slightly.

Number of Fish	Number of Trips	% of Trips	Cumulative Trip %	% of Harvest	Cumulative Harvest %
25	17,288	74	74	44	44
50	4,504	19	94	33	77
75	941	4	98	12	89
100	324	1	99	6	95
125	92	0	100	2	97
150	32	0	100	1	98
175	19	0	100	1	99
200	23	0	100	1	100
Average Pounds Per Trip	52				

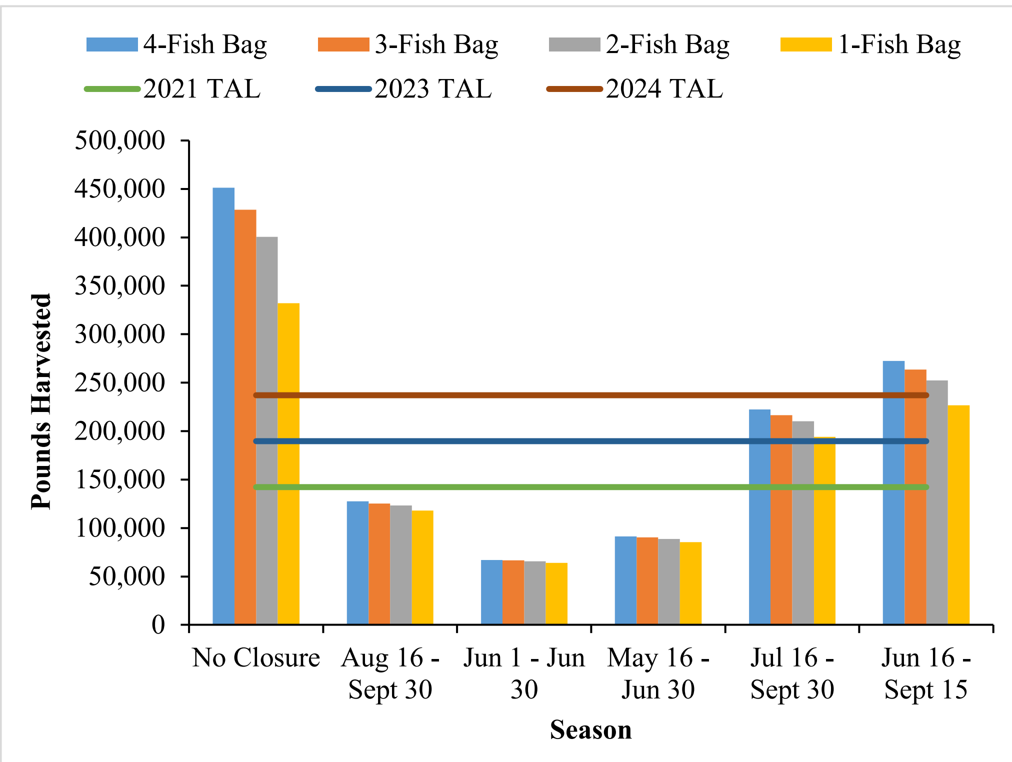

Figure 4.1.10. North Carolina southern flounder recreational fishing season relating to the increasing TAL (142,206 pounds in 2021 and 2022, 189,608 pounds in 2023, and 237,010 in 2024) and changes to the daily bag limit.

Table 4.1.14. Percent contribution of bag limit trips to total harvest of southern flounder for select seasons.

	Percent Contribution of Bag Limit to Total Harvest			
Season	**4-Fish Bag Limit**	**3-Fish Bag Limit**	**2-Fish Bag Limit**	**1-Fish Bag Limit**
No Season	5%	6%	15%	74%
Aug 1 - Sept 30	2%	2%	6%	90%
Aug 16 - Sept 30	2%	2%	4%	93%
Jun 1 - Jun 30	1%	1%	2%	95%
Apr 1 - June 30	1%	2%	4%	92%
Apr 1 - Sep 30	4%	6%	13%	77%
Mar 1 - Apr 15	0%	0%	0%	100%
Sep 1 – Sep 30	1%	1%	2%	96%
Apr 16 - Jun 30	1%	2%	4%	92%
May 1 - Jun 30	1%	2%	4%	93%
May 16 - Jun 30	1%	2%	3%	94%

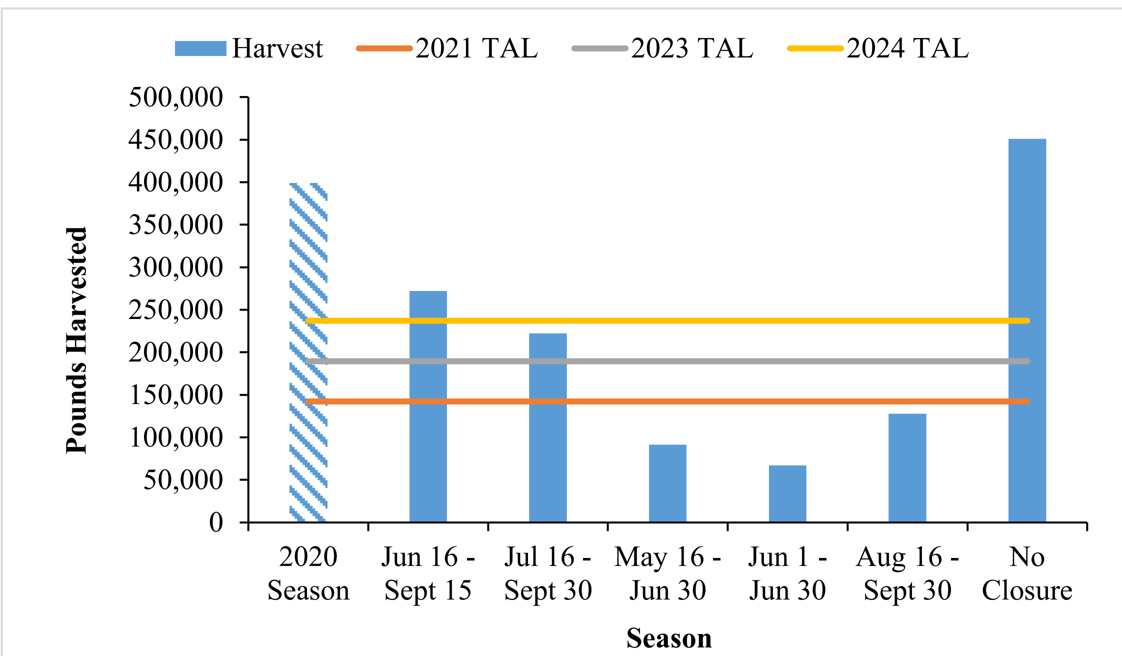

Figure 4.1.11. North Carolina southern flounder recreational fishing season relating to the increasing TAL (142,206 pounds in 2021 and 2022, 189,608 pounds in 2023, and 237,010 in 2024). The 2020 season was Aug. 16 through Sept. 30.

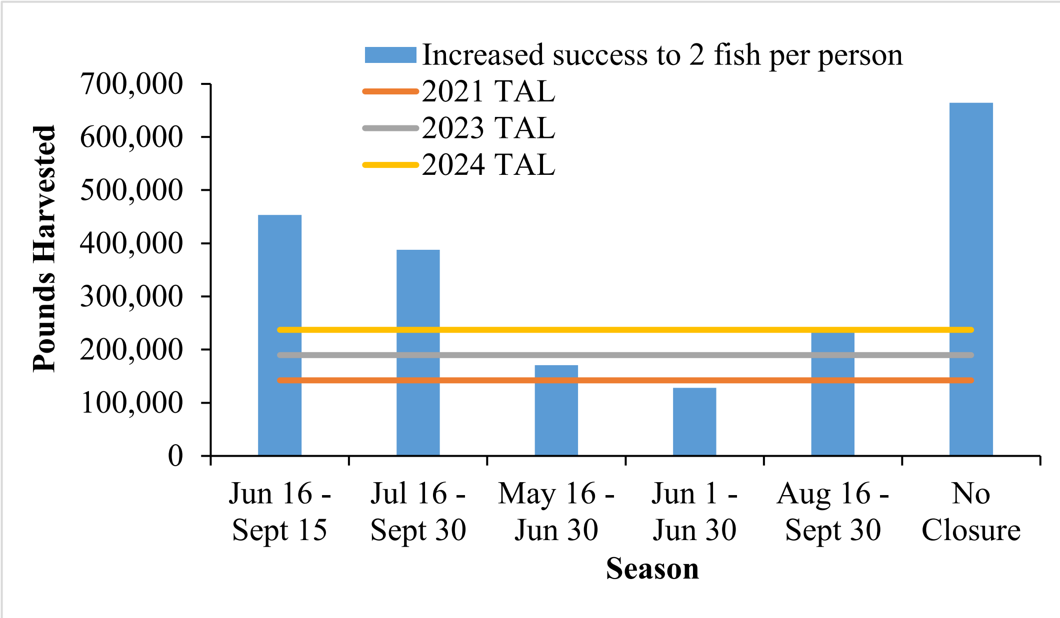

Figure 4.1.12. North Carolina southern flounder recreational fishing season relating to the increasing TAL (142,206 pounds in 2021 and 2022, 189,608 pounds in 2023, and 237,010 in 2024) anticipating angler success increasing to two fish per trip in the future.

Additional discussion of bag limits and the potential for increased angler opportunities through species-specific management of summer, southern, and Gulf flounder can be found in the *Increased Recreational Access* issue paper.

Recreational Commercial Gear

Recreational use of limited commercial fishing gears is allowed by law in North Carolina and is subject to the same reductions as the other recreational and commercial fisheries. Calculating reductions for the RCGL fishery is not possible because collection of RCGL harvest data has not occurred since 2008. Data collected in 2008 and prior may not be reliable for estimating reductions for Amendment 3 due to multiple management changes that have also occurred since the surveys ended. See the *Description of the Fisheries* section for trends in the RCGL fishery

Recreational gear license holders primarily use large-mesh gill nets to harvest southern flounder but may occasionally harvest southern flounder from shrimp trawls and crab pots. The use of commercial gears for recreational purposes is also only allowed during concurrently open recreational and commercial fishing seasons that allow the specific gear, and the user is only allowed harvest that does not exceed the recreational limits. Due to these requirements, the only measures available for harvest of flounder using a RCGL is during a period of time if and when the commercial and recreational fisheries are open simultaneously or prohibit the use of the RCGL for the harvest of southern flounder.

The volume of removals cannot be estimated for RCGL gears, but the number of license holders has continually declined from 6,055 participants in 2000 to a low of 1,662 participants in 2017 (additional information on RCGL can be found in the *Description of the Fisheries* section). Amendment 2 provides minimal opportunity to fish RCGL gears targeting southern flounder when both the recreational and commercial seasons are open. In addition, if the bag limit for recreational harvest is reduced, the resulting change could also further limit the impacts of the RCGL fishery. If harvest of southern flounder is prohibited from RCGL gear, then an increase in discards will occur if these gears continue in targeting other non-flounder species.

CONCLUSION

Certain measures are better to attain the goal to maintain sustainable harvest at the much-reduced harvest levels than others, while other measures provide more flexibility to benefit the sectors both in access to the resource and for higher economic value. Below we expand on the key measures that are the most risk averse in that they have the highest likelihood of succeeding in maintaining sustainable harvest while providing some flexibility in access to the resource for all sectors in the fisheries.

A summary of the key decision choices that are discussed as potential management measures in this paper are found in Tables 4.1.15 and 4.1.16.

Table 4.1.15. Summary of quantifiable management measures for Amendment 3.

Management Option	Management Sub-option	Management Measure	Gear	# Management Areas	Description
1	1.1A	Commercial Quota	All gear other than pound nets	2	Division at the ITP B-D Boundary Line
1	1.1B	Commercial Quota	All gear other than pound nets	1	Statewide
1	1.1C	Commercial Quota	All gear other than pound nets	3	Same areas as Amendment 2
1	1.2A	Commercial Quota	Pound Nets	3	Same areas as Amendment 2
1	1.2B	Commercial Quota	Pound Nets	1	Statewide
1	1.2C	Commercial Quota	Pound Nets	2	Division at approximately Pea Island
2	2.1	Commercial Sub-Allocations	All commercial gears	N/A	2017 landings
2	2.2	Commercial Sub-Allocations	All commercial gears	N/A	Maintain current pound net allocation
2	2.3	Commercial Sub-Allocations	All commercial gears except gill nets	N/A	Allocate gill net harvest to mobile and pound net gears equally (50/50)
3	3	Recreational Quota (through season)	Hook-and- Line, Gigs	1	Statewide

Table 4.1.16. Summary of non-quantifiable management measures for Amendment 3.

Management Option	Management sub-option	Management Measure	Description
4	4A	Commercial Fishery Trip Limits	Implement trip limits for pound nets and gigs only to maximize potential opportunities for reopening a fishery to harvest remaining allocation
4	4B	Commercial Fishery Trip Limits	Implement trip limits for all gears
4	4C	Commercial Fishery Trip Limits	Status quo, do not implement trip limits
5	5A	Recreational Fishery Bag Limits	Reduce recreational bag limit of flounder to one fish per person per day
5	5B	Recreational Fishery Bag Limits	Reduce recreational bag limit of flounder to no more than three fish per person per day
5	5C	Recreational Fishery Bag Limits	Reduce recreational bag limit of flounder to no more than two fish per person per day
5	5D	Recreational Fishery Bag Limits	Status quo, keep the recreational bag limit of flounder at no more than four fish per person per day
6	6A	Recreational Commercial Gear	Allow the RCGL to be used to harvest flounder only during a period of time when the commercial and recreational fisheries are both open
6	6B	Recreational Commercial Gear	Prohibit the use of RCGL to harvest southern flounder

VI. PROPOSED MANAGEMENT OPTIONS

Management Options

(+ potential positive impact of action)
(- potential negative impact of action)

Below are overarching positive (+) and negative (-) impacts for all options, specific impacts from an option may be found below that option.

+ May increase the abundance of female southern flounder helping to rebuild the spawning stock
+ Will impact both the commercial and recreational fisheries
+ No rule changes required
- Decreased harvest and economic impacts

Option 1. Implement A Quota for Mobile Gears and Pound Nets

The following positive and negative impacts apply to all of Option 1; specific impacts are listed under each sub-option.

+ Two gear categories reduce potential for increased error in dealer reporting
+ Allows individuals to fish and report multiple gears under the mobile gear category
+ Meets the requirements for rebuilding
+ If gill-net fishing is closed due to ITP, then allocation would be available to other gears in combined category
+ Would allow fishermen to explore alternate fishing gears to reduce bycatch
+/- Could allow for different opening dates
- Seasonal selections may impact landings from certain gears and locations more than others
- The more gears and areas are divided, the more complex dealer reporting and division monitoring becomes and we will be less likely to meet targets

1.1A. Dividing the states mobile commercial gears into two areas using the ITP boundary line for management units B–D.

+ Meets requirements for reductions
+ Maintains consistency for gill-net ITP boundary lines
+ Allows flexibility in opening dates for each area
+/- May shift fishing effort and alter behavior
- Some regions may be impacted more than others
- Some gears may be impacted more than others
- More areas make monitoring the daily landings more difficult

1.1B. A single statewide mobile commercial gear allocation that includes all coastal estuarine waters.

+ Single allocation area is easiest to monitor

- \+ Combing mobile gears makes reporting by dealers easier and reduces error
- \+ Equal access to commercial fishers
- \+ Meets requirements for reductions
- \- Seasonal selection may impede landings in certain locations

1.1C. Dividing the states mobile commercial gears into three areas (northern, central, and southern). The northern area would encompass the Albemarle Sound and its tributaries including the Croatan and Roanoke sounds, the central would encompass the Pamlico Sound and its tributaries, and the southern would encompass all waters from Core Sound south matching the boundaries described for the pound net fishery three-area option 2.2A.

- \+ Meets requirements for reductions
- \- Some regions may be impacted more than others
- \- Some gears may be impacted more than others
- \- Enforcement issues through increased boundaries not consistent with current ITP lines
- \- More areas make monitoring the daily landings more difficult
- \- More areas increase complexity for dealers daily reporting

1.2A. Dividing the state's pound net fishery into three areas maintaining consistency with areas in Amendment 2.

- \+ Meets requirements for reductions
- \+ Allows flexibility for different opening dates for each area
- \+ Maintains consistency with Amendment 2 boundaries
- \- Some regions may be impacted more than others
- \- Some fishers may have pound nets in multiple areas
- \- More areas make monitoring the daily landings more difficult

1.2B. A single statewide pound net allocation.

- \+ Meets requirements for reductions
- \+ Makes monitoring the daily landings easier
- \- No flexibility in opening dates
- \- Availability of fish varies across the state; may impact some areas more depending on when fishery is open

1.2C. Dividing the states pound net fishery into two-areas using the 35° 46.3000' N latitude.

- \+ Meets requirements for reductions
- \- Some fishermen may have pound nets in multiple areas
- \- Availability of fish varies across the state; may impact some areas more depending on when fishery is open

Option 2. Commercial Sub-Allocations

Decisions on commercial sub-allocations may be influenced based on the option selected in Appendix 4.7: *Phasing out Large-Mesh Gill Nets from the NC Southern Flounder Fishery* issue paper.

2.1. Maintain overall reductions of 72% and 2017 sub-allocations (Table 4.1.6)

- \+ Allows for all commercial gears to harvest southern flounder
- \+ Meets the requirements for sustainable harvest
- \- May reduce pound net sub-allocation to a level that is not economically viable
- \- May reduce pound net sub-allocations to a level where daily quota monitoring may be problematic

2.2. Maintain overall reductions of 72% and the current level of sub-allocation for the pound net fishery (Table 4.1.7).

- \+ Allows for all commercial gears to harvest southern flounder
- \+ Meets the requirements for sustainable harvest
- \- Reduces the available sub-allocation for mobile gears
- \- Decreases the economic benefit of the commercial mobile gear fisheries

2.3. Maintain overall reductions of 72% and redistributes the gill net allocation equally between mobile and pound net gears beginning in 2023 (shown in the 60% and 50% allocations) (Table 4.1.8).

- \+ Meets the requirements for sustainable harvest
- \+ Increases the sub-allocations for remaining mobile gears and pound nets
- \+ May increase the economic impact of the remaining gears
- \- Does not allow for harvest of southern flounder using gill nets
- \- Decreases the economic benefit of the commercial gill net fishery

Option 3. Recreational Quota

- \+ Meets requirements for reductions
- \+ Consistent with Amendment 2
- \+ Should limit removals and allow rebuilding of the stock
- \+ Allows for continued access to stock during rebuilding
- \- Several month delay to receive final estimates after season ends due to MRIP data availability
- \- Reduces access to anglers during closed seasons
- \- Difficult to account for angler behavior changes
- \- Does not stop indirect discards while targeting other species
- \- Does not limit future harvest during times of increased abundance from rebuilding

Option 4. Commercial Fisheries Trip Limits

The following positive and negative impacts apply to all of option 4; specific impacts are listed under each sub-option.

+ Allows for maximizing available allocations
+ Meets requirements for reductions
- May create additional discards if the trip limits are set too low
- Any SCFL or RSCFL holder can fish a permitted pound net with permission; a single net could distribute fish to multiple SCFL/RSCFL holders that normally would not use that gear

4A. Implement trip limits for pound nets and gigs only to maximize reopening after reaching division closure threshold.

+ Can be effective for gears with limited discard mortality
- Any SCFL or RSCFL holder can fish a permitted pound net with permission; a single net could distribute fish to multiple SCFL/RSCFL holders that normally would not use that gear

4B. Implement trip limits for all commercial gears.

+ May limit harvest from non-targeted gears as the stock recovers
+ May alleviate concerns of a derby fishery
- Not effective for gears where discard mortality is high (gill nets)
- May force fishermen to fish in unfavorable weather

4C. Status quo, do not implement trip limits

+ Any quota not harvested would act as additional savings for the spawning stock biomass

+/- Would not allow fisheries to re-open after closure due to approaching the TAL

- Economic impacts to the commercial sector would be greater if unable to harvest all of the TAL

Option 5. Recreational Fisheries Bag Limits

The following positive and negative impacts apply to all of Option 5; specific impacts are listed under each sub-option.

+ Meets requirements for reductions
- Decreases potential access to recreational anglers
- May increase discards

5A. Reduce recreational bag limit of flounder to one fish per person per day.

+ Provides the greatest chance of rebuilding and maintaining growth in the stock
+ May allow for quickest rebuilding of spawning stock biomass
+ May limit harvest during times of increased abundance from rebuilding
- May slow rebuilding if fish are continued to be harvested
- Would increase discards

5B. Reduce recreational bag limit of flounder to no more than three fish per person per day.

- \+ Reduces harvest for anglers who were successful at catching more than three flounder per trip
- \- Does not limit future harvest during times of increased abundance from rebuilding
- \- May delay rebuilding of spawning stock biomass

5C. Reduce recreational bag limit of flounder to no more than two fish per person per day.

- \+ Reduces harvest for anglers who were successful at catching more than two flounder per trip
- \- Does not limit future harvest during times of increased abundance from rebuilding
- \- May delay rebuilding of spawning stock biomass

5D. Status quo, keep the recreational bag limit of flounder at no more than four fish per person per day

- \+ Regulations are consistent with Amendment 2
- \- Does not limit future harvest during times of increased abundance from rebuilding
- \- May delay rebuilding of spawning stock biomass

Option 6. Recreational Commercial Gear

6A. Allow the RCGL to be used to harvest flounder only during a period of time when the commercial and recreational fisheries are both open.

- \+ Consistent with Amendment 2
- \+ Allows continued access to fishery
- \- Cannot account for harvest or discards from RCGL gear
- \- May increase discards if gear is allowed and bag limits are reduced
- \- Potential protected species interactions
- \- If allowed, there will be disparity among areas

6B. Prohibit the use of RCGL for the harvest of southern flounder.

- \+ Eliminates harvest from RGCL gears
- \- Cannot account for harvest or discards from RCGL gear
- \- Removes access to fishery for license holders
- \- May increase discards if species cannot be harvested but gear is still allowed

VII. RECOMMENDATION

See Appendix 6 for a summary of all comments and recommendations gathered from NCDMF, the NCMFC advisory committees, and public for the Southern Flounder FMP Amendment 3.

NCMFC Preferred Management Strategy

Commercial Fisheries:

- Combine mobile gears (gill nets, gigs, and "other" gears) into one gear category and maintain pound nets as their own separate commercial fishery (Option 1).
- Divide mobile gears into two areas using the ITP boundary line for management units B-D (Option 1.1A).
- Divide the pound net fishery into three areas maintaining consistency with areas in Amendment 2 (Option 1.2A).
- Maintain 72% reduction and current sub-allocation for the pound net fishery with direction from the MFC as follows: "In 2024, as the shift in allocation is set to start the Division will provide recommendations to the NCMFC on approaches to maintaining a sustainable sub-allocation for the commercial pound net fishery, as needed based on the economic and biotic conditions at that time".
- Implement trip limits for pound nets and gigs only to maximize reopening after reaching division closure threshold (Option 4A).

Recreational Fisheries:

- Implement a single season for the recreational gig and hook-and-line fisheries to constrain them to an annual quota (Option 3).
- Reduce the recreational bag limit of flounder to one fish per person per day (Option 5A).
- Do not allow harvest of southern flounder using RCGL (Option 6B).

**Includes management measures and clarifications in the carried forward from Amendment 2.*

In addition, the NCMFC adopted a resolution that the NCMFC recognizes that there may need to be consideration of a moratorium if there are continued excesses in the allowable catch of flounder in both sectors.

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APPENDIX 4.1.A. MANAGEMENT MEASURES AND STRATEGIES CONSIDERED BUT NOT DEVELOPED

Appendix 4.1.A was developed to provide additional data analysis and discussion on management measures and strategies that have been explored in this issue paper. These strategies do not have sufficient data necessary to support moving forward at this time but may provide research needs so they can be considered in future updates to the Southern Flounder Fishery Management Plan.

STATUS QUO

An option of "status quo," which means continue only what is in Amendment 2, is not presented in this issue paper. Final adoption of Amendment 2 to the Southern Flounder Fishery Management Plan authorized development of Amendment 3 with more comprehensive management strategies.

LIMITED ENTRY

North Carolina G.S. 113-182.1 states the NCMFC can only recommend the General Assembly limit participation in a fishery if the NCMFC determines sustainable harvest in the fishery cannot otherwise be achieved. Sustainable harvest can be achieved without the use of limited entry; therefore, limited entry is not an option at this time. For further information see *Appendix 1: Management Issues Considered but Not Developed*.

DYNAMIC QUOTA

A dynamic quota refers to a total allowable catch that fluctuates among years relative to the abundance of the resource and fishing pressure. In the case of southern flounder, the quota for a given year would be primarily driven by the strength of the year classes being subjected to fishing pressure. As with the static quota, all of the same drawbacks, including issues with monitoring the landings on a daily basis and the high degree of variability in the daily landings, go along with implementing a dynamic quota. In addition, to adequately manage a dynamic quota, the division would need to determine if the fishery-independent surveys used to estimate recruitment in the 2019 stock assessment can accurately predict year-class strength for quota management purposes. The terminal year estimates of recruitment from stock assessments tend to be the most uncertain; the use of recruitment indices to determine a dynamic quota is not a viable possibility. Due to limited availability of real time data that is reflective of the southern flounder stock, a dynamic quota is not a viable management option.

CHANGES TO SIZE LIMITS

Calculations necessary for developing projections based on increasing the current minimum size limit, decreasing the current minimum size limit, or developing a slot limit cannot be calculated on an individual state basis. The current stock assessment does not include a spatial component and, as a result, the lack of this spatial component means all size limit changes would be relative to the entire stock of southern flounder. Currently, there are multiple minimum size limits in place across the unit stock, ranging from 12- to 15-inches TL. If an increase or decrease in the minimum size limit, or a slot limit, for N.C. waters is considered, it is necessary to note that calculations referencing reductions that affect the fishing mortality rates of spawning stock biomass are not possible. Any changes made would be based on previous years' data for fish within North Carolina harvest estimates and may or may not have intended impacts on the rebuilding of the stock. It would not be possible to attribute changes to size limits as the cause of changes to stock size.

Using North Carolina harvest estimates, calculations were performed to determine what additional effect size limit changes would have on the TAL in North Carolina. As stated above, these calculations do not account for the entire unit stock and are only for guidance as the effect over the entire unit stock would be non-quantifiable. The discussion below addresses these effects, as well as potential drawbacks to increasing the minimum size. Slot limits and a decrease in the minimum size are discussed in the *Implementing a Slot Limit* issue paper.

Increase in Minimum Size Limit

An increase in the minimum size limits is not recommended for the commercial fishery. In 2017, 80% of the fish harvested in the commercial fishery were less than 18 inches TL (Figure 4.1.11 in the *Achieving Sustainable Harvest* issue paper). Increasing the minimum size limit would increase the volume of releases from this fishery. In addition, continued increase in the minimum size limit would place increased harvest on the largest fish in the stock, which would disproportionately be females. For the commercial fishery, an increase in the minimum size limit would result in additional dead discards, particularly in the gill-net fishery that has a discard mortality rate of 23% (Lee et al. 2018).

Public comment for increasing the minimum size limit in the recreational fishery has been received numerous times over the years, with an increase to 18-inches most often mentioned. For the recreational fishery, increasing the minimum size limit would increase the volume of releases from this fishery, many of which may be mortalities and would decrease angler success. In 2017, 71% of the southern flounder harvested (by weight, pounds) by the recreational fishery were under 18-inches TL (Figure 4.6.2 in the *Implementing a Slot Limit* issue paper). If the recreational minimum size limit were to be set at 18-inches TL, an additional 28,000 pounds of dead discards would be created based on 2017 data with a total harvest savings of approximately 283,352 pounds over the year. To determine what impact changing the minimum size limit to 18-inches TL would have on the TAL, seasonal calculations were re-evaluated. Several seasons were identified, in addition to the season currently established (Aug. 16 to Sept. 30) in Amendment 2, that would meet the overall harvest target reduction of 142,206 pounds (Table 4.1.A1). Although an increase in the minimum size limit has the potential to increase the length of a season, there is increased error around these estimates. Additionally, as the stock rebuilds, the seasons identified may not continue to meet the target harvest reduction due to increased angler success (Figure 4.1.A1).

Table 4.1.A1. Season and total harvest for an 18-inch TL minimum size limit based on 2017 data.

Season	Total Harvest (pounds)
No Closure	167,774
Aug 16-–Sep 30	47,401
Aug 1-–Sep 30	49,149
Jul 16-–Sep 30	64,576
Jul 1-–Sep 30	91,376
Aug 1–Oct 15	52,914
Aug 16–Oct 15	51,167
Jul 1–Aug 31	47,493
Jul 1–Sep 15	66,396
Sep 1–Oct 31	58,760
Sep 1–Nov 15	68,808

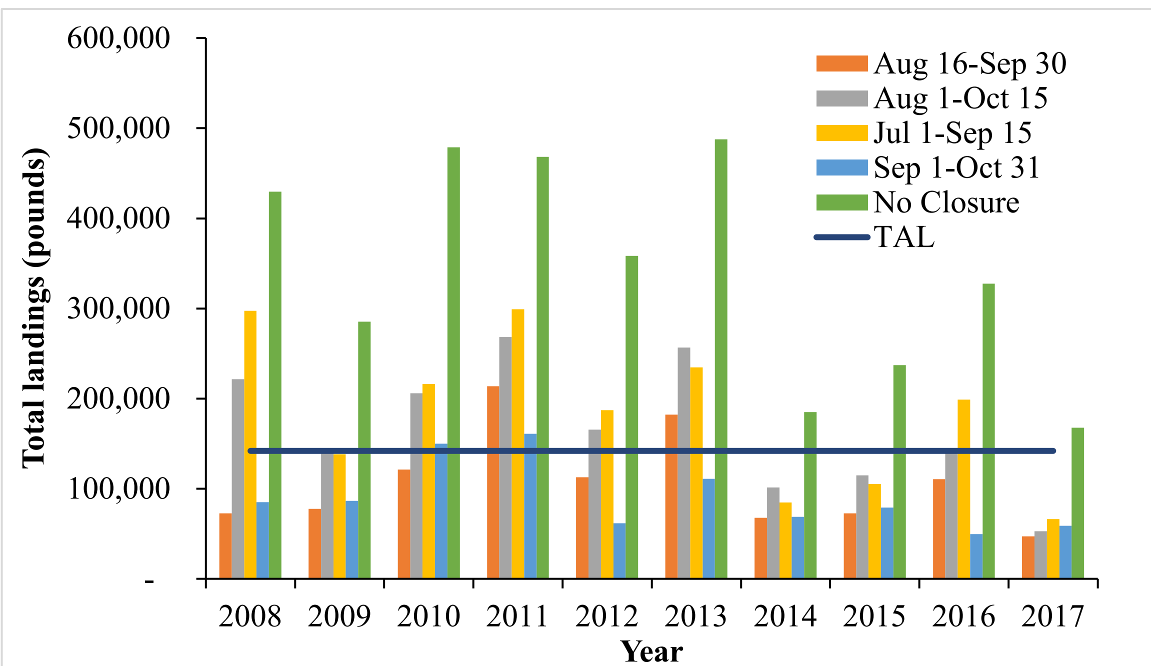

Figure 4.1.A1. Total hook-and-line harvest for seasonal options based on data for 18-inch minimum size limit from 2008–2017. Years 2010, 2011, and 2013 represent years of above average harvest. TAL of 142,206 pounds is represented by the blue solid line.

COMMERCIAL GEAR LIMITATIONS

Current gear configurations, including 6.0 ISM for large-mesh gill nets, 5 and ¾ ISM escape panels in pound nets combined with a 15-inch TL minimum size limit for flounder, have reduced the volume of discards observed. Although the only fishery for which discards can currently be estimated is the large mesh gill-net fishery, anecdotal evidence supports limited discards in the pound net fishery. Due to the apparent effectiveness of the current gear configurations and the current minimum size limit, additional changes to gear are not recommend at this time; however, if size limits are considered for the estuarine flounder fishery, changes to gear configurations may be warranted.

DEVELOPMENT OF FISHING DAYS (WEEKEND/WEEKDAYS/HOLIDAYS) FOR THE RECREATIONAL FISHERY

The adoption of Southern Flounder Amendment 2 by the NCMFC mandated a 72% reduction in pounds for both the commercial and recreational sectors beginning in 2020 to achieve sustainability of the stock within 10 years. To achieve this reduction within the recreational fishery, MRIP data from 2008-–2017 were analyzed to determine appropriate bag limits that operate in concurrence with seasonal closures. A reduction in pounds necessitated incorporation of the discard mortality estimates across specific bag and season combinations. The harvest of southern flounder exhibits a distinct seasonality and the bulk of the harvest occurs during the summer months. To achieve an acceptable reduction in harvest, seasonal scenarios focused on reducing harvest during the summer months. This analysis demonstrated that the only scenario in which the recreational TAL was not exceeded was through a four-fish bag limit on southern flounder within a season spanning Aug. 16 through Sept. 30. At the request of the NCMFC, the division explored the possibility of protracting the recreational season through combinations of weekday and weekend day types. Additional input from the Southern Flounder Advisory Committee recommended a weekday specific season during the summer months with an allowance for weekend only fishing during the fall.

MRIP catch rate estimates were obtained through a variety of weightings reflective of angler avidity including location, day type (weekend vs. weekday), and time of day. MRIP produces catch estimates by applying the weighted catch rates to estimates of effort obtained through the Fishing Effort Survey (see *Description of the Fisheries* section). Importantly, the MRIP definition of day type includes Friday as a weekend day type due to angler avidity aligning more closely with observations from Saturday and Sunday. As such, it is disproportionately weighted with expanded catch rate estimates reflecting this increased avidity. Thus, it is of particular note that Friday is included as a weekend day type when data are deconstructed for analysis. Initial analyses sought to achieve targeted reductions for particular day types as a proportion of day type specific contributions. Specifically, a weekend target of 76,000 pounds and a weekday target of 46,000 pounds would achieve the overall target reduction of 142,206 pounds. This analysis demonstrated that when individual day types were given equal consideration regarding targeted reductions, there was no deviation from initial reduction projections using the combined data set; however, when individual day types were considered within the context of the recreational hook-and-line TAL (142,206 lb), it is possible to achieve a variety of scenarios that extend the season for over three months and still achieve desired reductions but with increased error around the produced estimates.

The scenario that most closely approaches the harvest allowance includes a summer season from July 16 through Sept. 30 that permits harvest only during MRIP defined weekdays (Monday, Tuesday, Wednesday, and Thursday). This weekday season will provide a projected harvest of 92,354 pounds. A subsequent season consisting of MRIP defined weekend days (Friday, Saturday, Sunday) will begin on Oct. 15 and last until Nov. 30. This fall weekend season will provide a projected harvest of 27,803 pounds. The combined harvest of 121,666 pounds will fall below the TAL of 142,206 pounds (Table 4.1.A2; Figure 4.1.A2).

Alternate management scenarios incorporate species-specific harvest (i.e., summer, southern., Gulf) and are further evaluated in the *Increased Recreational Access* issue paper. When constituent flounder species are given consideration in establishing bag limits, there is potential to craft additional seasons that further extend the seasonal harvest of flounder. Verifying the recreational angling community's ability to differentiate among North Carolina's three flounder species will be requisite before single species management options can be explored.

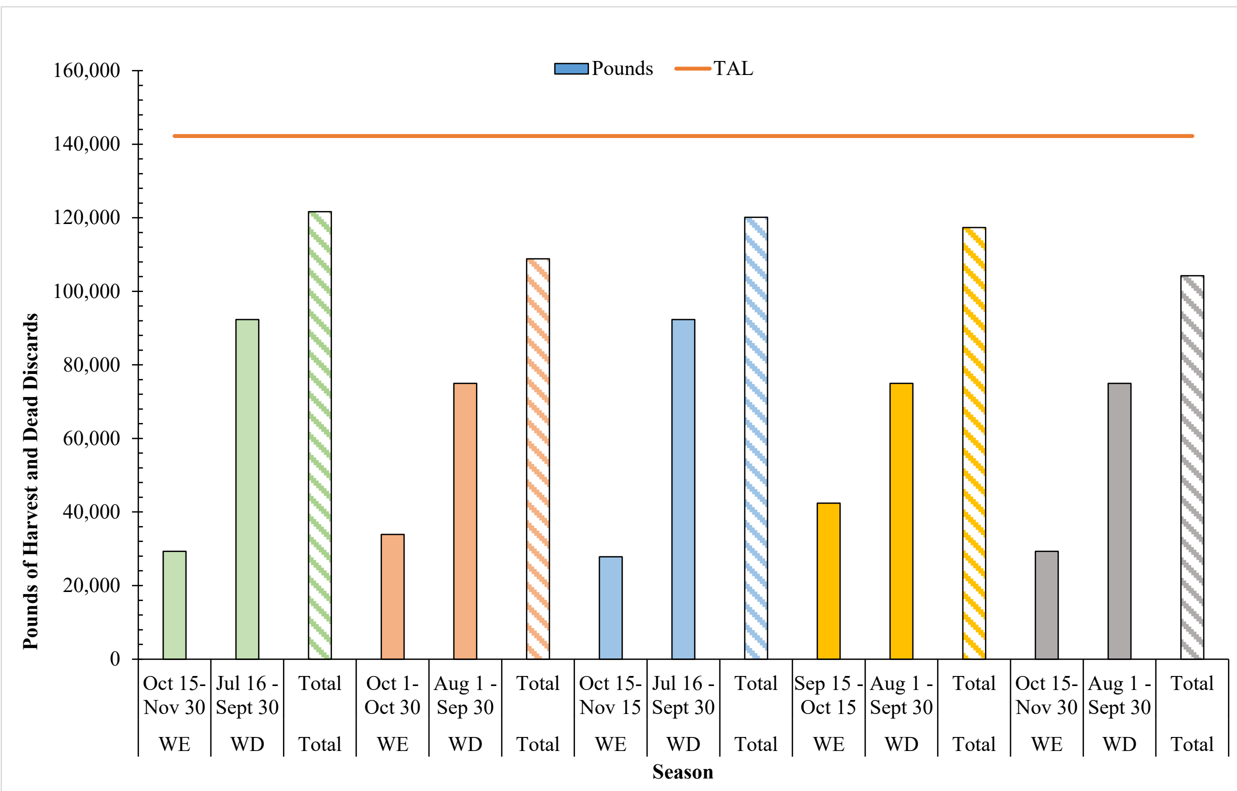

Figure 4.1.A2. Southern flounder harvest projections from seasons using day-type specific combinations. (Note: WD = Weekdays and WE = Weekends).

Table 4.1.A2. Southern flounder harvest projections from seasons using day-type specific combinations.

Day Type	**Season**	**Pounds**
Weekend	Oct 15 –Nov 30	29,313
Weekday	Jul 16–Sept 30	92,354
	Total	121,666
Weekend	Oct 1–Oct 30	33,903
Weekday	Aug 1– - Sep 30	74,953
	Total	108,856
Weekend	Oct 15 –Nov 15	27,803
Weekday	Jul 16–Sept 30	92,354
	Total	120,157
Weekend	Sep 15–Oct 15	42,386
Weekday	Aug 1–Sept 30	74,953
	Total	117,339
Weekend	Oct 15- Nov 30	29,313
Weekday	Aug 1 - Sept 30	74,953
	Total	104,266

The scenarios provided will allow greater access to the resource by providing concessions for for-hire stakeholders who rely heavily on weekday clientele during the summer months while also affording anglers access to the fall flounder fishery. The primary concern with this approach is that under the initial season combining all day types provided anglers with a defined window within which to fish, thus increasing the likelihood of achieving targeted reductions. The extension of a season across multiple months between specific day types increases the opportunity for individuals to alter their behavior to capitalize on the resource, which has the potential to compromise projected reductions. It may be beneficial to consider options with a lower projected harvest to provide a buffer against temporal displacement across a protracted season. This is also suggested as the reductions are based on the terminal year (2017) of the assessment. During periods of higher abundance (e.g., 2013), weekday and weekend estimates vary greatly and are often greater than allowed for the recreational hook-and-line TAL (Figure 4.1.A3).

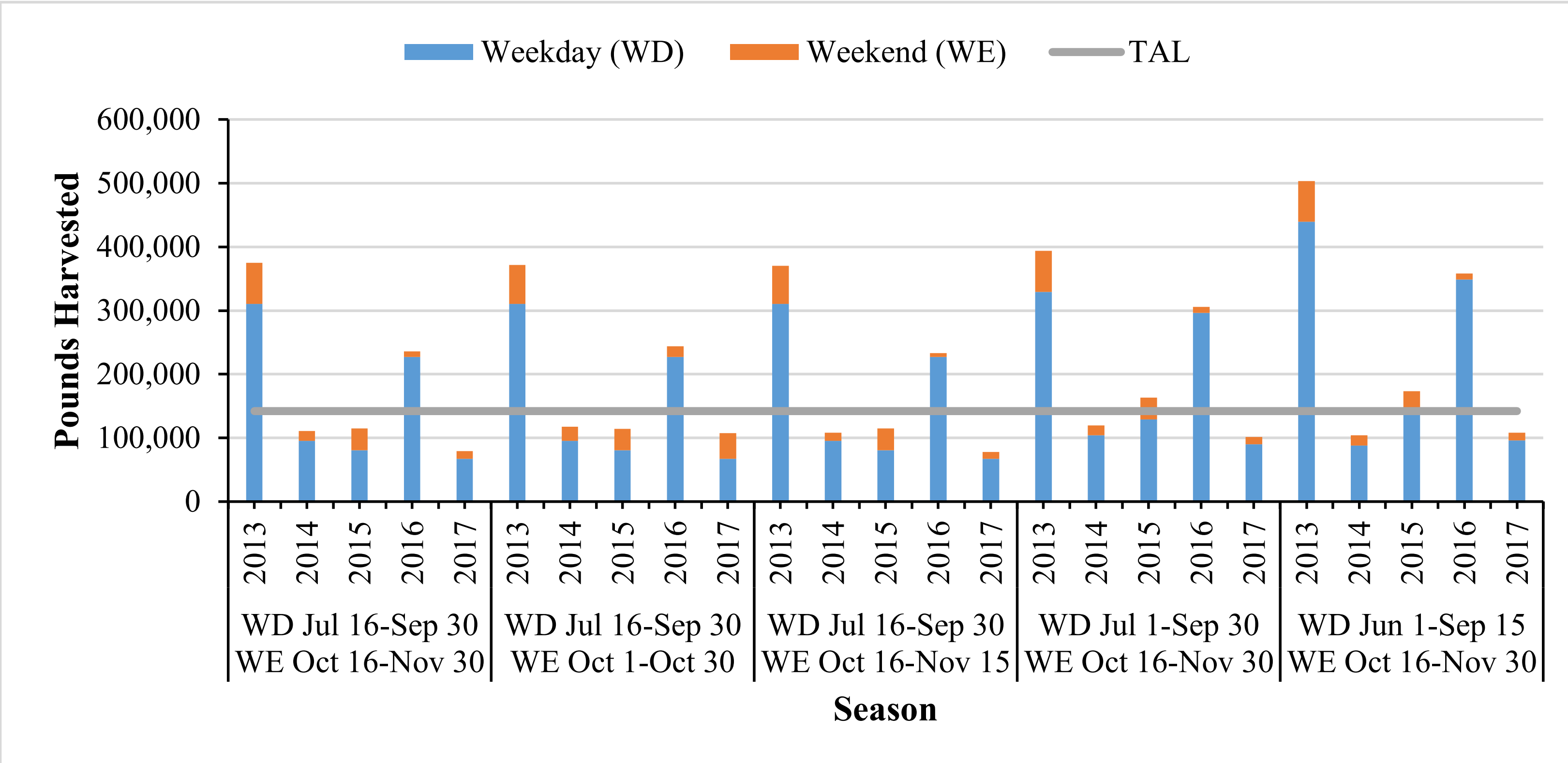

Figure 4.1.A3. Annual variability in harvest of southern flounder (pounds) during identified day type combinations, 2013–2017. (Note: WD = Weekdays and WE = Weekends)

RECREATIONAL FISHERY VESSEL LIMITS

Potential implementation of vessel limits for all recreational gear were evaluated. The Private/Rental boat mode in MRIP is responsible for the largest portion of the recreational landings of southern flounder. The vessels intercepted by MRIP had an average of two anglers present from 2008 through 2017; however, the number of anglers ranged from one to 11 (Table 4.1.A3). It is the trips where more than two anglers are present that cause concern. In the southern flounder recreational fishery, the use of a trip limit may be useful to maintain the quota allocation for the hook-and-line and gig fisheries. Vessel limits may have a larger impact to recreational southern flounder harvest if bag limits are not reduced from four fish per person per day. Much like reduction in bag limits, effects of vessel limits are not quantifiable at this time as estimates would be based on prior years which will not be reflective of the fishery moving forward. Due to this, implementing trip limits would serve to reduce the chances of exceeding the TAL for the recreational fishery and thus reduce the chances of significant impacts in subsequent seasons due to required accountability measures. As stock abundance increases during the rebuilding period, it is likely angler success will increase as well. If angler success improves, any gains achieved through limited open seasons will be lessened, limiting the actual recovery of the species. Harvest must be constrained using multiple measures in the recreational fisheries while rebuilding occurs; however, if the recreational bag limit is reduced to one fish then the implementation of vessel limits may not be necessary. If reductions in bag limits are not implemented and vessel limits are imposed, the vessel limits themselves may not be adequate to limit harvest as rebuilding occurs. Under the proposed quota system, any overages that occur, even if under vessel limit constraints, will be applied to subsequent years. Data suggest that limiting harvest and thus reducing the chances of exceeding the recreational TAL is best suited with a reduction in bag limit.

Table 4.1.A3. Average, minimum, and maximum number of anglers present on a vessel in the Private/Rental Boat mode for the recreational southern flounder fishery from 2008–2017.

Year	**Average**	**Minimum**	**Maximum**
2008	2	1	8
2009	2	1	9
2010	2	1	11
2011	2	1	10
2012	2	1	6
2013	2	1	7
2014	2	1	6
2015	2	1	6
2016	2	1	5
2017	2	1	6
Total	2	1	11

APPENDIX 4.2. INCREASED RECREATIONAL ACCESS BY MANAGING SOUTHERN FLOUNDER SEPARATELY FROM OTHER FLOUNDER SPECIES

I. ISSUE

Implement single species or genus level management to increase recreational access to summer and Gulf flounder while maintaining harvest reductions in the southern flounder fishery.

II. ORIGINATION

The adoption of Southern Flounder FMP Amendment 2 by the NCMFC mandated a 72% reduction in pounds starting in 2020 for both the commercial and recreational sectors to achieve sustainability of the stock within 10 years (NCDMF 2019). To achieve this reduction within the recreational fishery, MRIP data from 2008-2017 were analyzed relative to the terminal year (2017) landings to determine appropriate bag-limits that operate in concurrence with seasonal closures. Importantly, Amendment 2 contained acute management measures (seasons) to achieve sustainable harvest and was predicated on the immediate development of Amendment 3 for the purpose of implementing more comprehensive long-term management measures to achieve sustainable harvest.

At the request of the NCMFC and the Southern Flounder FMP Advisory Committee, the division examined alternative management scenarios that incorporate species-specific harvest of flounder (i.e., summer, southern, Gulf). When constituent flounder species are given consideration, the potential exists to develop additional scenarios that further extend the seasonal harvest of flounder species.

III. BACKGROUND

Southern flounder, or flounder species in general (*Paralicthys* spp.), are one of the most targeted recreational species in North Carolina. Southern flounder are primarily landed by recreational fishermen using hook and line. Additional harvest, albeit to a lesser extent, is accomplished with gigs and recreational use of commercial gears (e.g., anchored large-mesh gill nets). Between 2008 and 2017, North Carolina's total recreational removals (in pounds) were approximately 19% of the total coast-wide southern flounder removals (North Carolina to the east coast of Florida; NCDMF 2019). The recreational flounder fishery in North Carolina accounted for 28% of the state's total removals (26% in landings and an additional 2% of dead discards) in 2017 (the terminal year of the assessment; NCDMF 2019). Additionally, between 2008 and 2017 southern flounder contributed 73% of total flounder landings with summer contributing 22% and Gulf contributing 5%. For additional information on landings see the *Description of the Fisheries* section and *Achieving Sustainable Harvest* issue paper.

In North Carolina, the recreational flounder fishery is managed as an aggregate consisting of three main species of flounder (southern, summer, and Gulf). Thus, a closure on the southern flounder recreational fishery means the harvest of the other flounder species is prohibited. This is particularly relevant for the closure of the recreational ocean fishery and is acknowledged as an unintended consequence of this aggregate management. Based on MRIP data, most flounder harvest across all species occurs in estuarine waters (Figure 4.2.1). Of the flounder landed in state territorial seas and the EEZ (referred to as "ocean" from this point in the document forward), approximately 50% of the ocean recreational harvest are species other than southern flounder. Specifically, summer flounder are more frequently encountered in the ocean fishery relative to southern flounder. Gulf flounder represents less than 6% of total flounder harvest and is predominately harvested in ocean waters (Figure 4.2.1). Pending species-specific management, recreational access to summer and Gulf flounder will not be possible when the southern flounder season is closed.

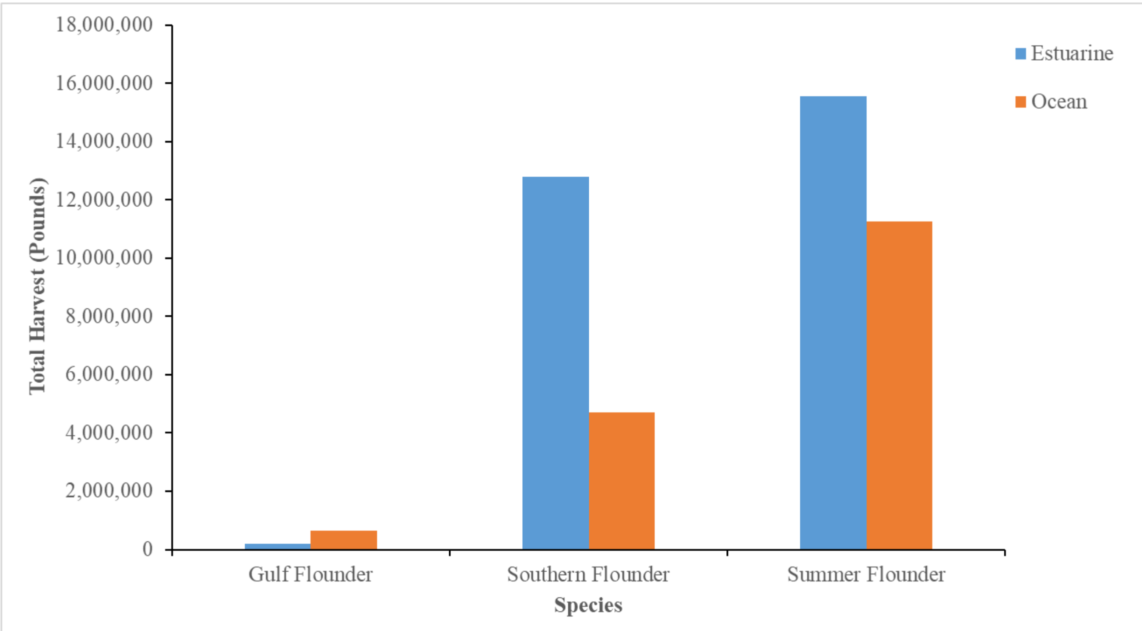

Figure 4.2.1. Pounds of harvest by flounder species from the ocean and estuarine waters, 1981–2019.

This issue paper examines the application of single-species management within a seasonal framework. The deconstruction of flounder species into discrete management units will provide an opportunity for stakeholders to have continued access to summer and Gulf flounder while simultaneously maintaining the required reduction for southern flounder as defined in Amendment 2.

Educational outreach is key to this issue as species identification lays the groundwork for successful implementation and long-term viability of managing flounder by species or aggregations. The division has developed a Flounder Identification Guide that is available through the "Hot Topics" page of the NCDEQ website. This guide describes the main characteristics (presence of ocellated or non-ocellated spots, gill rakers, and fin ray counts) to identify the three main flounder species in North Carolina waters and serves as a reference to educate anglers.

The absence of ocellated spots in southern flounder relative to Gulf and summer flounder is a defining characteristic that can used as the primary metric to differentiate among flounder species. Because the primary characteristic for identification (i.e., ocellated spots) is shared between summer and Gulf flounder, it may be possible to aggregate summer and Gulf flounder into a single ocellated flounder category.

In North Carolina, the management of flounder species has undergone several regulatory iterations to promote the sustainability of the stock. The first implementation of a minimum size limit occurred in 1979 at 11 inches TL for both estuarine and ocean waters. In 2005, the first bag limit was implemented for estuarine waters at eight fish. Subsequent minimum size limits have been implemented through the original North Carolina Southern Flounder FMP (NCDMF 2005), Amendment 1 (NCDMF 2013), Supplement A to Amendment 1 (NCDMF 2017), and revisions to the joint Atlantic States Marine Fisheries Commission (ASMFC) and Mid-Atlantic Fishery Management Council Summer Flounder, Scup, and Black Sea Bass FMP (ASMFC 2017; MAFMC 2019). Despite changes in regulations through time, the overall trend for southern flounder harvest has declined. This decline was underscored by the coast-wide stock assessment. As such, the acceptance of Amendment 2 to the Southern Flounder FMP mandated a 72% reduction in pounds beginning in 2020 to promote the recovery of the stock within 10 years. This reduction could best be accomplished through a 45-day southern flounder recreational season spanning Aug. 16 through Sept. 30 as discussed in the *Achieving Sustainable Harvest* issue paper.

IV. AUTHORITY

North Carolina General Statutes

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

North Carolina Marine Fisheries Commission Rules

15A NCAC 03H .0103 PROCLAMATIONS, GENERAL
15A NCAC 03I .0120 POSSESSION OR TRANSPORTATION LIMITS THROUGH STATE WATERS; SALE OF NATIVE SPECIES
15A NCAC 03M .0503 FLOUNDER
15A NCAC 03M .0512 COMPLIANCE WITH FISHERY MANAGEMENT PLANS

V. DISCUSSION

MRIP data from 2008 through 2017 were analyzed to determine seasons that would allow harvest of ocellated flounder and not jeopardize rebuilding of the southern flounder stock. Seasons for additional access to ocellated flounder have been identified, in addition to the Aug. 16 to Sept. 30 season for southern flounder. Seasons identified will be selected so as not to exceed the total allowable landings for the recreational fishery for southern flounder while minimizing the potential of additional discards to not exceed the total removals. See the *Achieving Sustainable Harvest* issue paper for further explanation.

Importantly, increases in minimum size limits for flounder species have caused an inversion of harvest between summer and southern flounder, such that the latter has accounted for most flounder harvest since 2001 (Figure 14 in the *Description of the Fishery* section). The ASMFC has implemented state and/or regional level conservation equivalencies for the management of summer flounder since 2001 (ASMFC 2017). The 2017 summer flounder landings were 33.2% lower than the 10-year average and 57.7% lower than the 20-year average. The ASMFC must be notified of any changes to the summer flounder fishery in North Carolina state waters; however, approval of changes by the ASMFC is not required if the changes are expected to be more restrictive than the management measures already approved by the ASMFC. Changes to the summer flounder fishery in EEZ waters off North Carolina may be impacted by the Mid-Atlantic Fishery Management Council and National Marine Fisheries Service (NMFS). Until conservation equivalencies are approved by NMFS, coast-wide measures for summer flounder in the EEZ include a four-fish possession limit, a 19-inch TL minimum size limit, and an open season of May 15–Sept. 15 (MAFMC 2019). These measures serve as a default each year until annual conservation equivalencies are approved by the NMFS, which allow state regulations to be applied to EEZ waters. The impacts to the proposed ocellated flounder fishery in the early season are that these conservation equivalencies are not usually approved until May or June, which is after this proposed season. The timing of NMFS approving conservation equivalency management measures in EEZ waters would potentially limit the ocellated flounder season to state territorial waters only. These federal regulations impact the North Carolina fishery differently as state management of flounder is collective and not by individual species.

Discussed below is the option that meets the required reductions for southern flounder and increases access to the summer and Gulf flounder fisheries. Some seasons are more conservative than others, which may be more prudent to select until factors such as correct species identification and increased discards can be evaluated as they relate to the recovery of southern flounder. Any southern flounder harvest during the additional season will need to be accounted for in the recreational fishery quota so the required reductions are not compromised. In addition, flounder harvest will only be allowed in the ocean when the southern flounder season is closed and only with hook-and-line; no gigging will be allowed as anglers cannot correctly identify species prior to harvest. All explored seasons presented assume that all anglers correctly identify all southern flounder and release them.

As stated above, flounder fishing will be limited to the ocean during the ocellated season and is allowed by the transportation limits rule, 15A NCAC 03I .0120. This rule allows summer and Gulf flounder to be transported during the open ocellated season through closed waters, provided anglers do not stop and fish in estuarine waters with flounder on board.

The division recommendation in the achieving sustainable harvest issue paper is that southern flounder harvest be constrained to the season selected in Amendment 2; this is a 45-day season spanning Aug. 16 through Sept. 30 with a one-fish bag limit. The most conservative alternative option (besides status quo) is allowing stakeholders access to ocellated stocks from March 1 through April 15 from ocean waters only with a one-fish bag limit and also a one-fish bag limit during the southern flounder season. This satisfies the target southern flounder reduction while allowing an estimated harvest of an additional 1,025 pounds of ocellated flounder (Table 4.2.1). Though the additional estimated harvest of ocellated flounder during this time is low, this does not account for potential changes in angler behavior wherein additional ocellated landings may occur within this short season. The March 1 through April 15 season also minimizes potential southern flounder harvest compared to other potential seasons. This additional season has the potential to increase the harvest of southern flounder by an estimated 1,267 pounds or approximately 1.0% of the annual harvest allocation.

Table 4.2.1. Estimated ocean ocellated flounder landings and anticipated southern flounder landings under various options for the hook-and-line fishery.

Ocean Only				Ocean and Estuarine				
Ocellated Flounder Season	**Bag Limit Ocellated Season**	**Estimated Ocellated Flounder Landings**	**Southern Flounder Landings Early Season**	**Southern Flounder Season**	**Bag Limit Southern Flounder Season**	**Southern Flounder Landings Late Season**	**Total Southern Flounder Landing**	**Total Allowable Southern Flounder Landings**
None	0	0	0	Aug 16 – Sep 30	1	118,128	118,128	142,206
Mar 1– Apr 15	1	1,025	1,267	Aug 16 – Sep 30	1	118,128	119,395	142,206
Apr 1– June 30	1	23,116	50,159	Aug 16 – Sep 30	1	118,128	168,287	142,206
Apr 1– Sep 30	1	56,009	143,330	Aug 16 – Sep 30	1	74,860	218,190	142,206

Note: Recreational gig fishery would not be allowed to operate during the ocellated season.
Note: None of the southern flounder seasons would allow harvest of more than one southern flounder in the aggregate.

Importantly, as the southern flounder stock recovers there will be increased access to the resource. Analysis of MRIP data during the development of Amendment 2 reveals that recreational anglers rarely achieved the four-fish bag limit and catch rates are typically one fish. From approximately 17,000 in-person angler intercepts conducted in 2017 only one angler achieved the four-fish bag limit and only 2% of trips harvested more than one fish. To buffer against increased harvest compromising targeted reductions it will be beneficial to constrain the bag limit to one fish in any flounder season. For additional discussion on bag limits and angler success see the *Achieving Sustainable Harvest* issue paper.

Additional analysis of ocellated flounder seasons provide examples of the potential for excessive southern flounder harvest during additional seasons relative to a year-round ocellated season. These included a three-month ocellated season from April 1 through June 30 and a six-month ocellated season from April 1 through Sept 30, with a one-fish bag limit with harvest allowed in ocean waters. These truncated seasons provide a means to further reduce incidental harvest of non-ocellated (southern) flounder while allowing an estimated 23,116 and 56,009 pounds of ocellated harvest respectively (Table 4.2.1). Conversely, the potential southern flounder harvest during these truncated seasons will negatively impact management actions necessary to constrain harvest below the TAL. These longer (three- and six-month) ocellated seasons are expected to have impacts on the southern flounder fishery by 50,159–68,470 additional pounds of southern flounder harvest if anglers misidentify southern flounder (Table 4.2.1; Figure 4.2.2). These estimates are the least conservative but provide contrast to show the potential problems when attempting to allow additional ocellated harvest. The potential magnitude of southern flounder harvest precludes these additional seasons from being developed as options.

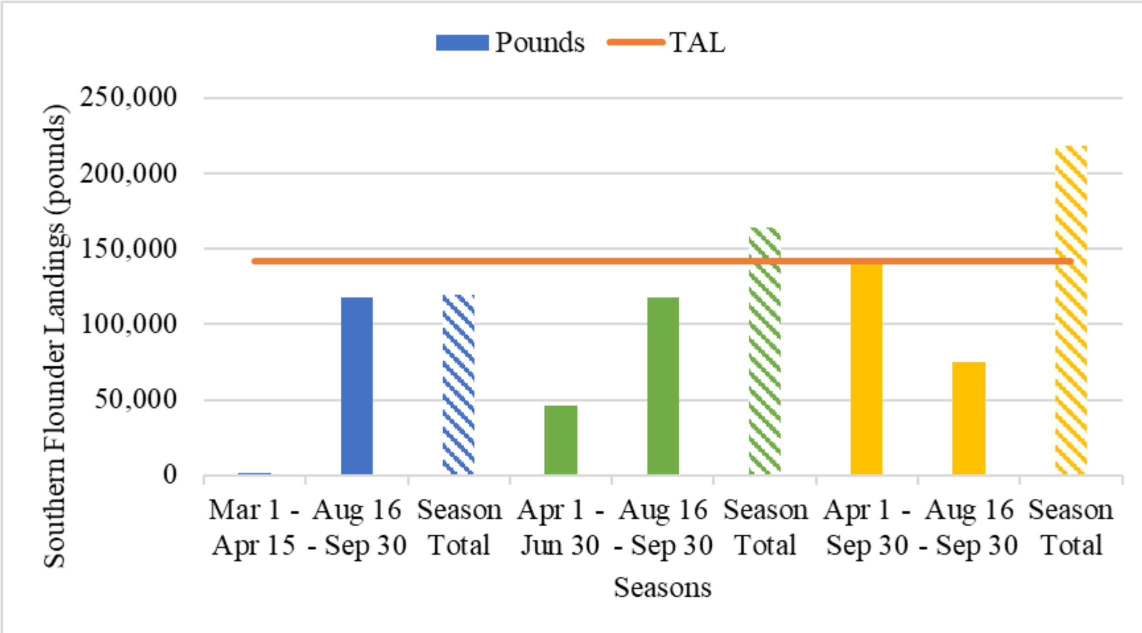

Figure 4.2.2. Southern flounder landings (in pounds) for seasons in reference to total allowable landings (TAL). All scenarios are based on a one-fish bag limit.

The most important caveat of single-species management is the evaluation of the recreational angler's ability to distinguish among North Carolina's constituent flounder species. The CAP is currently developing a mobile phone application to empirically investigate the recreational angler's ability to correctly identify flounder. The results of this investigation will be necessary before any implementation of single-species management. Analysis of potential ocellated flounder seasons assumed that accurate species identification does not occur to show the worst-case scenario projected. If anglers adapt and learn identification of flounder species, impacts presented will be lower and subsequently the southern flounder season during the fall may not be as impacted.

Allowing increased access to the recreational fishery through species-specific management by allowing the division to implement seasons through the adaptive management framework would be the most risk averse approach while still allowing harvest of other flounder species. It allows access to summer and Gulf flounder during a trial six-week season during March 1 through April 15 for the hook-and-line fishery in ocean waters only. Using gigs to harvest flounder may not be allowed during the ocellated flounder season as identifying flounder to the species level prior to harvest is necessary.

Anticipated harvest of southern flounder during the ocellated season will be accounted for through MRIP sampling. Though southern flounder are not allowed to be harvested during this time, if angler identification is not accurate, landings of southern flounder have the potential to be higher than currently estimated. If the preliminary estimates of southern flounder harvest are higher in the early season than anticipated, the fall fishery will be shortened. The total volume of southern flounder harvest from both seasons will comprise the estimates of harvest to compare to the annual quota. Any overages will be deducted from the subsequent year's quota and the seasons will be adjusted as necessary. This change in seasons to account for southern flounder harvest is necessary to maintain required reductions in the recreational southern flounder fishery.

Allowing harvest of summer and Gulf flounder when the southern flounder season is closed increases the possibility that southern flounder will be harvested to a greater extent than allowed under the sustainable harvest requirements. The potential for increased harvest may negate reductions achieved through the southern flounder season and limit rebuilding of the stock. Development of adaptive management measures to manage increased access to summer and Gulf flounder can be found in the *Adaptive Management* issue paper.

VI. PROPOSED MANAGEMENT OPTIONS

(+ potential positive impact of action)
(- potential negative impact of action)

Option 1: **Status quo, do not allow species-specific management to increase access to the recreational fishery**

+ Maintains stringent management measure to ensure best chance of rebuilding
- Does not allow for access to more abundant summer and Gulf flounder stocks

Option 2: **One-fish ocellated bag limit from March 1 through April 15 in ocean waters only and one-fish bag limit consisting of any species of flounder during the southern flounder season**

+ Allows for harvest of summer and Gulf flounder outside of identified southern flounder season
+ Complements recommended sustainable harvest bag limit
+ Minimizes potential impacts of misidentification by limiting seasons
+ Harvest of all southern flounder accounted for to meet required reductions
+/- Ocean harvest only during early season
- Increased chance of southern flounder harvest due to species misidentification concerns
- Unequal access among recreational fishing gears during the early season
- Potential impacts to fall season due to excess southern flounder harvest in the early season

VII. RECOMMENDATION

See Appendix 6 for a summary of all comments and recommendations gathered from NCDMF, the NCMFC advisory committees, and public for the Southern Flounder FMP Amendment 3.

<u>NCMFC Preferred Management Strategy</u>

Option 2: One-fish ocellated bag limit during March 1 through April 15 in ocean waters only using hook-and-ling gear and one-fish bag limit consisting of any species of flounder during the southern flounder season.

VIII. LITERATURE CITED

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APPENDIX 4.3. INLET CORRIDORS AS A MANAGEMENT TOOL TO INCREASE SOUTHERN FLOUNDER ESCAPEMENT

I. ISSUE

Consider the development of inlet corridors to provide additional protection to mature female southern flounder during their escapement or migration out of coastal inlets to oceanic spawning areas.

II. ORIGINATION

The feasibility of establishing inlet corridors as a management tool is being explored based on comments by the Southern Flounder Advisory Committee at their October 2019 meeting and comments provided during the public scoping period.

III. BACKGROUND

Southern flounder is an estuarine-dependent species, spending most of their early life history as juveniles and sub-adults in the estuary before exiting the estuary at maturity and migrating to the ocean to spawn offshore (see the *Description of the Stock* section). It is during these fall estuarine migrations southern flounder are most vulnerable to capture. Inlets, such as those common to North Carolina's estuaries, create a natural bottleneck that southern flounder must navigate to escape the final area of internal fishing pressure before entering the ocean to migrate offshore. The implementation of inlet corridors has been suggested as a possible management tool that, in theory, could alleviate fishing mortality on migrating southern flounder during this presumed period of increased vulnerability. This issue paper will explore available data and possible strategies regarding the use of inlet corridors for southern flounder management. The questions to be explored are as follows:

1) Do data exist that provide insight into which coastal inlets (i.e., corridors) are critical to southern flounder spawning migrations? Is there an inlet-specific seasonality to the migrations through these inlets to the ocean?
2) Do data indicate inlets are truly acting as a bottleneck where elevated fishing mortality is occurring due to increased vulnerability to capture?
3) What are the potential gear interactions that may occur in coastal inlets and what potential restrictions should be considered for these gears? What will be the impact to other fisheries (species) that are pursued by these same gears?
4) Can any savings from inlet corridors be quantified or do the data indicate this will be a non-quantifiable precautionary measure?

IV. AUTHORITY

North Carolina General Statutes

G.S. 113-134 RULES

G.S. 113-182 REGULATION OF FISHING AND FISHERIES

G.S. 113-182.1 FISHERY MANAGEMENT PLANS

G.S. 143B-289.52 MARINE FISHERIES COMMISSION – POWERS AND DUTIES

North Carolina Marine Fisheries Commission Rules
15A NCAC 03H .0103 PROCLAMATIONS, GENERAL
15A NCAC 03M .0503 FLOUNDER

V. DISCUSSION

1) Do data exist that provide insight into which coastal inlets (i.e., corridors) are critical to southern flounder spawning migrations? Is there an inlet-specific seasonality to the migrations through these inlets to the ocean?

Removals due to harvest and discards of southern flounder, regardless of sector, are comprised primarily of juvenile southern flounder residing in the estuary (Flowers et al. 2019a). Southern flounder tend to remain within the estuaries until the onset of maturity. As fish of both sexes begin to mature (approximately age-2), they undergo a fall migration. Eventually, mature southern flounder will traverse through one of several coastal inlets into oceanic waters where spawning occurs.

Current understanding of southern flounder movements and maturity is based on multiple studies that include tagging, otolith microchemistry, and maturity data along with commercial and recreational catch information. Movement of juveniles within the estuary has been shown to be limited and often somewhat localized (Scharf et al. 2015). Data indicate southern flounder overwinter as juveniles in the estuary (Monaghan 1996; Taylor et al. 2008; Craig et al. 2015). Southern flounder tend to reside in the estuary until age 2 or the onset of maturity (Rulifson et al. 2009), at which point migration offshore occurs from September through November of primarily age-2 and older fish (Monaghan and Watterson 2001; Loeffler 2018). Movement begins in a southerly direction within the Albemarle and Pamlico sound estuarine systems, with fish eventually exiting the estuaries through coastal inlets (Craig et al. 2015). After fish migrate into the ocean, fish tend to continue moving in a southerly direction. Fish leaving North Carolina estuaries in the fall have been recaptured in all states south of North Carolina [i.e., South Carolina, Georgia, and Florida; Monaghan 1992; NCDMF, unpublished data]. Craig et al. (2015) found all southern flounder recaptures that made large scale movements in the fall (>50 km) were recaptured in systems south of the original tagging location.

The timing of emigration through inlet corridors has been explored using acoustic telemetry methods (Scharf et al. 2015; Scheffel et al. 2020). These studies used acoustic tags to investigate seasonal movement patterns and determine the rate and seasonality of movements from the estuary to the ocean (emigration) in New River, North Carolina. In this system, southern flounder emigration peaked between October and November (Figure 4.3.1) and emigration patterns were similar across years (Scheffel et al. 2020). This period also corresponds to the seasonal peak in statewide landings seen in the commercial fishery each year with increased movement and landings occurring in the upper estuary during September and transitioning to the lower estuary into October and November. Existing data from conventional tagging and commercial landings indicate this general window of time (October through November) is likely the primary period of emigration for southern flounder, not just in New River, but throughout coastal North Carolina.

Current data do not allow any determination of which inlet(s) are most critical or most commonly used for southern flounder emigration. Tagging data do indicate, however, that Oregon Inlet is less frequently used than the numerous inlets to the south (NCDMF, unpublished data). As a result, inlets from Cape Hatteras southward are likely to be most critical for emigration by southern flounder, which is supported by available tagging data and the aforementioned studies. The timing of emigration is likely more defined and quantified than the specific inlets being used.

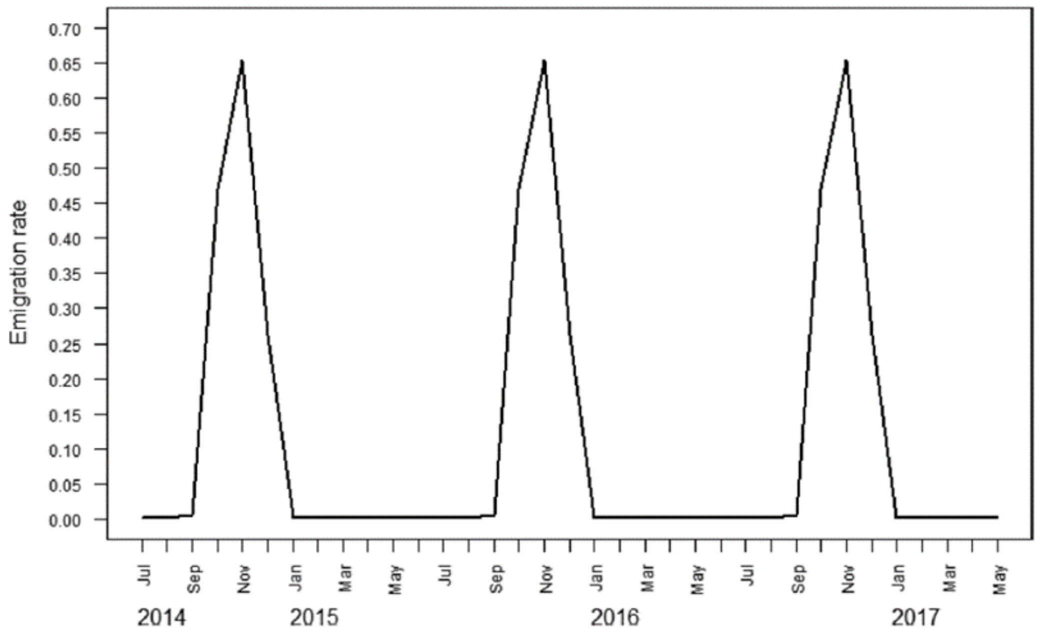

Figure 4.3.1. Estimates of instantaneous Emigration (E) for the New River estuary produced by a telemetry model. Annual E assumed to be equal across years. (Source: Scheffel et al. 2020)

2) Do data indicate inlets are truly acting as a bottleneck where elevated fishing mortality is occurring due to increased vulnerability to capture?

It is unknown if, and to what extent, southern flounder exploitation may be increased based on their emigration in the fall through coastal inlets. Harvest data specific to these locations would provide a good indicator to gauge whether coastal inlets serve as a bottleneck allowing for elevated exploitation. Unfortunately, landings data for neither commercial nor recreational sectors can be pared down to include only harvest or releases from inlets. Activities in and around coastal inlets include a variety of means used to capture southern flounder. Recreational fishing for flounder species is very popular in coastal inlets. It occurs over many months, particularly from summer through early fall; however, flounder harvested include not just southern flounder, but also summer and Gulf flounder. Gigging, by both the recreational and commercial sectors, occurs in and around coastal inlets with fish targeted from summer through fall. While these more active and mobile gears effectively capture flounder in coastal inlets, the high energy habitat in many coastal inlets can be a limiting factor to the use of passive gears such as gill nets and pound nets. That is not to say these gears are not used near coastal inlets, but the available areas suitable for fishing these gears in these high energy areas is limited.

Tagging data specific to coastal inlets may offer another indicator to gauge whether coastal inlets are areas of increased exploitation for southern flounder. During a telemetry study conducted by Scharf et al. (2015) in New River, the inlet corridors were monitored for any acoustically tagged southern flounder emigrating from the estuarine system. In the study, it was noted that southern flounder exhibited two distinct behaviors. One behavior was described as resident behavior where southern flounder were more sedentary with only limited movement within the estuary. This behavior occurred over a protracted time period. The second was a more sudden behavior where there was a brief but more extensive movement representing the onset of the spawning migration in the fall. This shift in behavior resulted in southern flounder leaving the system within a matter of days (Figure 4.3.2). This increased movement meant less time was spent by fish in the inlet corridor. Peak movement occurred between Oct. 19 and Nov. 16, when 85% of the emigrations occurred. Tagged fish harvested in this study occurred primarily within the estuary and movement through the inlet occurred over just a short time period.

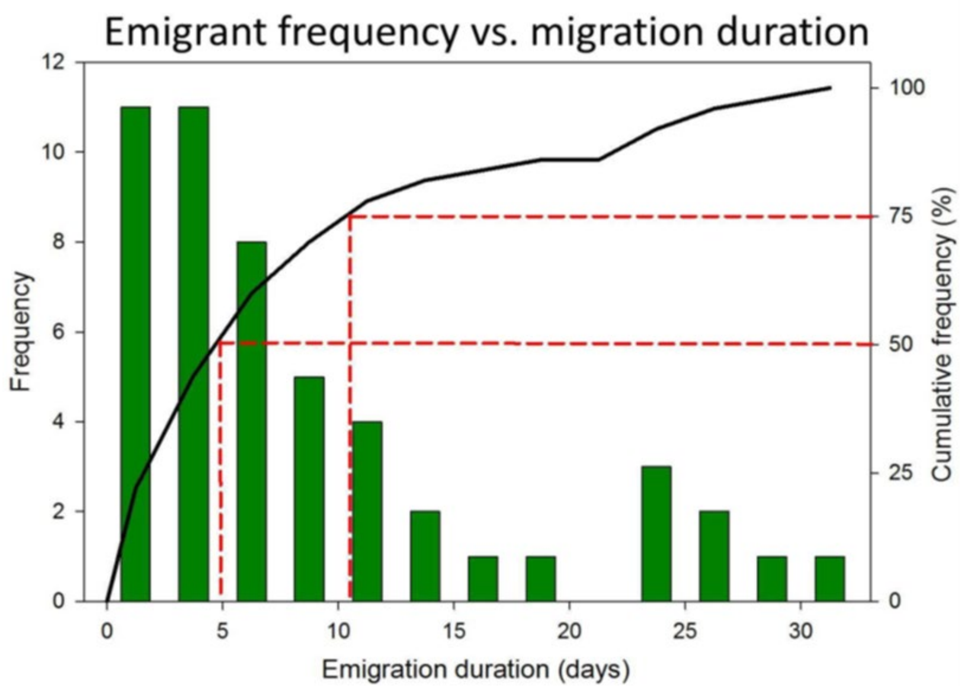

Figure 4.3.2. The number of days from the initiation of migratory behavior until southern flounder emigrated out of the New River estuary. The cumulative frequency distribution (solid black line) indicated that 50% of emigrants left the system within five days after initiation of migration behavior (bottom dashed red line), while 75% of emigrants exited within about 10 days of first showing emigration behavior (top dashed red line). (Source: Scharf et al. 2015)

A broader look at statewide tagging data provides more insight into whether coastal inlets act as a bottleneck leading to increased harvest of southern flounder. Data were examined for external tags applied to southern flounder by the NCDMF from 2014 through 2019 (NCDMF, unpublished data). These flounder were tagged over a wide range of areas and across all months (Figure 4.3.3). Movements of southern flounder documented in this study are consistent with those described by Scharf et al. (2015). During this period, 299 recaptures have occurred for southern flounder where time at large has been at least 10 days (Figure 4.3.4). Of these recaptures, 270 (90%) were recaptured within the estuary, 25 (8%) were captured in the inlet corridor, and four (<2%) were captured from the ocean. Inlet recaptures occurred from multiple gears and across sectors, with most taken by hook-and-line (n=10) followed by both recreational giggers (n=6) and commercial giggers (n=6). Inlet corridors were defined by placing two-mile perimeters around larger inlets (Oregon Inlet, Hatteras Inlet, Ocracoke Inlet and Barden Inlet) and one-mile or half mile perimeters around smaller southern inlets (Figure 4.3.4).

Available tagging data indicate coastal inlets do not appear to be acting as a bottleneck serving as an area of increased exploitation of southern flounder. The primary source of fishing mortality on this species is occurring within the estuarine system.

Figure 4.3.3. Tagging locations and number of southern flounder tagged (in circles by waterbody) in North Carolina estuarine waters from 2014 through 2019.

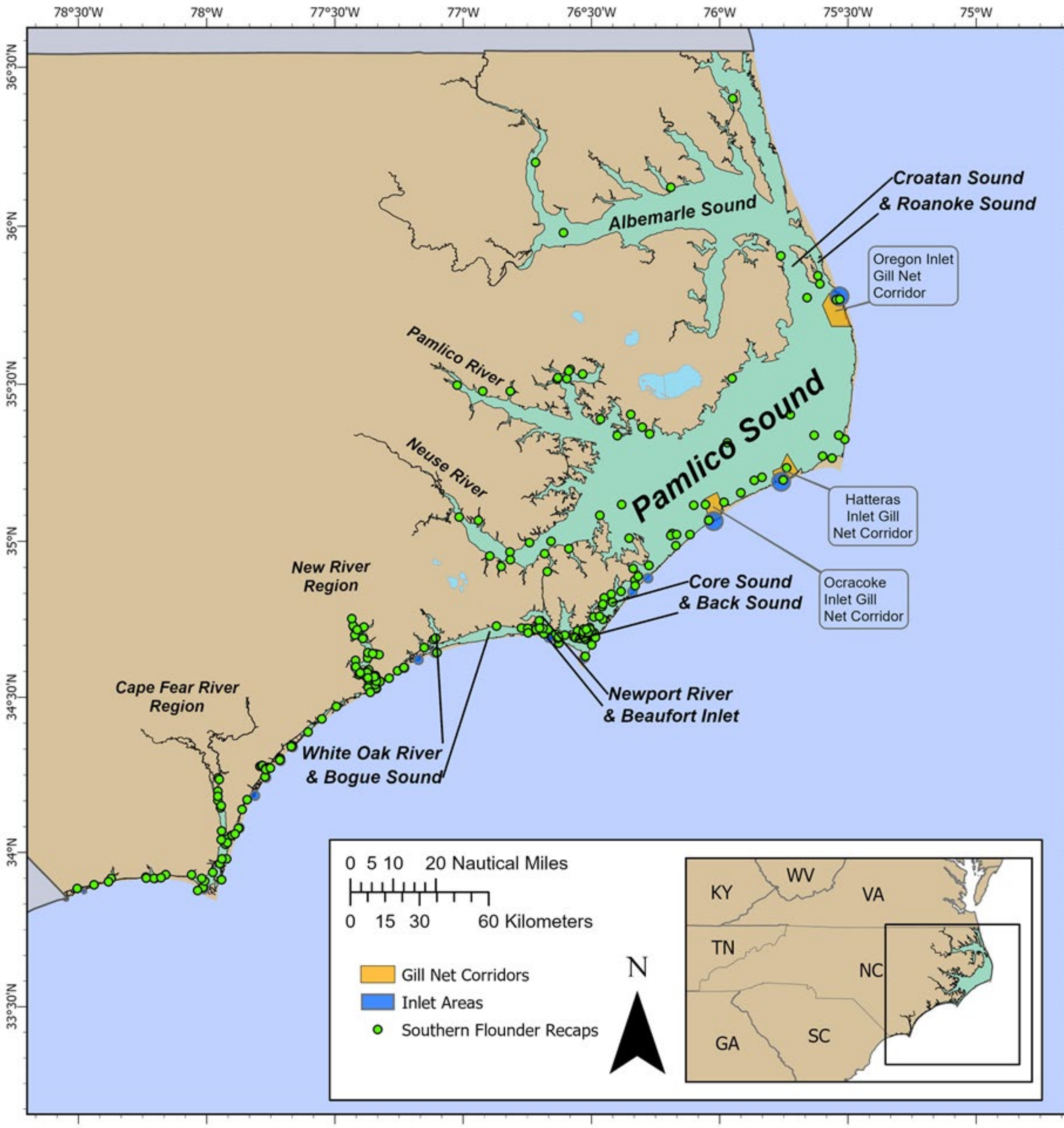

Figure 4.3.4. Recapture locations of southern flounder tagged in North Carolina estuarine waters from 2014 to 2019.

3) What are the potential gear interactions that may occur in coastal inlets and what potential restrictions should be considered for these gears? What will be the impact to other fisheries (species) that are pursued by these same gears?

The southern flounder stock is subject to fishing mortality from the recreational and commercial sectors for much of the year and across a wide range of habitats from the upper estuaries to the inlets and oceans. Recreational harvest typically peaks in the summer months, while commercial harvest peaks in the fall. A likely reason for this contrast is that recreational anglers are mobile and typically fish their gear in an active fashion that is not dependent on fish movement to capture fish. The commercial sector, however, relies primarily on passive gear (gill nets and pound nets). These passive gears by nature require southern flounder (or any fish species) to move in order to be captured. For this reason, the fall commercial fishery is directly linked to, and largely dependent on, the fall migration of southern flounder. It is during this fall migration period of September through November that harvest peaks for these gears (NCDMF Trip Ticket Program). Scharf et al. (2015) observed some evidence for southern flounder movements and the rate of emigration coinciding with the passage of cold fronts in the fall. This is consistent with observed increases in catches reported by pound netters in other parts of the state after these types of fall weather events.

Recreational hook-and-line trips occurring in coastal inlets capture a diverse set of species. Anglers fishing with gear typically used to capture southern flounder will commonly encounter other species, and southern flounder will also be encountered when targeting other species. Summer flounder, Gulf flounder, red drum, spotted seatrout, bluefish, and many other species are captured using similar tactics in coastal inlets. Closing inlet corridors to recreational fishing would be far reaching in its impact to these fisheries.

Gigging around coastal inlets is a commercial and recreational endeavor. Unlike hook-and-line fishing, gigging can be more selective as many fish species are typically identified before they are gigged while some are not. For example, southern flounder, there is the added issue of their similarity in appearance to summer and Gulf flounder, which occur in these same areas. For this reason, it is not likely that gigging for flounder species would be feasible in inlet corridors if the intention of the regulation was to protect southern flounder.

Stationary gears such as flounder pound nets and gill nets have traditionally been fished in areas adjacent to but not within inlets. All current flounder pound net sets are located from Core Sound and north to the Albemarle and Currituck sounds. As previously mentioned, flounder pound nets are somewhat limited in the immediate vicinity of coastal inlets. Flounder pound nets do, however, occur with regularity in areas adjacent to inlets as shallower habitat and lower energy conditions allow. These locations are productive fishing areas for southern flounder during the fall migration. Similarly, gill nets have traditionally been fished around coastal inlets, although much of the habitat in the high energy portion of the inlet is not conducive to setting anchored gill nets. It should be noted corridors already exist that limit large-mesh gill nets, crab pots, and trawling in the vicinity of inlets. The large-mesh gill-net closures exist in some inlet corridors because of restrictions maintained through the ITP under Section 10(a)(1)(B) of the ESA of 1973 (Public Law 93-205) to “minimize, monitor, and mitigate” sea turtle interactions in the commercial anchored gill-net fisheries. Inlet corridors to protect sea turtle ingress and egress through coastal inlets exist for Oregon Inlet, Hatteras Inlet, and Ocracoke Inlet (Figure 4.3.4). These inlet closures are in effect from Sept. 1 through Dec. 31, which is inclusive of the period of the spawning migration for southern flounder. Additionally, the area around Barden Inlet has also been closed to large mesh anchored gill nets during the last two years (2018 and 2019). This closure was due to excessive interactions with green sea turtles (*Chelonia mydas*) in 2017, but it is not explicitly required by the ITP.

4) How will any savings from inlet corridors be quantified or do the data indicate this will be a non-quantifiable precautionary measure?

Implementing inlet corridors for southern flounder cannot be quantified in terms of reductions in catch or harvest. No data sources exist to estimate what proportion of the catch comes from these specific areas. Based on available results from tagging studies, it does not appear that inlets serve as areas of increased exploitation (NCDMF, unpublished data). Telemetry studies indicate southern flounder may limit their travel time in inlets, specifically during their fall migration period (Scharf et al. 2015). Recapture data from traditional tags support this finding and show that most of the catch and exploitation on this species is occurring within the estuary and not in the inlet or ocean (NCDMF, unpublished data). Based on these findings, it is unlikely that inlet corridors would limit exploitation rates without more quantifiable and effective management measures across the fisheries.

While inlet corridors do not offer a viable management alternative that provides a quantifiable measure to rebuild southern flounder stocks, inlet corridors do provide an important transition habitat for this species, linking the estuarine nursery habitat with the offshore spawning habitat. For further information on habitat use and the importance of habitat by life stage for this species see the *Description of the Stock* and the *Ecosystem and Fishery Impacts* sections. Additionally, a comprehensive review of habitats important to southern flounder is further described in the CHPP (NCDEQ 2016).

In summary, inlet corridors, while providing an essential function in the life history of southern flounder, present specific challenges when considered as a management tool to reduce harvest. Specific inlets critical to southern flounder migration are not fully understood and additional research is currently underway to investigate southern flounder migration patterns and spawning locations. With respect to impacts on other fisheries, inlet corridor closures by season, area, or gear would have negative impacts on commercial and recreational fisheries for other species captured in these locations. Any potential harvest reductions resulting from inlet corridors would be unquantifiable. Further, available data do not suggest inlets currently serve as a bottleneck resulting in increased harvest. In terms of the overfished status, the most prudent approach would be to remove the incentive to overharvest southern flounder through more quantifiable measures such as quota management or seasonal closures. Seasonal closures could effectively act in the same manner as inlet corridors if the closed seasons correspond to periods of emigration related to spawning. Likewise, quota management would set harvest levels to end overfishing and rebuild depleted stocks. Finally, evaluation of inlet corridors may be best approached during the next revision of the CHPP. A thorough evaluation of inlet corridors for the protection of migrating or spawning species may be more applicable on a broad scale and not at the individual species level.

VI. PROPOSED MANAGEMENT OPTIONS

(+ potential positive impact of action)
(- potential negative impact of action)

Option 1: Status quo, do not establish inlet corridors for southern flounder during spawning migrations.

+ No negative impact on current fishing practices (commercial and recreational)
+ Inlet corridors do not appear to result in increased fishing pressure for southern flounder
- Corridors would afford additional, albeit unquantifiable protection for stock
- Corridors would indirectly provide additional protection for other species

Option 2: Implement inlet corridors during the southern flounder spawning migration for North Carolina coastal inlets.

+ Additional protection for southern flounder
+ Additional indirect impact and protection of other species
- Unquantifiable, would not contribute toward needed harvest reductions
- Loss of harvest opportunities for other species in these areas due to removal of gears that interact with southern flounder
- May simply shift fishing pressure to areas adjacent to inlet corridors Contribution in magnitude of southern flounder and exact timing of migration by inlet is unknown

2A. Implement inlet corridors affecting all gears in the selected areas
2B. Implement inlet corridors affecting only specific gears in the selected areas

VII. RECOMMENDATION

See Appendix 6 for a summary of all comments and recommendations gathered from NCDMF, the NCMFC advisory committees, and public for the Southern Flounder FMP Amendment 3.

NCMFC Preferred Management Strategy

Option 1: Status quo, do not establish inlet corridors for southern flounder during spawning migrations.

VIII. LITERATURE CITED

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APPENDIX 4.4. ADAPTIVE MANAGEMENT STRATEGY FOR THE NORTH CAROLINA SOUTHERN FLOUNDER FISHERY

I. ISSUE

Implement an adaptive management strategy for the North Carolina southern flounder fishery.

II. ORIGINATION

North Carolina Division of Marine Fisheries (NCDMF)

III. BACKGROUND

Adaptive management combines management and monitoring with the aim of updating knowledge and improving decision making over time. Adaptive management uses a learning process to improve management outcomes (Holling 1978). The challenge with using adaptive management is to find a balance between gaining knowledge to improve management and achieving the best outcome based on current knowledge (Allan and Stankey 2009). As more is learned about a fishery, adaptive management provides flexibility to incorporate new data and information to accommodate alternative and/or additional actions. In the context of North Carolina FMPs, adaptive management is an optional management framework that allows for specific management changes to be implemented between FMP reviews under specified conditions to accomplish the goal and objectives of the plan. A FMP that uses adaptive management as a tool needs to identify specifically:

- The circumstances under which adaptive management changes may be made (when);
- The types of measures that may be changed (what);
- The schedule for implementation of changes (effective date); and
- The procedural steps necessary to effect a change (how).

The more clearly defined "when," "what" and "how" for adaptive management, the fewer unintended consequences there will be and the more certainty there is for the regulated public and managers.

Amendment 3 to the Southern Flounder FMP establishes management strategies including an adaptive management strategy for the North Carolina southern flounder fishery based on the peer-reviewed and approved stock assessment for the South Atlantic southern flounder stock (Flowers et al. 2019). The stock assessment established biological reference points necessary for managing the southern flounder stock within sustainable harvest.

A reduction of 72% of total removals (in pounds of fish) is projected to end overfishing within two years to achieve sustainable harvest and rebuild the southern flounder spawning stock to the target within 10 years of the date of adoption of Amendment 2 with at least a 50% probability of success; this timeline does not restart with Amendment 3. This level of reduction is projected to bring spawning stock abundance to the target value of 12 million pounds of mature females.

Adoption of the adaptive management framework for Amendment 3 in conjunction with the other management strategies in the plan provides the best likelihood of success in achieving sustainable harvest in the southern flounder fishery while maximizing flexibility for fishermen in harvesting flounder. The Southern Flounder FMP Amendment 3 defines and documents the scope of management measures the Fisheries Director may implement within the bounds of Amendment 3. The record of specific actions is in the form of the issued flounder proclamations each year.

IV. AUTHORITY

North Carolina General Statutes
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.

North Carolina Marine Fisheries Commission Rules
15A NCAC 03H .0103 PROCLAMATIONS, GENERAL
15A NCAC 03M .0503 FLOUNDER
15A NCAC 03M .0512 COMPLIANCE WITH FISHERY MANAGEMENT PLANS

V. DISCUSSION

Adoption of management measures presented in the *Achieving Sustainable Harvest*, *Increased Recreational Access, Implementing a Slot Limit,* and *Phasing Out Large-Mesh Gill Net* issue papers will determine the adaptive management measures needed for Amendment 3. Adaptive management gives the Fisheries Director flexibility under specified conditions to manage the southern flounder fishery. Flexible management measures could include adjusting opening dates for gears and areas or sectors, implementing trip limits in the commercial sector for certain gears, or altering areas where the fishery can occur. This strategy allows changes to the framework of Amendment 3 and the specific management measures implemented each year may vary as the stock responds to selected measures. For example, if the recreational fishery sector exceeds its TAL for a given year, the Fisheries Director could cancel the early ocellated season or implement a complete closure for the recreational fishery. If a complete closure is not warranted, the Fisheries Director may choose to shorten the selected seasons or reduce the daily bag limit to reduce the chances of exceeding the TAL in subsequent years.

As long-term sustainable harvest strategies are implemented, participants in the commercial and recreational fisheries will likely adapt over time, potentially changing fishing behavior. As fisheries adapt to the new harvest levels, it will be crucial to provide flexibility to the Fisheries Director to close the seasons based on specified conditions, like the potential to exceed the TAL. This is within proclamation authority to adjust certain management measures for success in achieving sustainable harvest. Thorough discussion of each of the management actions presented below can be found in the *Achieving Sustainable Harvest*, *Increased Recreational Access, Implementing a Slot Limit,* and *Phasing out Large-Mesh Gill Net* issue papers.

Amendment 3 proposes modifying the commercial seasons to maintain a quota with allocations based on gear and area; modifying the recreational season with quota allocations to the hook-and-line and gig fisheries; implementing and altering recreational bag limits; and implementing commercial trip limits and recreational vessel limits. Upon adoption of Amendment 3, management strategies approved in Amendment 3, including adaptive management, will be implemented through use of proclamation authority allowing the Fisheries Director to:

- Determine opening dates for commercial seasons based on measures selected through the *Achieving Sustainable Harvest* issue paper.
- Close the commercial fishery based on quota monitoring data to maintain harvest levels at or below the TAL, including closure when a majority of harvest has occurred (typically about 80% of the quota allocation, but it can be less or more).
- Develop and implement commercial trip limits to maximize the harvest and minimize the risk of exceeding the quota during the open season.
- Select recreational season dates for the hook-and-line and gig fisheries.
- Implement and alter bag limits for the recreational fishery.
- Implement and alter vessel limits for the recreational fishery.
- Change the recreational southern flounder season based on harvest of southern flounder that occurs during the ocellated season.
- Cancel the early recreational ocellated season if it is necessary to prevent exceeding the TAL for the recreational southern flounder fishery.
- Apply accountability measures for both the commercial and recreational fisheries.

To inform the decision to exercise and implement this authority, the Fisheries Director would use available information including information on gear and area combinations and quota available for harvest for each management area as described in the *Achieving Sustainable Harvest* issue paper. The Fisheries Director would use the results from quota monitoring to determine when closures of the commercial fishery would occur. If the Fisheries Director decides there is sufficient quota remaining, the Fisheries Director may approve additional harvest periods using trip limits to constrain the harvest.

Selection of recreational season dates would be informed by the volume of quota allocation available for a year after any quota overages the prior year have been taken into account. The selected seasons must conform to the required reductions outlined in the *Achieving Sustainable Harvest* issue paper. The recreational seasons selected may be impacted if a separate non-southern flounder season is adopted as part of Amendment 3. Additional information on the potential impacts described below can be found in the *Increased Recreational Access* issue paper.

Quota overages in a year will need to be deducted from commercial or recreational allocations for subsequent years. Any overage adjustments would be completed prior to the identification of season dates for the subsequent year.

Development of trips limits could be based on annual or interannual harvest levels and the amount of quota allocation remaining for a specific gear/area combination. Trip limits can also vary among gear/area combinations due to the number of participants in the fishery or available landings. Trip limits would need to be identified on an annual basis and would only be implemented if sufficient quota remains to be caught and if continued harvest, with trip limits in place, does not increase the risk of exceeding the quota allocation. Determination of whether or not sufficient quota remains for a re-opening is solely within the discretion of the Fisheries Director.

The bag limit for flounder is currently set at four fish by Amendment 2; however, a bag limit of two or more fish increases the likelihood that the recreational sector will exceed its TAL due to increased angler success as the fishery rebuilds. The ability to implement and subsequently alter bag limits would allow the Fisheries Director to constrain the recreational fishery if an initial bag limit greater than one fish through Amendment 3 allows for unsustainable removals.

Currently, there are no vessel limit requirements in the North Carolina southern flounder recreational fishery. Vessel limits may be useful in constraining the harvest of southern flounder in the recreational fishery as the fishery rebuilds. Vessel limits may be more important if the recreational fishery bag limit is set at two fish or greater in order to avoid exceeding the TAL. This is especially important as the stock rebuilds and angler success increases. If the bag limit is reduced to one fish per person per day, the usefulness of a vessel limit is likely reduced. Additional information on vessel limits can be found in the *Achieving Sustainable Harvest* issue paper.

Development of the *Increased Recreational Access* issue paper outlines a strategy for a seasonal approach for additional harvest of ocellated species of flounder outside of the southern flounder recreational season. If the Fisheries Director determines that the allowed ocellated season is preventing a sustainable recreational southern flounder fishery due to excessive landings, the Fisheries Director may cancel subsequent ocellated seasons to maintain required reductions necessary to rebuild the southern flounder stock. In addition, the ASMFC must be notified of any changes to the summer flounder fishery in North Carolina state waters; however, approval of changes by the ASMFC is not required if the changes are expected to be more restrictive than the management measures already approved by the ASMFC. Changes to the summer flounder fishery in EEZ waters off North Carolina may be impacted by the MAFMC and NOAA Fisheries. Due to the ASMFC, MAFMC, and NOAA Fisheries requirements, the Fisheries Director's ability to adaptively manage the ocellated seasons may be impacted.

Future increases in quota would likely not occur until the southern flounder spawning stock biomass is recovered and this cannot be determined until completion of an updated stock assessment. If a stock assessment determines that an increase in quota is possible due to stock rebuilding, the resulting increase can be allocated to the sectors. Revisions to allocations can occur, most commonly to account for changes among sectors or stock status. Changes among sectors include scenarios where one group consistently has excess allocation remaining, or where one group consistently exceeds its allocation. Under each scenario TAL can be re-allocated to another sector based on management preferences. This can be achieved through future amendments.

Adoption of the adaptive management framework for Amendment 3 in conjunction with the other management strategies in the plan provides the best likelihood of success in achieving sustainable harvest in the southern flounder fishery while maximizing flexibility for fishermen in harvesting flounder. Not adopting an adaptive management framework for Amendment 3 would result in the division not having the flexibility to alter management measures to maintain sustainable harvest in the southern flounder fishery.

Upon adoption of this adaptive management strategy, any additional changes in management strategies beyond those outlined must be undertaken through the amendment or supplement process. These adaptive management strategies and measures will be evaluated for success by completing an updated stock assessment prior to the next comprehensive review of the N.C. Southern Flounder FMP.

VI. PROPOSED MANAGEMENT OPTIONS

(+ potential positive impact of action)
(- potential negative impact of action)

Option 1: Adopt the adaptive management framework based on the peer-reviewed and approved stock assessment.

+ Management is based on biological reference points for stock rebuilding.
+ Provides for the protection and future sustainability of the southern flounder stock
+ Provides for the greatest amount of flexibility while maintaining total allowable landings

+/- Provides potential for additional access to other flounder stocks while maintaining total allowable landings of southern flounder

- Potential uncertainty in selected seasons
- Impacts may be greater for some gear or areas more than others

Option 2: Do not adopt the adaptive management framework.

- Difficult to maintain TAL
- Does not allow for flexibility in management strategies
- Lack of flexibility jeopardizes stock rebuilding to meet statutory requirements

VII. RECOMMENDATION

See Appendix 6 for a summary of all comments and recommendations gathered from NCDMF, the NCMFC advisory committees, and public for the Southern Flounder FMP Amendment 3.

<u>NCMFC Preferred Management Strategy</u>

Option 1: Adopt the adaptive management framework based on the peer-reviewed and approved stock assessment.

VIII. LITERATURE CITED

Allan, C., and G.H. Stankey. 2009. Adaptive environmental management: a practitioner’s guide. Dordrecht, Netherlands.

Flowers, A.M., S.D. Allen, A.L. Markwith, and L.M. Lee (editors). 2019. Stock assessment of southern flounder (*Paralichthys lethostigma*) in the South Atlantic, 1989–2017. Joint report of the North Carolina Division of Marine Fisheries, South Carolina Department of Natural Resources, Georgia Coastal Resources Division, Florida Fish and Wildlife Research Institute, University of North Carolina at Wilmington, and Louisiana State University. NCDMF SAP-SAR-2019-01. 213 p.

Holling, C.S., editor. 1978. Adaptive environmental assessment and management. John Wiley and Sons, London, England.

APPENDIX 4.5. RECREATIONAL AND COMMERCIAL SECTOR ALLOCATION IN THE NORTH CAROLINA SOUTHERN FLOUNDER FISHERY

I. ISSUE
Provide the NCMFC with analysis that shows various commercial and recreational allocation percentages.

II. ORIGINATION
At the November 2020 NCMFC business meeting, the NCMFC passed a motion to consider commercial and recreational allocations in the Southern Flounder FMP Amendment 3 of 70/30, 65/35, 60/30 with 10% allotment for gigging, 60/40, and 50/50.

III. BACKGROUND
The NOAA defines allocation as a direct and deliberate distribution of the opportunity to participate in a fishery among identifiable, discrete user groups or individuals (Blackhart 2005). In fisheries managed by the South Atlantic and Gulf of Mexico fishery management councils, the share a sector gets is typically based on historical harvest amounts. Revisions to allocations do occur, most commonly to account for changes among sectors or stock status. Changes among sectors includes scenarios where one group consistently has excess allocation remaining, which can be re-allocated to another sector based on management preferences. Changes to stock status also impact reallocation; if the stock rebuilds and harvest levels can be increased, quota would be increased to allow for more harvest. Authority to make changes to allocations lies with the commission or body charged with making management decisions. For the purpose of this paper the term “sector” will be used to differentiate between the commercial and recreational components of the southern flounder fisheries.

At its November 2020 business meeting, the NCMFC asked the division to review several allocation scenarios for Amendment 3 to the N.C. Southern Flounder FMP. The sector allocation selected by the NCMFC will provide the basis for implementing quota management in the southern flounder fishery. Selection of allocations is informed by data provided by the division, in this case historical landings. The commission can also rely on economic, social, and behavioral aspects of each sector that may influence allocation decisions.

The historically based allocation of 73% commercial 27% recreational (Table 4.5.1) in Amendment 2 is based on historical harvest for each sector from 2017. As with the 73/27 historically based allocation, the commercial and recreational sectors include gear sub-allocations based on historical harvest. In the initial draft of Amendment 3 discussed with the FMP advisory committee, the recommendation for the commercial sector is for separate mobile gear (all gears except pound nets) and pound net categories (approximately 50/50 sub-allocations) and for the recreational sector to have separate hook-and-line and gig gears (89/11 sub-allocation). Different allocation scenarios will significantly change available harvest in a sector, so the commission will need to consider ramifications to the gear sub-allocations and whether those fisheries remain realistically viable to prosecute. The available landings for a specific fishery may be too low to invest further in the expense of the gear, if sub-allocations are not changed.

Much like regional councils, the NCMFC and N.C. Wildlife Resources Commission have historically allocated quotas to fishing sectors based on historical harvest. In some fisheries, like the Albemarle Sound and Roanoke River Management Areas striped bass fishery, the quota was ultimately revised so a 50/50 parity was achieved between the commercial and recreational sectors. In 1991, the initial striped bass quota was allocated 62.5/37.5 based on historical landings. After seven years of rebuilding at this initial allocation, the stock's SSB was declared recovered, allowing for an increase in quota. In 1998, the quota was increased by 94,340 pounds, of which 29% was allocated to the commercial sector and the remaining 71% was allocated to the recreational sector. This increase brought the quota allocation to a 50/50 parity.

Table 4.5.1. Allocation options for the North Carolina southern flounder fishery that maintain overall landings reduction of 72%.

	Total Allowable Landings (TAL) in Pounds				Change in TAL
	Commercial		Recreational		
NCMFC Options (% Allocation)	**TAL**	**% Reduction**	**TAL**	**% Reduction**	**Pounds**
Historical Harvest	390,493	72	141,859	72	0
70/30	372,646	73	159,706	68	+/- 17,847
65/35	346,029	75	186,323	63	+/- 44,464
*.60/30/10	358,459	74	173,893	66	+/- 32,034
60/40	319,411	77	212,941	58	+/- 71,082
50/50	266,176	81	266,176	47	+/- 124,317

**This denotes a 10% allocation for gigs that was further divided out to each sector based on historical allocation (73/27).*

IV. AUTHORITY

North Carolina General Statutes

G.S. 113-134 RULES

G.S. 113-182 REGULATIONS OF FISHING AND FISHERIES

G.S. 113-182.1 FISHERY MANAGEMENT PLANS

G.S. 143B-289.52 MARINE FISHERIES COMMISSION – POWERS AND DUTIES

V. DISCUSSION

Initial analyses of southern flounder quota allocations followed the convention of using historical landings from a previous year or years. To provide information for the NCMFC motion, commercial and recreational data were analyzed based on 2017 harvest data, the terminal year of the stock assessment. Table 4.5.1 shows the allocation options as requested by the NCMFC.

Shifting allocation between sectors is within the authority of the NCMFC (G.S. 113-134, 113-182, 113-182.1, and 143B-289.52). Changes to sector allocation may have negative and positive impacts to different sub-sectors in the southern flounder fishery. Allocation shifts to the recreational sector would provide additional harvest, possibly allowing for longer seasonal access if the daily bag limit is lowered. If the bag limit is not lowered, gains from increased allocation may help to provide a buffer against potential overages from increased angler success (see the *Achieving Sustainable Harvest* issue paper).

The commercial sector TAL would be lowered by the same amount of the recreational gains. As noted earlier, it is also prudent to consider the gear sub-allocations within the sectors (Table 4.5.2) as allocation shifts may have consequences that impact one gear category more than another. Reductions in the commercial allocation may have negative impacts on the commercial fishery as a lower allocation will result in a reduced harvest period.

The *Description of the Fisheries* section contains additional information that provides background details on landings, effort, and economic data for the commercial and recreational fisheries. Tables 4 and 5 in the *Description of the Fisheries* section provides commercial southern flounder landings by year and gear and the number of trips, average pounds per trip, and the number of participants by year and gear.

Table 4.5.2. Sub-allocations for the commercial and recreational sectors for the NCMFC options based on the 2017 harvest.

	Commercial		**Recreational**	
NCMFC Option	**Mobile Gear**	**Pound Net**	**Hook-and-Line**	**Gig**
Historical Allocation	195,105	195,388	126,315	15,544
70/30	186,188	186,458	142,206	17,500
65/35	172,889	173,140	165,907	20,416
*60/30/10	180,228	178,231	159,706	14,187
60/40	159,590	159,821	189,608	23,333
50/50	132,992	133,184	237,010	29,166

*This denotes a 10% allocation for gigs that was further divided out to each sector based on historical allocation (73/27).

Table 4.5.3 shows the annual variation in harvest for the recreational hook-and-line fishery and what the following years' TAL consequences might have been. In Table 4.5.3, landings during the identified season are displayed on a yearly basis to provide examples of overages that could occur while trying to meet the TAL necessary for rebuilding based on historical allocations. If more fish are available because of a good year class both sectors would likely see increases in harvest. For the recreational sector, where daily reporting is not available, the larger the bag limit the greater the risk of exceeding the landings.

Tables 4.5.4 and 4.5.5 demonstrate the effects to the recreational sector between the historical allocation (73/27) and a 60/40 allocation. For each table, annual landings data (2008 through 2017) were prorated to an Aug. 16–Sept. 30 season under different bag limits (one fish, two fish, three fish, four fish). Estimated landed pounds were then compared to a 73/27 allocation (Table 4.5.4) and a 60/40 allocation (Table 4.5.5) to determine whether or not the TAL would be exceeded for each bag limit option based on the percent of the allocated harvested. Finally, the percent of the allocated harvested for each year was used to calculate the subsequent year allocation for each bag limit option. Any overages that occur in one year will be deducted in subsequent years, possibly resulting in no recreational fishery for a year or more. It should be noted that for the recreational sector, where daily reporting is not realistic, the larger bag limits increase the risk of exceeding the TAL. When compared to each other, Tables 4.5.4 and 4.5.5 also show that with more allocation provided to the recreational fishery and a lower bag limit, the lower the chance of the recreational fishery of exceeding their TAL.

Table 4.5.3. Recreational hook-and-line landings of southern flounder Aug. 16–Sept. 30 at the four-fish bag limit for current season and years compared to the status quo allocation (73/27 does not include discards). Highlighted cells indicate overages in TAL the previous year resulting in closures the following year.

Year	Pounds Landed	% Overage	Subsequent Year Allocation
2008	106,493	-15.7	126,315
2009	204,422	61.8	48,209
2010	260,665	*106.4	0
2011	348,203	*175.7	0
2012	213,170	68.8	39,461
2013	396,543	^213.9	0
2014	133,016	5.3	119,615
2015	142,540	12.8	110,091
2016	172,348	36.4	80,283
2017	108,420	-14.2	126,315

* *Denotes a scenario where the recreational hook-and-line fishery would not have quota in subsequent year resulting in a one-year closure due to overages.*

^ *Denotes a scenario where the recreational hook-and-line fishery would not have a quota in two subsequent years resulting in a two- year closure due to overages.*

Future increases in total quota would not occur until the southern flounder SSB is recovered and this cannot be determined until an updated stock assessment is completed. Additionally, changes in allocation may alter the rebuilding schedule. Projections for rebuilding use a model that estimates changes in SSB by looking at the rate of removals according to the size classes that each sector harvests. Allocation changes would impact the overall size range of fish removed from the population and could therefore impact model projections.

All of the proposed reallocation scenarios increase recreational quota while lowering the commercial quota, there is the expectation that similar economic effects will follow. Specifically, as the overall commercial allocation is reduced, the total value of the commercial southern flounder industry will decrease, while the value of the recreational southern flounder fishery may be mitigated to some extent due to increased angler expenditures to target this species (Table 4.5.6; *Description of the Fisheries* section Tables 8 and 10); however, economic losses and gains are unpredictable.

Decreasing the commercial allocation may result in a proportional decrease in value. It is possible, per-pound southern flounder prices may rise with reduced supply, counteracting the losses from reduced quota; however, if commercial quota reductions were large enough, the southern flounder fishery could see reduced participation, creating even larger socio-economic losses. The magnitude of these economic changes within each sector is unknown and unquantifiable.

Allocation deliberations should take into consideration the limited southern flounder TAL. Reallocation between sectors at this time could have unintended social and economic consequences that are most noticeable at the finer level of specific fisheries within each sector. It may be more prudent to allocate future quota increases towards one sector over the other as SSB expands. This can be achieved in future amendments with methodic increases until the preferred allocation is achieved.

Table 4.5.4. Example of predicted harvest of southern flounder for a recreational hook-and-line season and compared to a 73/27 allocation and then applied to subsequent years to show future harvest during an Aug. 16–Sept. 30 season. Highlighted cells indicate bag limits that exceed the TAL for the indicated year: the darker the shade the higher the overage.

		Harvest of Southern Flounder (pounds)				Percent of Allocation Harvested based on 73/27 allocation				Subsequent Year Allocation (pounds)			
Season	Year	4-Fish Bag	3-Fish Bag	2-Fish Bag	1-Fish Bag	4-Fish Bag	3-Fish Bag	2-Fish Bag	1-Fish Bag	4-Fish Bag	3-Fish Bag	2-Fish Bag	1-Fish Bag
Aug 16 - Sep 30	2008	106,492	106,492	106,492	91,066	84	84	84	72	126,315	126,315	126,315	126,315
Aug 16 - Sep 30	2009	204,486	187,897	160,774	126,395	162	149	127	100	48,144	64,733	91,856	126,235
Aug 16 - Sep 30	2010	260,612	246,868	218,187	166,911	206	195	173	132	-	5,762	34,443	85,719
Aug 16 - Sep 30	2011	349,421	326,406	310,900	247,169	277	258	246	196	-	-	-	5,461
Aug 16 - Sep 30	2012	213,292	198,612	184,701	145,504	169	157	146	115	39,338	54,018	67,929	107,126
Aug 16 - Sep 30	2013	396,801	313,050	278,762	210,948	314	248	221	167	-	-	-	41,682
Aug 16 - Sep 30	2014	132,458	132,458	127,395	114,937	105	105	101	91	120,172	120,172	125,235	126,315
Aug 16 - Sep 30	2015	142,881	137,615	129,351	90,711	113	109	102	72	109,749	115,015	123,279	126,315
Aug 16 - Sep 30	2016	168,236	168,236	165,769	156,700	133	133	131	124	84,394	84,394	86,861	95,930
Aug 16 - Sep 30	2017	114,667	114,667	110,461	97,184	91	91	87	77	126,315	126,315	126,315	126,315

Table 4.5.5. Example of predicted harvest of southern flounder for a recreational hook-and-line season and compared a 60/40 allocation and then applied to subsequent years to show future harvest during an Aug. 16–Sept. 30 season. Highlighted cells indicate bag limits that exceed the TAL for the indicated year.

		Harvest of Southern Flounder (pounds)				Percent of Allocation Harvested based on 60/40 allocation				Subsequent Year Allocation (pounds)			
Season	**Year**	**4-Fish Bag**	**3-Fish Bag**	**2-Fish Bag**	**1-Fish Bag**	**4-Fish Bag**	**3-Fish Bag**	**2-Fish Bag**	**1-Fish Bag**	**4-Fish Bag**	**3-Fish Bag**	**2-Fish Bag**	**1-Fish Bag**
Aug 16 - Sep 30	2008	106,492	106,492	106,492	91,066	56	56	56	48	189,608	189,608	189,608	189,608
Aug 16 - Sep 30	2009	204,486	187,897	160,774	126,395	108	99	85	67	174,730	189,608	189,608	189,608
Aug 16 - Sep 30	2010	260,612	246,868	218,187	166,911	137	130	115	88	118,604	132,348	161,029	189,608
Aug 16 - Sep 30	2011	349,421	326,406	310,900	247,169	184	172	164	130	29,795	52,810	68,316	132,047
Aug 16 - Sep 30	2012	213,292	198,612	184,701	145,504	112	105	97	77	165,924	180,604	189,608	189,608
Aug 16 - Sep 30	2013	396,801	313,050	278,762	210,948	209	165	147	111		66,166	100,454	168,268
Aug 16 - Sep 30	2014	132,458	132,458	127,395	114,937	70	70	67	61	189,608	189,608	189,608	189,608
Aug 16 - Sep 30	2015	142,881	137,615	129,351	90,711	75	73	68	48	189,608	189,608	189,608	189,608
Aug 16 - Sep 30	2016	168,236	168,236	165,769	156,700	89	89	87	83	189,608	189,608	189,608	189,608
Aug 16 - Sep 30	2017	114,667	114,667	110,461	97,184	60	60	58	51	189,608	189,608	189,608	189,608

Table 4.5.6. Ex-vessel value of the commercial southern flounder fishery by year and gear.

	Gear				
Year	**Gigs**	**Gill Net**	**Other**	**Pound Net**	**Total**
2008	$173,360	$3,798,463	$132,613	$1,545,858	$5,650,295
2009	$159,031	$3,160,714	$116,727	$1,173,459	$4,609,932
2010	$267,482	$2,067,067	$66,801	$1,294,539	$3,695,889
2011	$256,846	$1,397,565	$34,239	$1,064,477	$2,753,128
2012	$388,313	$2,343,199	$126,800	$1,593,169	$4,451,482
2013	$320,380	$2,742,687	$114,816	$2,495,307	$5,673,190
2014	$414,206	$1,884,626	$53,263	$2,487,577	$4,839,672
2015	$417,189	$1,235,836	$38,535	$2,132,007	$3,823,567
2016	$506,533	$1,442,921	$42,423	$1,618,655	$3,610,533
2017	$547,308	$2,220,595	$32,975	$2,854,873	$5,655,751
Total	**$3,450,649**	**$22,293,674**	**$759,193**	**$18,259,922**	**$44,763,437**

VI. PROPOSED MANAGEMENT OPTIONS

Management Options

(+ potential positive impact of action)
(- potential negative impact of action)

Below are overarching positive (+) and negative (-) impacts for all options. The options are listed after the impacts.

+/- Allocation not based on biological need.
+/- Allocation other than status quo not based on historical landings.
+/- Increasing allocation to the recreational sector provides more fish to harvest but depending on amount may not increase the season dates, season lengths, or bag limits.
\+ Increasing allocation to the recreational sector mitigates some of the economic impact of the reductions to the recreational fishery.
\- Decreasing allocation to the commercial fishery exacerbates the economic impact of the commercial fishery.
\- Increasing allocation to the recreational fishery provides additional harvest to the sector with the least precise estimates.
\- Changes in allocation may alter the rebuilding schedule (changing allocation changes the fish available to each sector and their associated selectivity, projections are based on sector specific selectivity).
\- Depending on how much allocation is shifted to the recreational sector there may be significant impacts to the commercial seasons.
\- May be necessary to adjust allocations within a sector to maintain specific gear-based fisheries.

Option 1. Historical Harvest/ Status quo (73 commercial/27 recreational)
Option 2. 70/30
Option 3. 65/35
Option 4. 60/30/10, includes a 10 percent allocation for the gig fishery
Option 5. 60/40
Option 6. 50/50

VII. NCMFC SELECTED MANAGEMENT STRATEGY

The NCMFC approved a motion to set the allocation for Amendment 3 at 70% commercial and 30% recreational at the February 26, 2021, business meeting.

At a March 2021 special meeting, the NCMFC approved a motion to amend the previously adopted southern flounder allocation to adjust the allocation to 70/30 in 2021 and 2022 to 60% commercial and 40% recreational in 2023 and achieve a 50/50 parity in allocation in 2024.

At its February 2022 business meeting, the NCMFC approved a motion that "based on recognition of a series of coincident concerns specific to the initial steps in rebuilding the southern flounder fishery [they delayed] the transition to a 50/50 commercial/recreational parity allocation by 2 years (time for at least 1 cycle of larval to female maturity) allocations: 2023: 70/30; 2024: 70/30; 2025: 60/40; 2026: 50/50."

VIII. LITERATURE CITED

Blackhart, K., D.G. Stanton, and A.M. Shimada. 2005. NOAA Fisheries Glossary, U.S. Dept. of Commerce, NOAA Tech. Memo. F/SPO-69, 61 p.

APPENDIX 4.6. IMPLEMENTING A SLOT LIMIT IN THE SOUTHERN FLOUNDER FISHERY

I. ISSUE

Examine the impacts of changing size limits by implementing a harvest size slot limit in the southern flounder fishery.

II. ORIGINATION

This issue originated from a request brought forth by the North Carolina Marine Fisheries Commission.

III. BACKGROUND

Managing fisheries using size regulations to constrain harvest is common practice, but there is often a trade-off between conservation (i.e., spawning stock biomass) and fishery objectives (i.e., maximizing sustainable yield or harvest numbers; Gwinn et al. 2015; Ayllon et al. 2018, 2019). Often minimum size limits are used but can negatively impact a stock by truncating the age and size structure if effort is high (Moreau and Matthais 2018). Slot limits, particularly in freshwater recreational fisheries, are becoming more popular as they have the ability to protect juveniles and spawning adults (Gwinn et al. 2015) and can help maintain a more mature age structure when compared to minimum size limit regulations (Ayllon et al. 2019). However, if overfished stocks are to be recovered, management actions must first focus on reducing both fishing effort and hooking/bycatch mortality. Once these rates are under control, slot limit regulations could lead to improved sustainability (Ayllon et al. 2018).

Slot limits are not appropriate for all species, but should be considered if the population in question has the following characteristics (Baker et al. 1993; Brousseau and Armstrong 1987):

- good natural reproduction,
- slow growth, especially of young fish,
- relatively high natural mortality of young fish, and
- high angling effort.

Additionally, the upper limit of a slot limit should provide meaningful harvest protection for the species in question (Oliver et al. 2021). If discard mortality and non-compliance for a species are high, then slot limits become less effective as a management tool (Ayllon et al. 2019). Based on the criteria defined by Baker et al. (1993) for slot limits, southern flounder may not be an appropriate candidate as the current fishing mortality is above the threshold reference point, the spawner-recruit relationship is unknown, and juvenile flounder are fast growing (Flowers et al. 2019).

Slot limits may be useful to constrain harvest after fishing effort and mortality are reduced and the stock rebuilds. Benefits for the development of a slot limit for southern flounder revolve around increasing harvest of males, protection of large mature females, and the idea that releasing all larger southern flounder would speed up recovery through increased egg production.

Southern flounder are sexually dimorphic, with females reaching larger sizes than males. Males over 20 inches TL have not been recorded and few males are over 17 inches TL (Figure 4.6.1). While a 50:50 ratio is assumed for southern flounder smaller than 5-inches TL, the female proportion increases for fish 5.5-inches TL or greater and becomes more pronounced at 12-inches TL. Therefore, a slot limit does not guarantee a higher harvest of males. Water temperatures have been shown to influence the sex ratios of southern flounder where higher or lower temperatures can result in a higher proportion of males to females (Luckenbach et al. 2003, 2009; Honeycutt et al. 2019; Montalvo et al. 2012) indicating there may be more males available for harvest. It is unknown what impact annual changes in environmental factors have on the recovery of southern flounder, even if all fish over a certain size are released. For more information on environmental influence on sex ratios, see the *Ecosystem and Fishery Impacts* section.

Most, if not all, fish released over a potential slot limit would be female (Figure 4.6.1). However, the length at which half of female southern flounder are mature is 16-inches TL (Midway and Scharf 2012; Flowers et al. 2019). Division data indicates all females over 19 inches TL are likely mature (NCDMF, unpublished data). While there are no fecundity data currently available from wild individuals to indicate whether larger fish produce more offspring, fecundity generally increases with female body size. In a hatchery setting, southern flounder are capable of producing up to 18 million eggs with an average hatching rate of 15% (Watanabe et al. 2001). These estimates should be viewed with caution because the laboratory experiments were conducted under ideal conditions.

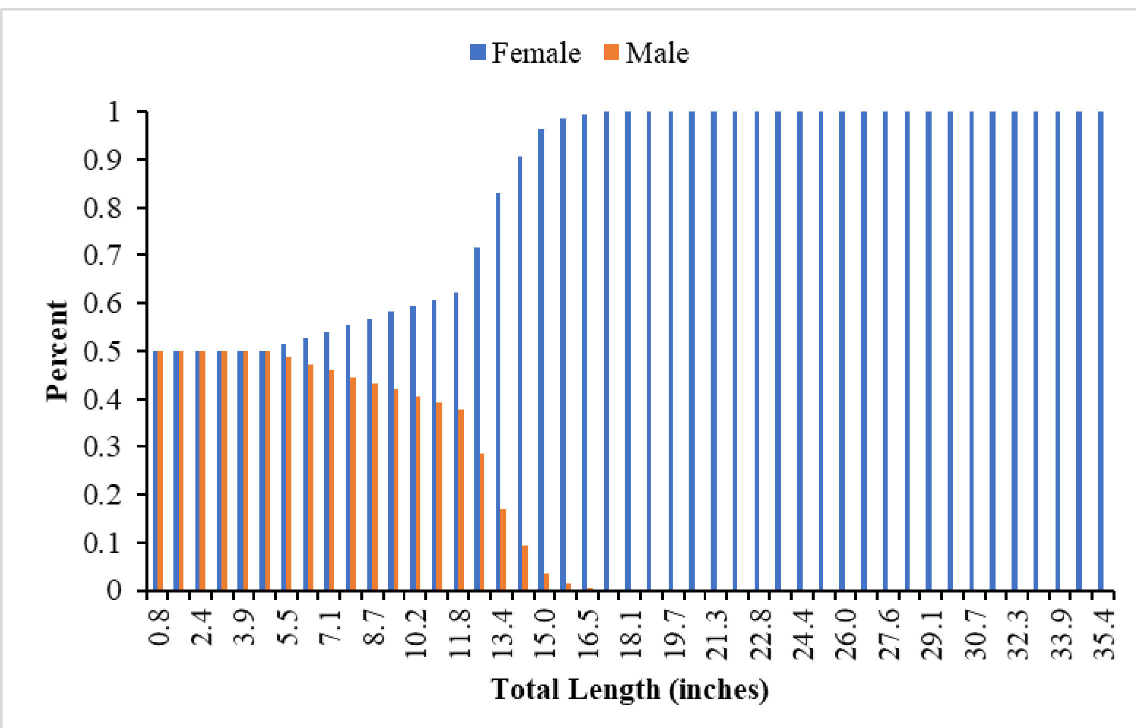

Figure 4.6.1. Sex ratios of southern flounder relative to total length.

In 2017, approximately 10% of the total commercial and recreational harvest were fish greater than 20 inches TL (Figures 4.6.2 and 4.6.3). In 2020, catches of fish larger than 20 inches TL increased for both sectors. It is expected that larger fish will continue to show up in the catches due to the limited seasons occurring in the fall which allow for a longer period of growth prior to being harvested. The current stock shows a truncated age and size structure (Flowers et al. 2019), meaning larger fish are not necessarily older fish. The maximum age observed in both fisheries has decreased over the last decade, and the majority of fishing pressure for both sectors is focused on one or two age classes of fish where most fish harvested are age-2 (NCDMF 2021). Both the age and length structure of the population are expected to improve as the stock recovers. Along with the poor age structure of the stock, it is unknown if the few fish over age-3 have spawned multiple times. It should be noted that while the additional escapement of larger fish may benefit the stock, any fish discarded outside of the slot have an associated post-release mortality, adding to the dead discards.

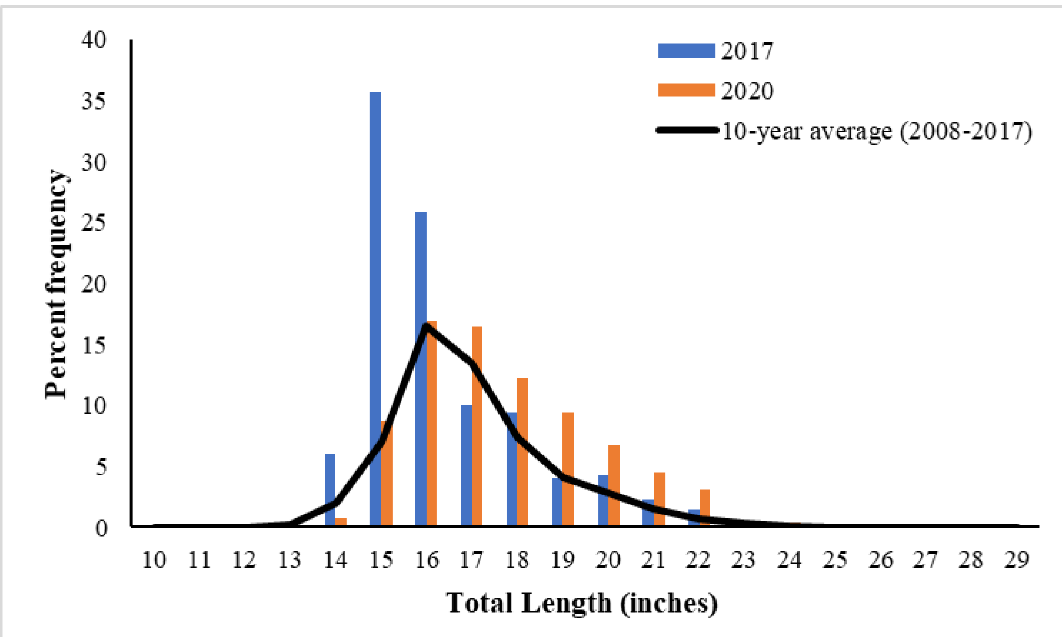

Figure 4.6.2. Percent frequency (by pound per inch) of commercial southern flounder harvest by total length, 2017 and 2020. The 10-year average (2008-2017) is also included for reference. (Source: North Carolina Trip Ticket Program and NCDMF fish house sampling biological data)

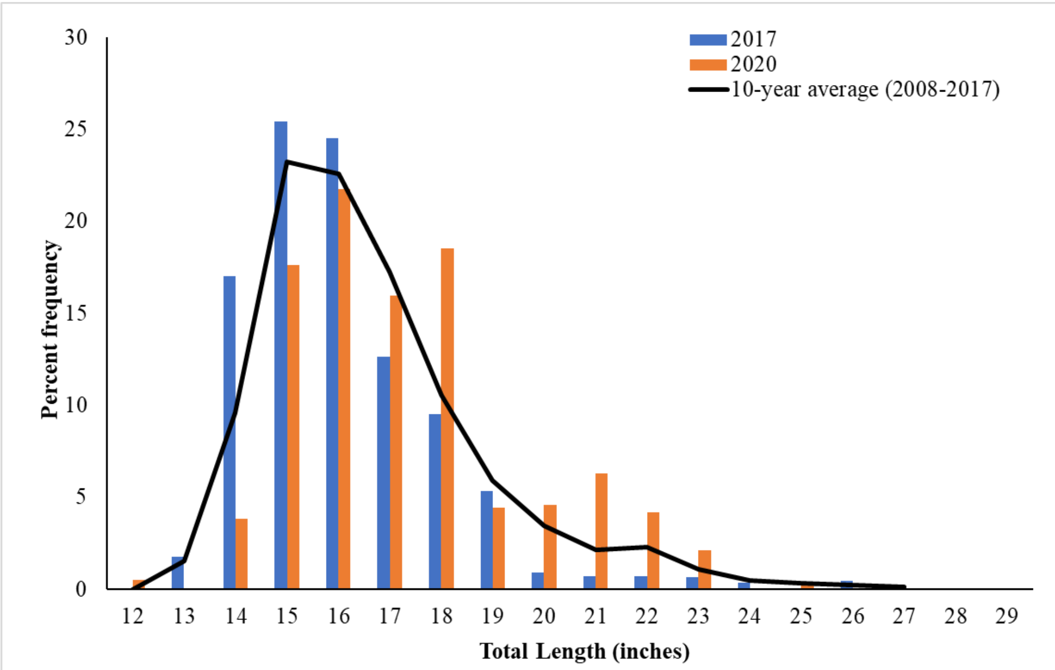

Figure 4.6.3. Percent frequency (by pound per inch) of recreational southern flounder harvest by length, 2017 and 2020. The 10-year average (2008-2017) is also included for reference. (Source: Marine Recreational Information Program)

In North Carolina, the management of flounder species has undergone several regulatory changes to promote the sustainability of the stock. The first implementation of a minimum size limit occurred in 1979 at 11 inches TL for both estuarine and ocean waters. Subsequent minimum size limits have been implemented through the original North Carolina Southern Flounder FMP (NCDMF 2005), Amendment 1 (NCDMF 2013), Supplement A to Amendment 1 (NCDMF 2017), and revisions to the joint Atlantic States Marine Fisheries Commission (ASMFC) and Mid-Atlantic Fishery Management Council Summer Flounder, Scup, and Black Sea Bass FMP (ASMFC 2018; MAFMC 2019). The use of a slot limit, as a potential management tool for curtailing harvest in the southern flounder fishery, has not been explored in previous management plans. A slot limit could be implemented for the recreational and/or commercial fisheries. At this time, the focus of this issue paper will be the potential implementation of a slot limit for the recreational hook-and-line fishery only as requested by the NCMFC.

IV. AUTHORITY

North Carolina General Statutes

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

North Carolina Marine Fisheries Commission Rules
15A NCAC 03H .0103 PROCLAMATIONS, GENERAL
15A NCAC 03M .0503 FLOUNDER
15A NCAC 03M .0512 COMPLIANCE WITH FISHERY MANAGEMENT PLANS

V. DISCUSSION

The population level effects of implementing a slot limit for the recreational southern flounder hook-and-line fishery in North Carolina is non-quantifiable as developing projections based on a slot limit cannot be calculated on an individual state basis. The 2019 stock assessment does not include a spatial component; as a result, all size limit changes would be relative to the entire stock of southern flounder. There are multiple minimum size limits in place across the unit stock, which have ranged in recent years from 12- to 16-inches TL. The analyses of implementing a slot limit are based solely on North Carolina harvest estimates and may or may not be representative of the coast-wide stock and it would not be possible to attribute the implementation of a slot limit as the cause of changes to stock size.

Slot limits of 15 to16 inches (1 inch), 15 to17 inches (2 inch), 15 to 18 inches (3 inch), and 15 to 19 inches (4 inch) TL were explored for the recreational hook-and-line fishery. For ease of enforcement and education, these slot limits include fish at but not greater than the maximum length. For example, the 15- to 16-inch TL slot is only one inch as it includes fish from 15 inches up to and no greater than 16 inches TL. Most harvest for both sectors is less than 20 inches TL thus, implementing a slot limit may act as a buffer to prevent overages to the TAL. The implementation of a slot limit will not extend the season or increase the TAL (Table 4.6.1). In fact, to account for the additional dead discards the TAL would need to be reduced, resulting in fewer harvest opportunities so not to exceed the TAC. Releasing larger fish may help in the recovery of the stock but at this time the effects cannot be quantified. It is also likely that more larger fish are emigrating to the ocean since implementation of the harvest reductions through seasonal closures implemented in Amendment 2.

Estimates in recreational harvest can only be analyzed at the season and bag level for the hook-and-line fishery as length data are not available from the gig survey. The identified slot limits are very narrow and may be imperceptible to fishermen using gigs. Therefore, it is not realistic for the recreational gig fishery to operate under a slot limit as gigs have an assumed 100% mortality associated with capture. Due to the anticipated increase in dead discards that would occur outside of the slot limit, gigs become detrimental to re-building unless a non-lethal gig-like gear was implemented. The gig fishery could continue to operate under the current minimum size limit. However, this creates a greater potential for enforcement issues and non-compliance.

Table 4.6.1. Pounds of southern flounder harvest (no discards) at a four-fish and one-fish bag limit, 2013. This year represents a year of high harvest and what could happen as the stock rebuilds. For reference, the NCMFC allocations are 142,206 lb (30% recreational allocation), 189,608 lb (40%), and 237,010 lb (50%).

	Landings (lb)- Slot Limit							
	15 to 16 inches		15 to 17 inches		15 to 18 inches		15 to 19 inches	
Season	4-Fish Bag Limit	1-Fish Bag Limit	4-Fish Bag Limit	1-Fish Bag Limit	4-Fish Bag Limit	1-Fish Bag Limit	4-Fish Bag Limit	1-Fish Bag Limit
No closure	266,659	218,399	380,114	280,432	544,443	396,391	638,143	439,743
Apr 16–Jun 30	29,669	26,707	47,222	42,164	95,532	69,216	141,213	94,341
May 1–Jun 30	29,669	26,707	40,159	35,101	88,469	62,153	134,149	87,277
Jun 1–Jul 15	24,130	24,130	41,736	38,370	96,656	72,344	145,238	99,257
Aug 1–Sep 30	170,542	127,984	226,416	147,034	313,735	208,979	347,159	218,135
Aug 16–Sep 30	156,752	114,193	204,120	128,528	284,590	184,428	316,724	193,202
July 16–Sep. 30	178,324	135,232	234,197	154,282	323,470	217,495	359,504	229,262
July 1 -Sep.30	189,893	146,801	252,883	171,698	522,892	242,022	389,586	256,474
June 16–Sep. 15	161,353	131,993	222,932	162,920	354,683	257,242	437,354	293,976
Aug 16-Oct 15	159,344	116,785	209,928	133,809	295,774	195,085	330,095	206,047
Aug-16-Oct 30	183,686	138,921	253,082	164,360	344,925	231,068	385,245	243,618

The MRIP survey design for the hook-and-line fishery includes length data with an associated sampling weight equivalent to the sampling weight applied to generate the expanded harvest estimates. Therefore, slot limit analyses can be compared to estimates produced in reference to the TAL but not the TAC. Importantly, the contribution of generated discards can be substantial. For example, analysis of MRIP size data demonstrates that the only slot limit scenario with landings below the TAL during the 2020 6-week season was 15 to 16 inches TL (Table 4.6.2). Generated dead discards for those fish greater than the upper bound for this slot limit are 24,604 pounds. Estimates of existing dead discards average 41,331 pounds between 2008 and 2017. The additional generated dead discards would increase this average creating the need to reduce the TAL to offset the increase in discards. Additionally, changes in bag limits substantially decrease reliability of estimates. For example, in 2017 only 29 southern flounder were observed between Aug. 16 and Sept. 30. A one fish bag limit analysis during this season excludes 41% of the observations. This is further compounded by a skewed age structure where 89% of observed southern flounder were 19 inches TL or less. For these reasons, estimates produced for slot limits are not a reliable indicator of the effect a slot may have on recreational harvest.

Table 4.6.2. Pounds of southern flounder harvested by the recreational hook-and-line fishery during the 2020 season, by slot limit option. The no slot example shows the harvest under the current 15-inch TL minimum size limit. The TAL in 2020 was 126,315 pounds.

Season	Slot Limit (in)	Harvest (lb)
Aug. 16 - Sept. 30	No slot	362,119
Aug. 16 - Sept. 30	15-16	88,743
Aug. 16 - Sept. 30	15-17	140,448
Aug. 16 - Sept. 30	15-18	218,009
Aug. 16 - Sept. 30	15-19	238,565

There are several data limitations hindering the evaluation of slot limits including fecundity at age, effect of seasons on the size of fish harvested, and distribution of flounder as they emigrate into the ocean. Additionally, species level biological data are currently unavailable for unobserved discarded flounder. North Carolina's three constituent flounder species are notoriously difficult to differentiate. This ambiguity presents a unique challenge for fisheries management in that discard information provided by the recreational angling community may be inadvertently errant. To properly consider the discard estimates of these species produced by the APAIS conducted in North Carolina, the number of fish discarded and reported at the genus species level must be evaluated. Only a very small percentage of the angling community are perceived to have the ability to identify flounder to the species level. Thus, samplers are instructed to record all reported flounder discards at the left-eyed flounder genus level. To partition the unobserved catch to the species level, a ratio of southern, summer, and Gulf flounder is first determined from the observed catch. The ratio of catch is applied to the estimated unobserved catch to produce estimates of discards for each species. It is unlikely that the relative contribution of each species within the harvested catch is identical with that of discarded catch. Specifically, the assumption that discarded individuals share the same spatiotemporal distribution as those harvested has not been validated. This concern is underscored by demonstrated ontogenetic differences in habitat use and migratory patterns for these congener species (Walsh et al. 1999; Dorval et al. 2005). The ability to accurately identify discarded flounder to the species level is critical to characterize unobserved dead discards. If these data limitations can be addressed, it will be possible to more accurately quantify the use of implementing a slot limit.

While these analyses have data limitations, they do illustrate potential annual variation. Figures 4.6.4-4.6.7 illustrate the effect a slot limit may have on the recreational fishery relative to the allocation changes passed by the NCMFC in March 2021. As the stock rebuilds the potential recreational seasons identified in the *Achieving Sustainable Harvest* issue paper may fail to meet the target harvest reduction due to increased angler success (Figures 4.6.4-4.6.7). In 2020, angler success increased relative to the last five years, particularly for anglers catching only one fish. Catch rates, indicative of success, almost doubled between 2019 and 2020. Therefore, decreasing the bag limit, even if a slot limit is implemented, is necessary to constrain harvest and prevent massive overages. For further discussion on the effects of increased angler success and bag limits, see the *Achieving Sustainable Harvest* issue paper.

Moreau and Matthias (2018) found narrow slot limits for certain freshwater species can be used to prevent overharvest when bag limits are left unchanged. However, in this study if the bag limit was reduced to one fish, the slot limit range could potentially be expanded allowing for the harvest of larger fish. This would be more appropriate as the stock rebounds and the length and age structure expands. Any slot limit will potentially increase the discarded fish which is problematic for species such as southern flounder which have high post-release mortality (9%) and discard to catch ratios (nine released for every fish kept; Moreau and Matthias 2018). Slot limits generally result in lower harvest and more discards by weight, and therefore higher and more frequent overages would occur compared to a minimum size limit (Wiedenmann et al. 2013). As older, larger fish become more abundant, the volume of removals due to discard mortality and non-compliant harvest is expected to increase (Kasper et al. 2020).

The discards of larger, heavier fish will increase the poundage of dead discards. This increase could be especially problematic for the recreational fishery due to the volume of releases each year. It is assumed that most fish discarded in the recreational fishery are discarded because they are below the minimum size limit and therefore weigh less than half a pound. By discarding fish above the slot limit the overall weight of dead discards would increase, potentially to greater than five pounds per fish. Thus, increasing the likelihood of not just exceeding the TAL each year but the TAC as well.

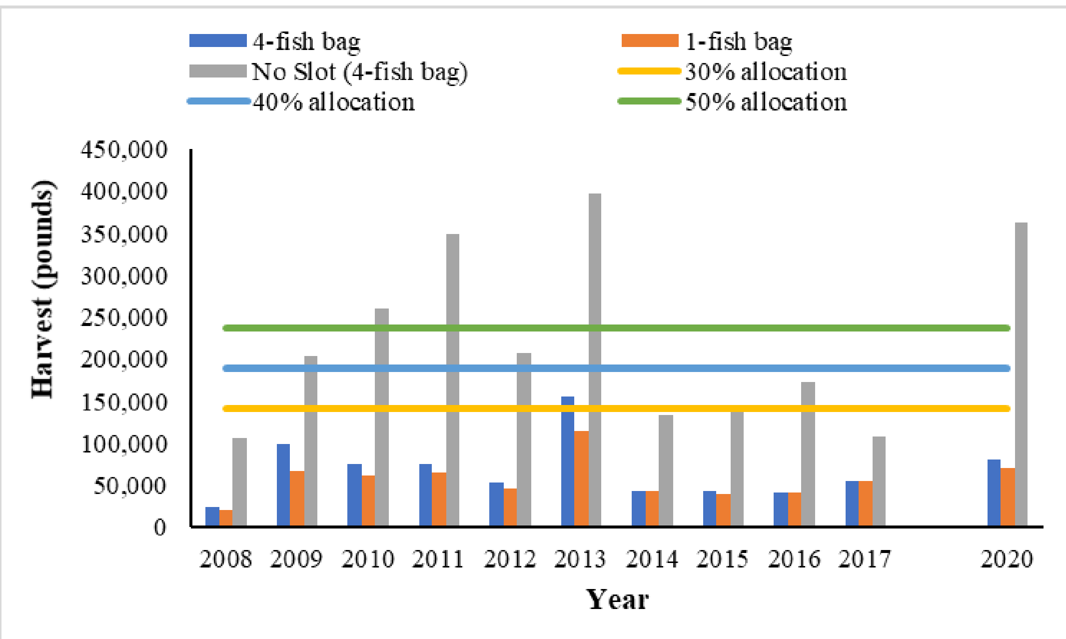

Figure 4.6.4. Total hook-and-line harvest during Aug. 16–Sept.30 at a four-fish and one-fish bag limit and a 15–16-inch slot based on data from 2008 to 2017 and 2020. The years 2010, 2011, and 2013 represent years of above average harvest; 2020 represents the first full year under seasonal management through Amendment 2. NCMFC allocations are presented for reference.

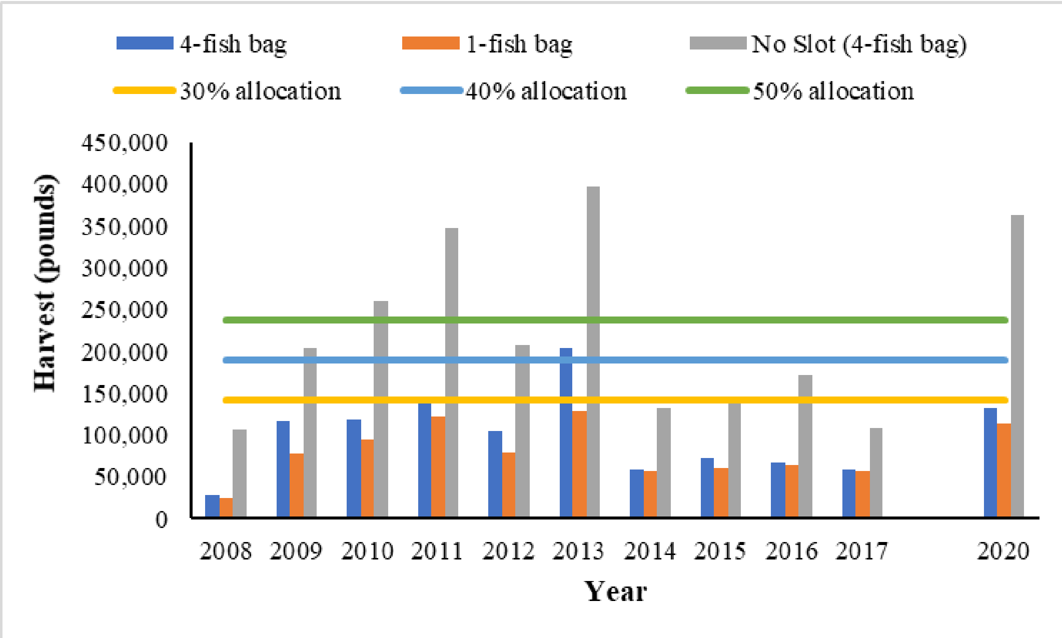

Figure 4.6.5. Total hook-and-line harvest during Aug. 16–Sept.30 at a four-fish and one-fish bag limit and a 15–17-inch TL slot based on data from 2008 to 2017 and 2020. The years 2010, 2011, and 2013 represent years of above average harvest; 2020 represents the first full year under seasonal management through Amendment 2. NCMFC allocations are presented for reference.

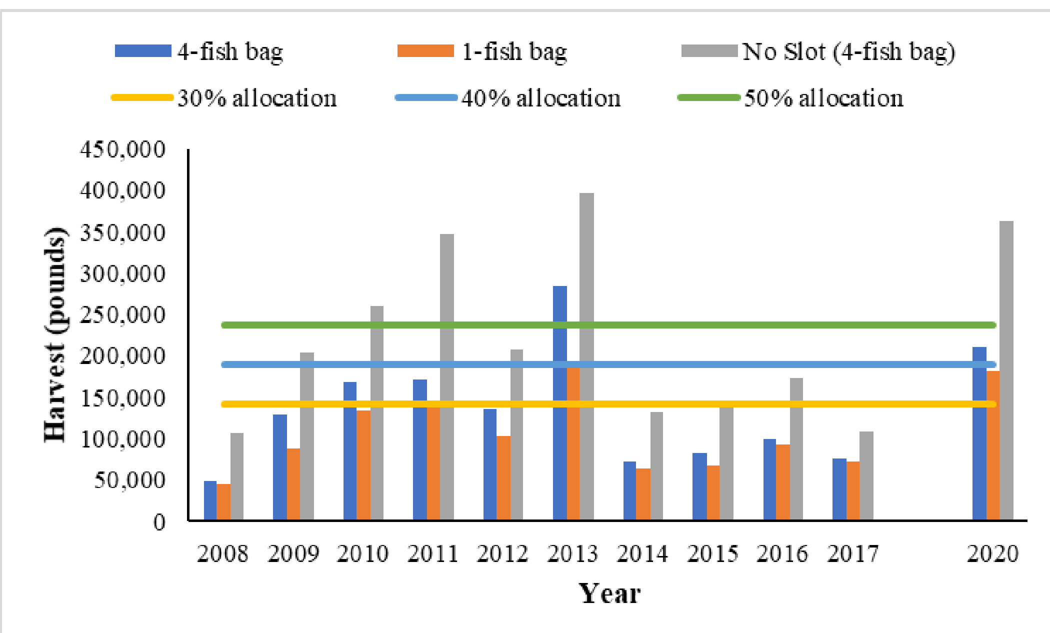

Figure 4.6.6. Total hook-and-line harvest during Aug. 16–Sept.30 at a four-fish and one-fish bag limit and a 15–18-inch TL slot based on data from 2008 to 2017 and 2020. The years 2010, 2011, and 2013 represent years of above average harvest; 2020 represents the first full year under seasonal management through Amendment 2. NCMFC allocations are presented for reference.

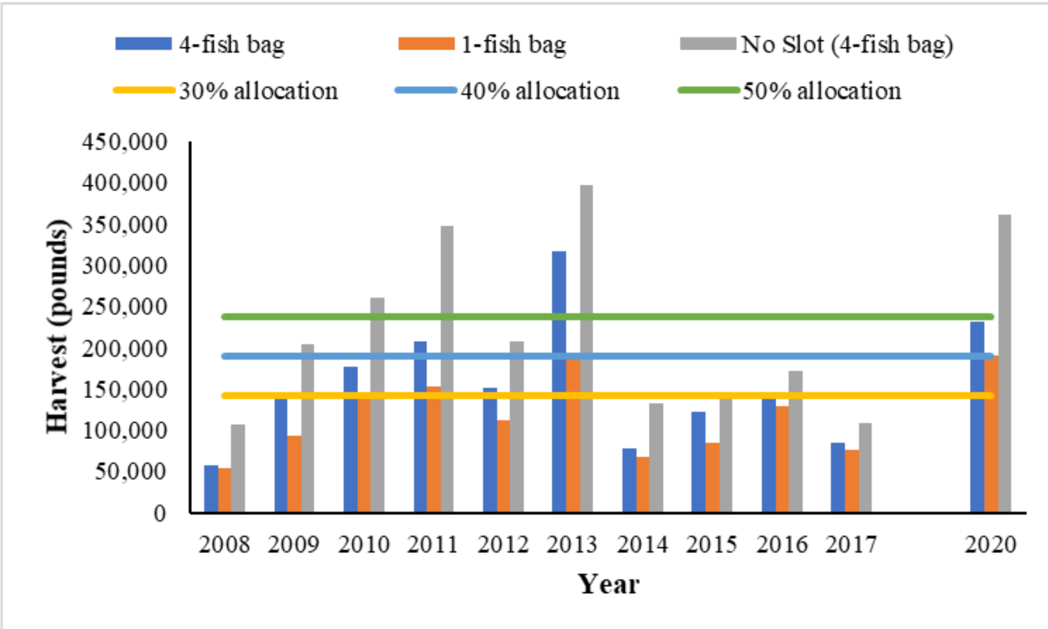

Figure 4.6.7. Total hook-and-line harvest during Aug. 16–Sept.30 at a four-fish and one-fish bag limit and a 15–19-inch TL slot based on data from 2008 to 2017 and 2020. The years 2010, 2011, and 2013 represent years of above average harvest; 2020 represents the first full year under seasonal management through Amendment 2. NCMFC allocations are presented for reference.

Previous analysis of summer flounder slot limits showed an increase in harvest of smaller fish, while only reducing some harvest on the larger fish. This increased fishing mortality rates and resulted in only marginal benefits (Wong 2009). Non-compliance and high-grading within the slot were concerns with the implementation of a slot limit. As such, it was recommended that narrow slot ranges be avoided due to issues related to angler satisfaction, non-compliance, and enforcement. Importantly, the use of slot limits for a flounder species was not recommended until rebuilding goals and data needs for the species were met (Wong 2009; ASMFC 2018).

As the stock rebuilds, any benefit of a buffer may disappear as more fish become available within the slot. Though slot limits are normally associated with the recreational sector, slot limits may be implemented in both sectors since there are differences in fishing seasons. Any savings may be lost if larger fish are released by the recreational sector only to be available for harvest in the commercial fishery (as is currently being discussed). This is also true within the recreational sector if gigs are not held to the same slot. Finally, it is also an important consideration for the recreational fishery if there is an early and late season; fish may grow into or out of the slot between those seasons to an unknown effect.

Though size limits could not be changed under Amendment 2, the 2020 season offers an opportunity to see how the implementation of a slot limit may have affected landings under seasonal management. Of the options presented in this issue paper, only the narrowest slot limit may have possibly prevented the recreational hook-and-line fishery from exceeding their TAL

(126,315 pounds) in 2020 (Table 4.6.2). The other options presented would have minimized the overages when compared to no slot limit.

Selection of Slot Limits with a Minimum Size Limit Lower than 15 Inches

Decreasing the minimum size limit could potentially increase harvest on males while decreasing pressure on larger females. However, it cannot be guaranteed that more males will be harvested. Depending on the minimum slot size, males could account for 10% to 40% of the fish available for harvest (Figure 4.6.1). In the summer flounder headboat fishery, Morson et al. (2017) found that lowering the minimum size for a slot limit below the current minimum size regulations could potentially meet management goals while distributing harvest over both sexes for summer flounder. However, the slot limits that did not increase fishing mortality were all narrow (2-4 inches), contained the current minimum size within the slot limit, and were not applicable to all areas and habitats.

Even at previous minimum size limits, southern flounder landings were still dominated by female fish (NCDMF, unpublished data). It is thought that males move offshore at a smaller size than females and do not return to the estuary after spawning (Stokes 1977), potentially decreasing the efficacy of a lower minimum size. While it is understood that harvest of larger females could be detrimental to the recovery of the stock, many female fish less than 16 inches TL are not mature, and harvest of these fish can also negatively impact recovery. It is not possible to determine the sex of southern flounder prior to harvest and therefore, immature females would still be harvested.

Slot limits with a minimum length smaller than the current minimum length would increase the harvest of small fish. Because the southern flounder population is dominated by young fish (Flowers et al. 2019), this could significantly increase the overall number of fish harvested due to their greater availability. This increase in harvest would increase the fishing mortality rate.

In contrast, a reduction in the minimum size limit when implementing a slot limit may allow increased harvest on summer flounder. Summer flounder caught in North Carolina are typically smaller than southern flounder. As recreational size limits have increased through regulatory changes over the years, the ratio of harvest between summer and southern flounder has changed (Figure 14 in the *Description of Fisheries* section).

The recreational size limit for flounder has been 15 inches TL since 2011 and multiple size limit changes have occurred over the time series making it difficult to determine any effect lowering the size limit would have. Any calculations performed would introduce a high level of imprecision and be based on data that may not be representative of the current fishery. There are numerous concerns with decreasing the minimum size limit for the recreational sector. These concerns revolve around the large volume of recreational discards of fish that are currently under the 15-inch TL minimum size limit (approximately 1.9 million fish in 2017). Lowering the minimum size limit would potentially turn these discards into harvest. Increasing the harvest from the recreational fishery would not meet the projected reductions necessary for rebuilding, and under adaptive management would lead to shortened or closed seasons. Data are not available on the size of discards so it is unclear how harvest would change if the minimum size for a slot was dropped to 12- or 13-inches TL. When the size limits were lower (1989-2007), these smaller fish accounted for 30-40% of the recreational harvest.

The slot limit options proposed have a minimum size of 15 inches TL. This is because MRIP staff do not see discarded flounder and therefore do not collect any associated biological data. Data on the species composition and length of discarded flounder is not available. This overwhelming data limitation prohibits calculating the potential impact of lowering the size limit or implementing a slot limit with a lower bound below the current size limit. The division's License and Statistics section has developed a smartphone application (Catch U Later!) to collect information on discarded flounder to help identify not only species composition of discards but length frequency as well. Data from this app will be available over the next several years. As these data are collected, determining the impact of lowering the size limit will be possible.

The following are additional positive (+) and negative (-) impacts on lowering the minimum size limit below 15 inches TL.

+ Would reduce the harvest of larger females
+ May increase the harvest of males
- Cannot evaluate sustainable harvest of slot limits with a reduced minimum size limit
- Would likely increase the number of fish harvested
- Smaller minimum size limit would expose smaller fish to harvest, including smaller females
- No guarantee that harvest of males will increase
- Would not prevent dead discards of larger fish
- The larger fish that are released and die will contribute to increasing the average weight of dead discards reducing the available weight for harvest
- The combination of increased harvest of small fish and increased dead discard weight of larger fish is likely to lead to overages in the fishery
- Would impact summer flounder harvest and require ASMFC/MAFMC approval

<u>Additional Management Considerations</u>

It should be noted that while the NCMFC may choose a preferred slot limit as a management option, the NCDMF would need approval from ASMFC to implement any changes to the current minimum size limit. The ASMFC has implemented state and/or regional level conservation equivalencies for the management of summer flounder since 2001 (ASMFC 2017). Conservation equivalency management measures are reviewed annually and based on the coast-wide summer flounder recreational harvest limit and overages when they occur. The ASMFC must be notified of any changes to the summer flounder fishery in North Carolina state waters; however, approval of changes by the ASMFC is not required if the changes are expected to be more restrictive than the management measures already approved by the ASMFC. Conservation equivalencies may not be approved by ASMFC until the February following Amendment 3 implementation. Therefore, slot limits, if approved by the NCMFC and the ASMFC, would not be implemented until the 2023 fishing year at the earliest. If ASMFC does not approve slot limits as part of North Carolina's conservation equivalency for summer flounder, the state could be found out of compliance through the Summer Flounder, Scup, and Black Sea Bass FMP. These interjurisdictional regulations impact the North Carolina fishery as state management of flounder is collective and not by individual species. Further, management regulations through ASMFC continue to increase the summer flounder minimum size limit, indicating approval of a lower minimum size might not occur. If the NCMFC were to implement a slot limit with a lower minimum size without ASMFC approval, North Carolina could be found out of compliance leading to a closure of the fishery.

Changes to the summer flounder fishery in EEZ waters off North Carolina may be impacted by the Mid-Atlantic Fishery Management Council and National Marine Fisheries Service (NMFS). Until conservation equivalencies are approved by NMFS (which usually occurs in May or June), coast-wide measures for summer flounder in the EEZ include a four-fish possession limit, a 19-inch TL minimum size limit, and an open season of May 15–Sept. 15 (MAFMC 2019). These measures serve as a default each year until annual conservation equivalencies are approved by the NMFS, which allow state regulations to be applied to EEZ waters.

VI. PROPOSED MANAGEMENT OPTIONS

Management Options

(+ potential positive impact of action)
(- potential negative impact of action)

Below are overarching positive (+) and negative (-) impacts for all options, specific impacts from an option may be found below that option.

Option 1. Status quo, Do not implement a slot limit and maintain the 15-inch TL current minimum size limit.

+ Maintains current regulations and allows anglers to harvest citation size flounder
+ Meets compliance requirements for summer flounder through the joint ASMFC/MAFMC plans
+ Doesn’t create regulatory disparity between the recreational hook-and-line and gig fisheries
+ Meets sustainability if harvest is below the TAL
+ Escapement of mature fish is occurring through the 72% reduction
- Would not reduce the harvest of larger, more fecund females
- Does not provide additional protections to the stock

Option 2. Implement a slot limit for the recreational hook-and-line fishery.

The following positive and negative impacts apply to all of option 2.

+ May help to constrain harvest and prevent overages if used in conjunction with the TAL and seasons for the recreational hook-and-line fishery
+ Meets sustainability if harvest is below the TAL
+/- Potentially allows for additional escapement of the larger, more fecund females
- Requires approval from ASMFC/MAFMC for conservation equivalency, which may not be approved

- Larger fish protected by the slot limit in the recreational fishery may be harvested by the commercial fishery later in the year
- Fish discarded outside of the slot have an associated mortality and dead discards would increase
- May increase the number of fish harvested to meet the same TAL
- Would increase overall weight of dead discards and could potentially lead to exceeding TAC and not meeting the needed overall reduction
- May disproportionately impact gig and RCGL gill-net fisheries if applied to all recreational gear, not just the hook-and-line fishery
- Greater potential for noncompliance and high grading
- Does not allow anglers to harvest citation size flounder

2A. Implement a 15 to16 Inch (1 inch) TL Slot Limit.
2B. Implement a 15 to 17 Inch (2 inch) TL Slot Limit.
2C. Implement a 15 to 18 Inch (3 inch) TL Slot Limit.
2D. Implement a 15 to 19 Inch (4 inch) TL Slot Limit.

VII. RECOMMENDATION

See Appendix 6 for a summary of all comments and recommendations gathered from NCDMF, the NCMFC advisory committees, and public for the Southern Flounder FMP Amendment 3.

NCMFC Preferred Management Strategy

Option 1. Status quo, Do not implement a slot limit and maintain the 15-inch TL current minimum size limit.

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APPENDIX 4.7. PHASING OUT ANCHORED LARGE-MESH GILL NETS IN THE NORTH CAROLINA SOUTHERN FLOUNDER FISHERY

I. ISSUE

Explore the impacts of phasing out anchored large-mesh gill nets from the North Carolina southern flounder fishery by the end of the current Incidental Take Permit (ITP) year.

II. ORIGINATION

This issue originated from a request brought forth by the North Carolina Marine Fisheries Commission.

III. BACKGROUND

At their March 2021 NCMFC special business meeting, the NCMFC requested the division explore the impacts of phasing out anchored large-mesh gill nets from the southern flounder fishery by the end of the current ITP. The current North Carolina ITP for the authorized incidental take of threatened and endangered sea turtles expires August 31, 2023, and the ITP authorizing incidental takes of threatened and endangered Atlantic sturgeon expires July 17, 2024 (NMFS 2013, 2014). The division is drafting an application for a new ITP to authorize incidental takes of sea turtles and Atlantic sturgeon for 10 years after the sea turtle ITP expires in 2023. If an option included in this issue paper is approved by the NCMFC, the use of anchored large-mesh gill nets could be phased out by the end of the current sea turtle ITP in August 2023. Due to the timing of the southern flounder season, 2022 may be the final year of the North Carolina southern flounder large-mesh gill net fishery if these measures are adopted by the NCMFC.

Early commercial fishermen tended to use pound nets, seines, gill nets, and spears (gigs) to harvest southern flounder in North Carolina (Chestnut and Davis 1975). Throughout the 1970s - early 1990s, pound net gear ranked highest in the total landings of southern flounder. During the mid-1990s, gill net landings surpassed those of pound nets. Gill nets continued to maintain the highest ranking in landings until 2014, when pound nets once again moved into the top position. The third highest ranking gear for southern flounder is gigs. From 2008 to 2017, on average 53% of southern flounder landings have been from gill nets, 38% from pound nets, and 7% from gigs (Table 4 in the *Description of the Fishery* section, Figure 4.7.1). Landings from other gears accounted for, on average, 2% of the total landings and included crab and peeler pots, crab and shrimp trawls, rod and reel, fyke nets, and haul seines. Due in part to increased regulatory measures, landings from gill nets have declined from 68% to near 40% during this time frame.

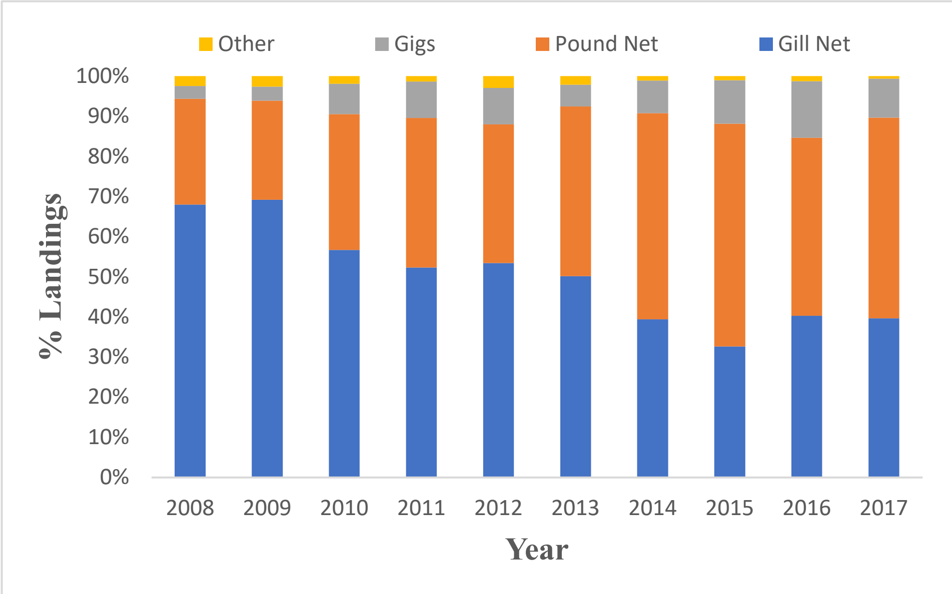

Figure 4.7.1. Percent of annual southern flounder commercial landings by gear type, 2008-2017.

Phasing out a single gear in the southern flounder fishery does not impact sustainable harvest of the southern flounder stock if a quota management system is implemented. Harvest by all gears can be allowed if the total harvest level does not exceed the TAL and dead discards and harvest combined do not exceed the TAC. Phasing out anchored large-mesh gill nets would allow the sub allocation for that gear to be applied to the remaining gears in the commercial fishery. This would result in additional TAL for pound nets and/or mobile gears, but the dead discards of southern flounder occurring through other large-mesh gill net fisheries (i.e., shad, catfish) would be applied to the TAC.

North Carolina additionally allows the recreational use of commercial gears. RCGL holders may use large and small mesh gill nets as well as shrimp trawls and crab pots to harvest species including southern flounder. Between 2002 and 2008, large-mesh gill nets comprised 74% of southern flounder harvested using RCGL gears, with small mesh gill nets (21%), crab pots (4.0%), and shrimp trawls (1%) constituting the remainder among RCGL gears. The number of flounder species harvested between 2002 and 2008 ranged from 18,414 to 53,785 fish annually (Figure 4.7.2).

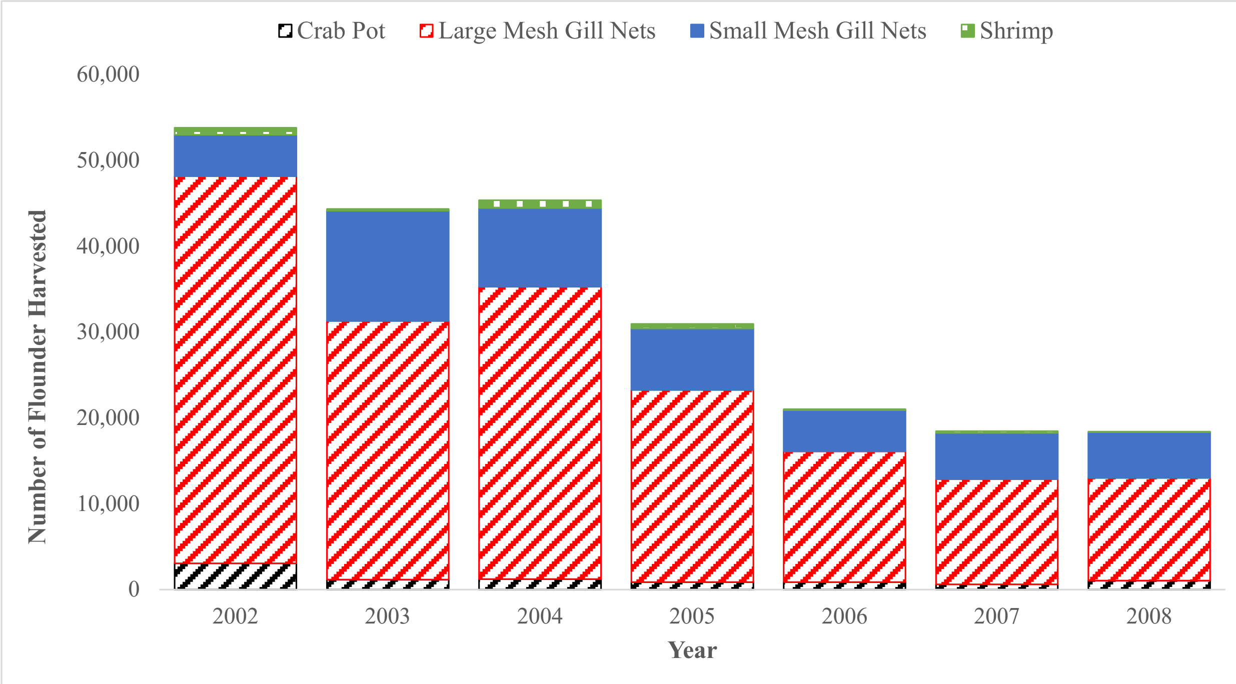

Figure 4.7.2. Number of flounder *species* harvested by RCGL gear type, 2002-2008.

Estimates of RCGL harvest have not been available since 2008 and thus impacts are not quantifiable. If phasing out of the large-mesh gill net commercial fishery is not approved, the use of RCGL gill nets to harvest southern flounder may still be disallowed through Amendment 3 under sustainable harvest. For more information on RCGL and southern flounder see the *Description of the Fisheries* section and the *Achieving Sustainable Harvest* issue paper.

IV. AUTHORITY

North Carolina General Statutes

G.S. 113-134 RULES
G.S. 113-173 RECREATIONAL COMMERCIAL GEAR LICENSE
G.S. 113-182 REGULATION OF FISHING AND FISHERIES
G.S. 113-182.1 FISHERY MANAGEMENT PLANS
G.S. 143B-289.52 MARINE FISHERIES COMMISSION – POWERS AND DUTIES

North Carolina Marine Fisheries Commission Rules

15A NCAC 03H .0103 PROCLAMATIONS, GENERAL
15A NCAC 03M .0503 FLOUNDER
15A NCAC 03O. 0302 AUTHORIZED GEAR

V. DISCUSSION

At the March 2021 special meeting, the NCMFC requested that the division evaluate the potential to phase out the use of large-mesh gill nets in the southern flounder fishery by the end of the current ITP during development of Amendment 3. The possible elimination of specific gears (i.e., anchored large-mesh gill nets) for harvesting southern flounder for either the commercial or recreational fishery is statutorily granted to the NCMFC by G.S. 143B-289.52. The division provides the best available data for a fishery (gear) to meet the mandate for producing a sustainable harvest of the southern flounder stock and to evaluate impacts to habitat.

Large-mesh gill nets are regulated by NCDMF through proclamation authority provided by the NCMFC to the Fisheries Director. Phasing out large-mesh gill nets in the southern flounder fishery would be accomplished using this authority by prohibiting the use of large-mesh gill nets for harvesting southern flounder. This would impact RCGL holders as well since large-mesh gill nets would not be an allowable gear to harvest southern flounder. Regulations involving the RCGL are found in G.S. 113-173 and NCMFC Rule 15A NCAC 03O.0302 that authorize certain commercial fishing gear for recreational use. A rule change(s) by the NCMFC is required to completely prevent a specific gear from being used across all fisheries in the state by commercial and RCGL license holders. Additional information on the RCGL can be found in the *Description of the Fisheries* section and the *Achieving Sustainable Harvest* issue paper.

Southern Flounder Large-Mesh Gill Net Fishery

During 2008-2017, an annual average of 808 participants (range: 591- 992) reported southern flounder landings from gill nets. These participants landed southern flounder from 14,643 trips on average from 2008-2017, though not all trips that landed southern flounder were targeting them (Figure 4.7.3). The number of trips landings southern flounder has declined from a high of 23,691 trips in 2009 to a low of 8,422 trips in 2016 (Table 5 in the *Description of the Fishery* section).

In order to characterize common species caught in the southern flounder gill net fishery, a targeted southern flounder trip reported to the NCTTP was defined as any large-mesh gill net trip where southern flounder represented the most abundant species (by weight). This definition accounted for greater than 93% of all southern flounder landings from large-mesh gill nets from 2013 to 2017. Generally, trips targeting southern flounder increased through the summer and peak in the fall (September and October) coinciding with the migration of southern flounder from the estuaries to the ocean prior to spawning as shown in Figure 4.7.3. During the remainder of the year, southern flounder were harvested in gill nets as part of other directed fisheries but were most commonly taken as part of a mixed finfish fishery. From 2013 to 2017, 73% of the large-mesh gill net trips landed southern flounder and 54% met the definition of a targeted trip for southern flounder. From June through October, greater than 75% of all trips made were targeted flounder trips. Only during December (closed season) and January through April, were directed southern flounder trips not the dominate trip type in the large-mesh gill net fishery. Trips during these months tend to be dominated by catches of catfishes, striped bass, and American shad, among other species.

Both finfish and shellfish species may be caught as bycatch in gill net trips targeting southern flounder. This bycatch may be retained or discarded as a result of economic, regulatory, or personal considerations. While southern flounder dominates the catch, the estuarine gill net fishery represents a mixed fishery with multiple species being taken on any given trip. Species include red drum, black drum, catfish species (including invasive blue catfish), sheepshead, spotted seatrout, American and hickory shad, striped bass, bluefish, striped mullet, and an additional 40+ species (Figure 4.7.4). Phasing out anchored large-mesh gill nets would impact the harvest of these other species as well. In addition, continuing to set large-mesh gill nets in areas where southern flounder are present could have an impact on rebuilding the stock as the species would be required to be discarded. Southern flounder caught in gill nets have an initial at net mortality associated with entanglement and an approximate 23% post-release mortality (Flowers et al. 2019).

Protected Species and Incidental Take Permits

Since the 1970s, the NCDMF has been proactive in developing ways to minimize impacts to threatened and endangered marine species. The NCDMF works closely with the National Oceanic and Atmospheric Administration (NOAA) Fisheries and other state and federal agencies to develop regulations that minimize impacts to protected species and still allow for economically important fisheries. Of the many federal and state protected species, sea turtles and sturgeon are considered to have the greatest potential to interact with the North Carolina southern flounder fishery. Gill nets may capture protected species as a result of entanglement in the webbing or buoy and anchor lines.

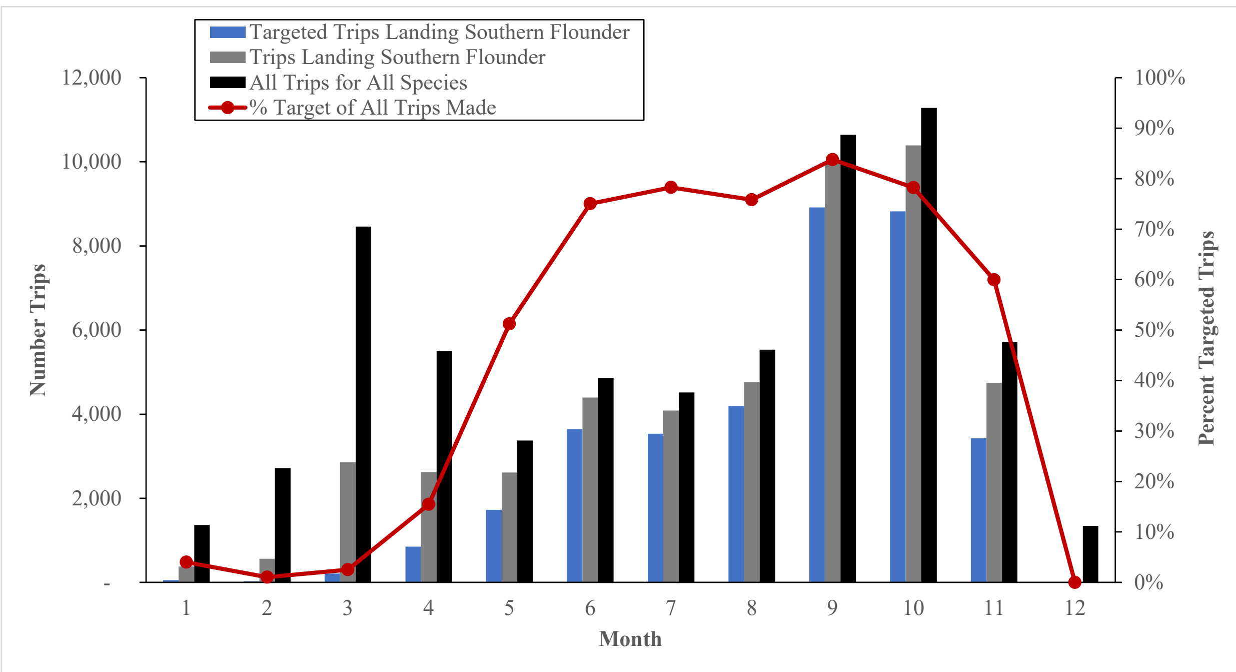

Figure 4.7.3. Total gill net trips compared to gill net trips targeting or landing southern flounder.

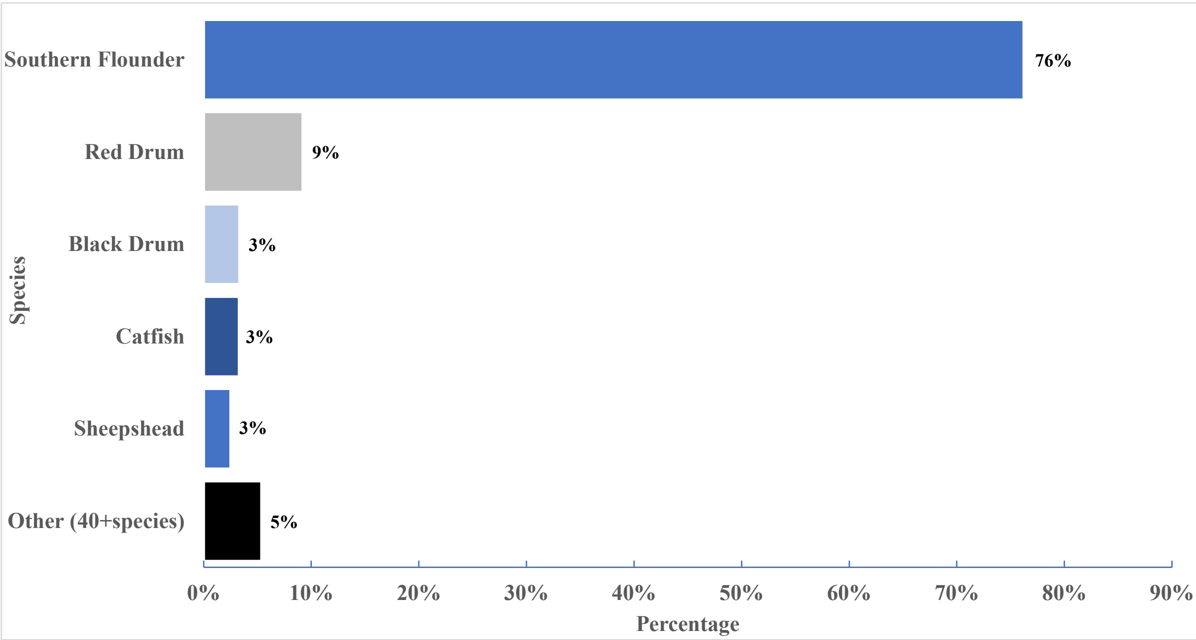

Figure 4.7.4. Top species harvested from anchored large-mesh gill nets where southern flounder are the most abundant species, 2013-2017.

Incidental capture of protected sea turtles and Atlantic sturgeon commonly occurs in the southern flounder gill net fishery. The fishery has undergone various regulations since the early 2000s to monitor and minimize impacts to protected sea turtles. The NCDMF currently allows the estuarine anchored gill net fishery to operate under the authorization from permits (ITP; Section 10(a)(1)(B) of the ESA) granted to the state by NOAA Fisheries for the incidental take of sea turtles and Atlantic sturgeon associated with otherwise lawful commercial gill net fishery in North Carolina inshore state waters (NMFS 2013, 2014). The permits outline authorized levels of annual incidental takes in these fisheries. The state as permit holder must monitor, minimize, and mitigate incidental takes as set forth in the conservation plan provided in the permit. The permits are in effect for a 10-year period: the sea turtle permit was issued in September 2013 and the Atlantic sturgeon permit was issued in July 2014. Since September 2014 (2015 license year), the division has been issuing estuarine gill net permits to any commercial fisherman or RCGL holder who wants to fish anchored gill nets (https://files.nc.gov/ncdeq/Marine-Fisheries/fisheries-management-proclamations/2014/M-24-2014-EGNP.pdf). During 2016-2021, an average of 2,619 permits were issued annually (Table 3 in the *Description of the Fishery* section). These permits provide the division with the number of participants who may choose to participate in the gill net fishery using large-mesh or small-mesh gill nets. Not all commercial license holders who obtain an estuarine gill net permit report flounder landings using the gear. For information specific to the North Carolina Incidental Take Permit for sea turtle interactions in the estuarine gill net fishery see: https://www.federalregister.gov/documents/2013/09/17/2013-22592/endangered-species-file-no-16230. For specific details related to the Atlantic sturgeon incidental take permit see: https://www.federalregister.gov/documents/2014/07/28/2014-17645/endangered-species-file-no-18102.

Habitat Impacts

Phasing out anchored large-mesh gill nets in the southern flounder fishery would not offer significant habitat protections. Studies on the effect of anchored (or fixed) gill nets on habitat degradation indicate their impact is minor for soft bottom and SAV habitat (Barnette 2001; West et al. 1994; ASMFC 2000).

Economic Impacts

Economic impacts of phasing out the anchored large-mesh gill net fishery for southern flounder would be negative to all commercial license holders who participate in the fishery. The landings could be transferred to the pound net or other mobile gear fisheries, increasing the economic benefits of those gears. The economic impacts may include up to 808 participants on average in the gill net fishery but the participants may choose to enter the gig and or pound net fishery if they do not already participate in them (Table 5 in the *Description of the Fishery* section). This could alter the average ex-vessel dockside value of $4,476,342 from the southern flounder commercial fishery by moving the gill net values to another gear category where price per pound may be higher on average (Table 8 in the *Description of the Fishery* section). Over the last 10 years, the gill net fishery has accounted for a total of $22,293,674 of ex-vessel value from the southern flounder fishery (Table 4.5.6 in the *Recreational and Commercial Sector Allocation* issue paper). If large-mesh gill nets are no longer allowed to harvest southern flounder these values may shift to another gear. These effects are a guide as some license holders participate in multiple fisheries.

In terms of evaluating the economic impact of removing all inshore large-mesh gill nets from North Carolina, traditional methods of quantifying this change would not be adequate. Specifically, a change of this magnitude would no longer result in marginal shifts in landings from specific fisheries in the state. Rather, this regulation would likely lead to large-scale behavioral adjustments from a range of stakeholders in the seafood supply chain, causing market shifts, changes in spending and employment, and an overall reorganizing of the state's inshore fisheries. While there would likely be large benefits in certain facets, such as stock health and recreational access, the costs associated with restructuring part of the state's inshore fishing fleet are nearly impossible to predict and go beyond traditional economic impact assessments.

Impacts to the stock due to changes in gill net regulations can be difficult to quantify due to many factors including behavior shifts in the fishery participants. Luczkovich et al. (2021) developed a pair of socio-ecological model scenarios that showed differing impacts based on no additional effort using alternative gears and increasing effort using alternative gears in Core Sound, NC. If effort using alternative gears was not increased, the model predicted increases to the stock size, but if effort using alternative gears did increase the model predicted reductions to the stock size, depending on the behavior changes within the industry (Luczkovich et al. 2021). This study showed a species response to management actions can be contrary to management goals. That is, prohibiting the use of gill nets may alter the behavior of fishermen and make them use alternate gears with higher impacts on the target species or the ecosystem as a whole (Luczkovich et al. 2021).

VI. PROPOSED MANAGEMENT OPTIONS

Management Options

(+ potential positive impact of action)
(- potential negative impact of action)

Option 1. Phase out anchored large-mesh gill nets from the southern flounder fishery at the end of the current sea turtle ITP.

+ Would allow for increased harvest from other commercial gears
+ Would increase protections of threatened and endangered species
+ May increase the economic impact of the remaining gears
+ May reduce user conflict
+ May reduce costs associated with the large mesh observer program or allow increased coverage for other gears
+/- Gear elimination not based on sustainable harvest
+/- Would require adjusting the sub-allocations for the commercial fishery
+/- Would impact harvest of non-target species
- Would eliminate a historical gear from the southern flounder fishery
- Would impact the largest group by number of trips and participants in the commercial fishery
- Gill nets would still be allowed for other species so discards of southern flounder may still occur
- Would decrease the economic benefit of the commercial gill net fishery
- Some regions may be impacted more than others

Option 2. Status Quo, continue to allow anchored large-mesh gill nets to harvest southern flounder in the North Carolina southern flounder fishery.

+ Continued use of large-mesh gill net fishery to harvest southern flounder
+ Maintain economic impacts of the large-mesh gill net fishery
+ Less impacts to the largest user group in numbers and trips
+/- Continued harvest of non-target species
+/- Less impacts to sub-allocations
- Continued impacts to threatened and endangered species
- May not allow for increased harvest of other gears

VII. RECOMMENDATION

See Appendix 6 for a summary of all comments and recommendations gathered from NCDMF, the NCMFC advisory committees, and public for the Southern Flounder FMP Amendment 3.

NCMFC Preferred Management Strategy

Option 2. Status Quo, continue to allow anchored large-mesh gill nets to harvest southern flounder in the North Carolina southern flounder fishery.

VIII. LITERATURE CITED

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APPENDIX 6. SUMMARY OF NCDMF AND ADVISORY COMMITTEE RECOMMENDATIONS FOR ISSUE PAPERS IN DRAFT AMENDMENT 3 TO THE SOUTHERN FLOUNDER FISHERY MANAGEMENT PLAN

Table 6.1. NCDMF and MFC regional and standing committees recommendations and public review for Southern Flounder FMP Amendment 3, March 2022.

Issue paper recommendations	NCDMF	Northern Regional Advisory Committee - 1/11/22	Southern Regional Advisory Committee - 1/12/22	Finfish Standing Advisory Committee - 1/13/22	Public Questionnaire
Sustainable Harvest Issue Paper					
Commercial - quota	Implement a commercial quota through a mobile gear and pound net category with the mobile gears divided in to 2 areas at the B-D boundary line and the pound net fishery divided into 3 areas consistent with Amendment 2	Support the division's recommendation of Option 1.1.A and 1.2.A.	Accept the division recommendation option 1.1.A and 1.2.A.	Accept division recommendations Option 1.1.A and 1.2.A.	• Respondents who self-identified as recreational supported a single state-wide area for both mobile gears and pound nets • Respondents who self-identified as commercial supported three areas for both mobile gears and pound nets
Commercial - sub-allocation	Maintain the commercial pound net allocation as reductions occur through allocation changes	Support the division recommendation of Option 2.2 Maintain current sub-allocations for pound net fishery.	Accept the division recommendation of Option 2.2 Maintain current sub-allocation for pound net fishery.	Support Option 2.1 Sub-allocations based on 2017 landings.	Respondents supported dividing the gill net landings between the other mobile gears and pound nets.
Recreational Season - hook & line/gigs	Implement a recreational quota through a single recreational season	Support the division's recommendation on managing the recreational fishery by season.	Accept the division recommendation Option 3 recreational season.	Support the division recommendation Option 3 of a recreational season	Respondents supported managing the recreational fishery by a season
Commercial - trip limit	Allow the division to implement trip limits for the commercial pound net and gig fishery only as a way to reopen the fishery after initial closure	Support Option 4A: Implement trip limit for pound net and gigs upon reopening after reaching division closure threshold.	Accept the division recommendation Option 4A: Implement trip limit for pound net and gigs upon reopening after reaching division closure threshold.	Support Option 4C: Status quo, no trip limits.	• Respondents who self-identified as recreational supported trip limits. • Respondents who self-identified as commercial narrowly did not support trip limits. • Respondents who supported trip limits supported trip limits for all gears.
Recreational - bag limit	Reduce the recreational hook-and-line and gig fisheries bag limit to a 1-fish per person/per day	Support the division recommendation of Option 5.A 1 fish/person/day.	Support 1 fish/person/day bag limit if there was a considerably longer open season (during summer/fall).	Support division recommendation Option 5.A. 1 fish/person/day.	• Most respondents supported changing bag limits • Most respondents still supported 4 fish/person/day. The second most supported bag limit was 2 fish/person/day

Issue paper recommendations	NCDMF	Northern Regional Advisory Committee - 1/11/22	Southern Regional Advisory Committee - 1/12/22	Finfish Standing Advisory Committee - 1/13/22	Public Questionnaire
Recreational - RCGL	Prohibit RCGL holders from harvesting southern flounder	Follow the division recommendation Option 6B- prohibit use of RCGL to harvest flounder.	Support the division recommendation Option 6B: Prohibit use of RCGL to harvest flounder.	Support Option 6A: Allow RCGL to harvest flounder when commercial and recreational fisheries both open.	• Respondents who self-identified as recreational supported not allowing RCGL to harvest flounder • Respondents who self-identified as commercial supported allowing RCGL to harvest flounder when commercial and recreational fisheries both open
Increased Recreational Access Issue Paper	Allow an ocellated flounder season in the ocean using hook-and-line gear only from March 1 through April 15 with a 1 fish bag limit	Support Option1 status quo, manage as one group.	Support the division recommendation Option 2: 1-fish ocellated bag March 1-April 15 in ocean; 1-fish any species bag during southern flounder season.	Recommend the MFC design an ocean caught recreational ocellated flounder fishery that will not hinder the present southern flounder fishery established in Amendment 3.	Respondents did not support increasing recreational access through an ocellated season.
Inlet Corridors Issue Paper	Do not implement inlet corridors at this time	Support Option 1: Status quo, do not establish inlet corridors during spawning migration.	Maintain the ability to implement inlet corridors as adaptive management if research indicates it is appropriate.	Support Option 1: Status quo, do not establish inlet corridors during spawning migration.	• Respondents who self-identified as recreational supported implementing inlet corridors for all gears • Respondents who self-identified as commercial supported not implementing inlet corridors. If inlet corridors were implemented, commercial respondents supported them for specific gears only.
Adaptive Management Issue Paper	Adopt adaptive management framework for Amendment 3	Support Option 1- adaptive management framework.	Support the division recommendation to adopt an adaptive management framework.	No motion passed	Respondents supported adopting the adaptive management framework.
Slot Limits Issue Paper	Do not implement slot limits for flounder at this time	Support slot limits be considered as soon as the division has sufficient data on discard size distribution to inform the size of slot.	Support the division recommendation Option 1 status quo, no slot limit.	Support Option 1: Status quo, no slot limit.	• Most respondents did not support a slot limit. • Respondents that supported a slot limit supported a 15 – 19-inch slot.
Phase Out Large-Mesh Gill Nets Issue Paper	Allow harvest of southern flounder using commercial anchored large- mesh gill nets	Support Option 2: Status quo, allow large-mesh gill nets to harvest southern flounder during the commercial season.	No motion passed.	Support Option 2: Status quo, allow large-mesh gill nets to harvest southern flounder during the commercial season.	• Respondents who self-identified as recreational supported phasing out anchored large-mesh gill nets. • Respondents who self-identified as commercial supported not phasing out anchored large-mesh gill nets.