North Carolina
Striped Mullet
Fishery Management Plan

Amendment 1

By

North Carolina Department of Environment and Natural Resources

Division of Marine Fisheries
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1.0 ACKNOWLEDGMENTS

The 2014 North Carolina Striped Mullet Fishery Management Plan (FMP) Amendment 1 was developed by the North Carolina Department of Environment and Natural Resources Division of Marine Fisheries (NCDMF) under the direction of the North Carolina Marine Fisheries Commission (MFC) with the advice of the Finfish Advisory Committee acting as the Striped Mullet Advisory Committee (AC), the Plan Development Team (PDT), and the Rules Subcommittee who contributed their time and knowledge to this document.

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AC – Advisory Committee

AFSA – Anadromous Fish Spawning Areas

APAIS – Access Point Angler Intercept Survey

ASMA – Albemarle Sound Management Area

CAHA – Cape Hatteras

CAMA – Coastal Area Management Act

CHPP – Coastal Habitat Protection Plan

CHTS – Coastal Household Telephone Survey

CPI – Consumer Price Index

CRC – North Carolina Coastal Resources Commission

CRFL – Coastal Recreational Fishing License

DO – Dissolved oxygen

DENR – North Carolina Department of Environment and Natural Resources

EIS – Environmental Impact Statement

EMC – North Carolina Environmental Management Commission

EPA – United States Environmental Protection Agency

ESA – Endangered Species Act

F – Fishing Mortality

FL – Fork Length

FMP – Fishery Management Plan

FRA – Fisheries Reform Act

FSC – Federal species of concern

GS – General Statute

GSI – Gonadosomatic Index

HC – Hatteras Corridor

HCP – Habitat Conservation Plan

HQW – High Quality Waters

IWW – Intracoastal Waterway

In – Inches

ITP – Incidental Take Permit

lb – Pounds

M – Natural Mortality

MBTA – Migratory Bird Treaty Act

MFC – North Carolina Marine Fisheries Commission

MGNRA – Mainland Gill Net Restricted Area

Mm – Millimeters

MMPA – Marine Mammal Protection Act

MRFSS – Marine Recreational Fisheries Statistical Survey

MRIP – Marine Recreational Information Program

MSY – Maximum Sustainable Yield

NCAC – North Carolina Administrative Code

NCDCM – North Carolina Division of Coastal Management

NCDMF – North Carolina Division of Marine Fisheries

NCDWQ- North Carolina Division of Water Quality

NCDWR – North Carolina Division of Water Resources

NCSU – North Carolina State University

NCTTP – North Carolina Trip Ticket Program

NCWRC – North Carolina Wildlife Resources Commission

NMFS – National Marine Fisheries Service

NNCESS – Northern North Carolina Estuarine System Stock

NOAA – National Oceanic and Atmospheric Administration

NPDES – National Pollutant Discharge Elimination System

NSW – Nutrient Sensitive Waters

NSWS – Nutrient Sensitive Waters Strategy

OC – Ocracoke Corridor

OIC – Oregon Inlet Corridor

ORW – Outstanding Resource Waters

PAH – Polycyclic aromatic hydrocarbons

PCB – Polychlorinated biphenyls

PDT – Plan Development Team

PNA – Primary Nursery Area

PPT – Parts per thousand

PSGNRA – Pamlico Sound Gill Net Restricted Area

PSE – Proportional Standard Error

RCGL – Recreational Commercial Gear License

RDD – Random Digit Dialing

SAV – Submerged Aquatic Vegetation

SAB – South Atlantic Bight

SCAR – Scientific Council on Amphibians and Reptiles

SCFL – Standard Commercial Fishing License

SGNRA – Shallow Water Gill Net Restricted Area

SHA – Strategic Habitat Area

SL – Standard Length

SNCESS – Southern North Carolina Estuarine System Stock

SPR – Spawning Potential Ratio

SSB – Spawning Stock Biomass

SSNA – Special Secondary Nursery Area

STAC – Sea Turtle Advisory Committee

STSSN – Sea Turtle Stranding and Salvage Network

TED – Turtle Excluder Device

TL – Total Length

TNPA – Trawl Nets Prohibited Area

USACE – United States Army Corp of Engineers

USFWS – United States Fish and Wildlife Service

WS – Water Supply

YOY – Young-of-the-Year

3.0 EXECUTIVE SUMMARY

The North Carolina striped mullet commercial fishery harvests an average of 1.94 million lb per year (1994–2011) and is the largest striped mullet fishery along the east coast of the United States. The first North Carolina Striped Mullet Fishery Management Plan (FMP) was developed and approved by the North Carolina Marine Fisheries Commission (MFC) in April 2006 and reclassified the stock as viable. The goal of Amendment 1 of the North Carolina Striped Mullet FMP is to manage the striped mullet fishery to preserve the long-term viability of the resource that maintains sustainable harvest, maximizes the social and economic value, and considers the needs of all user groups. Plan objectives include: develop an objective management strategy that provides for conservation of the striped mullet resource and promotes sustainable harvest while considering the needs of all user groups; ensure the spawning stock is of sufficient capacity to prevent recruitment-overfishing; initiate, enhance, and/or continue studies to collect and analyze the socio-economic data of all user groups needed to properly monitor and manage the striped mullet fishery; promote the protection, enhancement, and restoration of critical habitats necessary for the striped mullet population; promote research to improve the understanding of striped mullet population dynamics and ecology to improve management of the striped mullet resource; and promote public awareness regarding the status and management of the North Carolina striped mullet stock.

A population assessment of the North Carolina striped mullet stock was conducted using the Stock Synthesis model, which incorporated data from commercial fisheries and three fishery-independent surveys from 1994 to 2011. Spawning stock biomass increased from 2003 through 2007 and has since declined. Recruitment has also declined in recent years, though a slight increase was observed in 2011. Fishing mortality (F) has increased in recent years, but F in the terminal year (F_{2011} = 0.437) was below both the fishing mortality target ($F_{35\%}$ = 0.566) and threshold ($F_{25\%}$ = 0.932). Based on these results, the stock is not undergoing overfishing. A poor stock-recruit relationship resulting in unreliable biomass-based reference points prevents determining if the stock is currently overfished. However, minimum and maximum landings thresholds of 1.13 million and 2.76 million lb have been established to monitor the striped mullet fishery. If landings fall below the minimum landings trigger or exceed the maximum landings trigger the NCDMF will initiate further analysis of the data to determine if a new stock assessment and/or interim management action is needed.

The proposed management strategy for the striped mullet fisheries in North Carolina is to: 1) optimize resource utilization over the long-term; 2) reduce user group conflicts; and 3) promote public education. The first strategy will be accomplished by protecting critical habitats, and monitoring stock status. To address user conflicts, a rule change will be made to limit how much of a waterway may be block by runaround, drift, and other non-stationary gill nets. Specific user conflict issues will continue to be dealt with on a case-by-case basis and management actions will be implemented to address specific fishery related problems. The North Carolina Division of Marine Fisheries (NCDMF) will work to enhance public information and education.

Issues addressed in formulating Amendment 1 of the management plan for North Carolina's striped mullet fishery included: 1) resolution of Newport River gill net attendance and 2) user group conflicts, and 3) updating the management framework for the N.C. striped mullet stock. Specific issues and recommendations are as follows:

1) Resolution of Newport River gill net attendance: The management recommendation to have the "permanent shrimp line" in the Newport River located from the Hardesty Farm subdivision to Penn Point was unanimously supported during the 2006 Shrimp FMP and was implemented by adding it to the Trawl Net Prohibited Area (TNPA) rule. In 2011, the Newport River TNPA was added to the attended gill net areas in N.C. Marine Fisheries Commission Rule 15A NCAC .03R .0112 (b) (1). Marine Patrol has been enforcing the attended gill net rule in a manner that only requires small mesh gill net attendance in the Newport River TNPA from May 1 through September 30, allowing the striped mullet fishery to occur. The NCDMF recommneds a rule change to remove the Newport River TNPA from the attended gill net areas in N.C. Marine Fisheries Commission Rule 15A NCAC 03R .0112 (b) (1) but leave it subject to 03R .0112 (b) (5), which requires small mesh gill net attendance from May 1 through September 30.

2) User group conflicts: There are documented conflicts between boaters, commercial fishermen, shoreline residents, and recreational fishermen. The broad issue of user group conflicts affects many of the fisheries in North Carolina. The specific issue under the purview of Amendment 1 to the Striped Mullet FMP is determining management measures to reduce conflicts occurring in confined creeks and in the vicinity of docks and marinas between shoreline residents, recreational hook-and-line fishermen, and commercial runaround gill net fishermen. Any new measures enacted are not resource-related and should be considered only as conflict resolution measures. The NCDMF recommends a rule change to N.C. Marine Fisheries Commission Rule 15A NCAC 03J .0103 to make it unlawful for runaround, drift, or other non-stationary gill nets to block more than two-thirds of any natural or manmade waterway or in a location where it will interfere with navigation or other traditional uses of the area.

3) Updating management framework for the N.C. striped mullet stock: The original 2006 Striped Mullet FMP adopted a fishing mortality overfishing threshold of $F_{25\%}$ spawning potential ratio (SPR) and a fishing mortality target of $F_{30\%}$ SPR and determined overfishing was not occurring (NCDMF 2006). The FMP also established minimum and maximum commercial landings triggers that if exceeded would prompt a reassessment of the striped mullet stock before the normal five-year review outlined in statute as required by the Fisheries Reform Act. In Amendment 1, the NCDMF recommends updating the minimum and maximum commercial landings triggers to 1.13 and 2.76 million lb, respectively, raising the fishing mortality target from $F_{30\%}$ SPR to $F_{35\%}$ SPR, and implement adaptive management.

4.0 INTRODUCTION

4.1 RECOMMENDED MANAGEMENT PROGRAM

4.1.1 Management Authority

Fisheries management includes all activities associated with maintenance, improvement, and utilization of the fisheries resources of the coastal area, including research, development, regulation, enhancement, and enforcement.

All authority for management of North Carolina's striped mullet fishery is vested in the State of North Carolina. Management of the striped mullet fishery includes all activities associated with maintenance, improvement, and utilization of the striped mullet population and their habitats in the coastal area, including research, development, regulation, enhancement, and enforcement. Most striped mullet harvest occurs from coastal waters and is under rules of the North Carolina Marine Fisheries Commission (MFC); there is limited harvest from inland waters under the jurisdiction of the North Carolina Wildlife Resources Commission. However, the North Carolina Department of Environment and Natural Resources (DENR) is the agency directed by North Carolina General Statute 113-182.1 (G.S. 113-182.1) to prepare Fishery Management Plans for all commercially or recreationally significant species or fisheries that comprise State marine or estuarine resources. These plans must be approved and adopted by the MFC.

Many different state laws (General Statutes – G.S.) provide the necessary authority for fishery management in North Carolina. General authority for stewardship of the marine and estuarine resources by the DENR is provided in G.S. 113-131. The NCDMF is the branch of the DENR that carries out this responsibility. G.S. 113-136 provides enforcement authority for NCDMF Marine Patrol officers. General Statute 113-181 authorizes research and statistical programs. The MFC is charged to "manage, restore, develop, cultivate, conserve, protect, and regulate the marine and estuarine resources of the State of North Carolina" (G.S. 143B-289.51). The MFC can regulate fishing times, areas, fishing gear, seasons, size limits, and quantities of fish harvested and possessed (G.S. 113-182 and 143B-289.52). General Statute 143B-289.52 allows the MFC to delegate authority to implement its regulations for fisheries "which may be affected by variable conditions" to the Director of NCDMF by issuing public notices called "proclamations". Thus, North Carolina has a very powerful and flexible legal basis for coastal fisheries management. The General Assembly has retained for itself the authority to establish commercial fishing licenses and permit fees greater than $100. It has delegated to the MFC authority to establish permits for various commercial fishing activities.

The Fisheries Reform Act of 1997 (FRA) establishes a process for preparation of coastal fishery management plans in North Carolina (G.S. 113-182.1.) The FRA has been amended several times. The FRA states that "the goal of the plans shall be to ensure the long-term viability of the State's commercially and recreationally significant species or fisheries. Each plan shall be designed to reflect fishing practices so that one plan may apply to a specific fishery, while other plans may be based on gear or geographic areas. Each plan shall:

1) Contain necessary information pertaining to the fishery or fisheries, including management goals and objectives, status of relevant fish stocks, stock assessments for multiyear species, fishery habitat and water quality considerations consistent with Coastal Habitat Protection Plans adopted pursuant to G.S. 143B-279.8, social and economic impact of the fishery to the State, and user conflicts.

2) Recommend management actions pertaining to the fishery or fisheries.
3) Include conservation and management measures that will provide the greatest overall benefit to the State, particularly with respect to food production, recreational opportunities, and the protection of marine ecosystems, and that will produce a sustainable harvest.
4) Repealed by Session Laws 2010-13, s. 1, effective June 23, 2010.
5) Specify a time period, not to exceed two years from the date of the adoption of the plan, to end overfishing. This subdivision shall not apply if the Fisheries Director determines that the biology of the fish, environmental conditions, or lack of sufficient data make implementing the requirements of this subdivision incompatible with professional standards for fisheries management.
6) Specify a time period, not to exceed 10 years from the date of the adoption of the plan, for achieving a sustainable harvest. This subdivision shall not apply if the Fisheries Director determines that the biology of the fish, environmental conditions, or lack of sufficient data make implementing the requirements of this subdivision incompatible with professional standards for fisheries management.
7) Include a standard of at least fifty percent (50%) probability of achieving sustainable harvest for the fishery or fisheries. This subdivision shall not apply if the Fisheries Director determines that the biology of the fish, environmental conditions, or lack of sufficient data make implementing the requirements of this subdivision incompatible with professional standards for fisheries management." (G.S. 113-182.1)

Sustainable harvest is defined in the FRA (§ 113-129) as "the amount of fish that can be taken from a fishery on a continuing basis without reducing the stock biomass of the fishery or causing the fishery to become overfished". Overfished is defined as the condition of a fishery that occurs when the spawning stock biomass of the fishery is below the level that is adequate to replace the spawning class of the fishery. Overfishing is defined as fishing that causes a level of mortality that prevents a fishery from producing a sustainable harvest (G.S. 113-129).

4.1.2 Goal and Objectives

The goal of Amendment 1 to the North Carolina Striped Mullet FMP is to manage the striped mullet fishery to preserve the long-term viability of the resource that maintains sustainable harvest, maximizes the social and economic value, and considers the needs of all user groups. The following objectives will be used to achieve this goal.

Objectives:
1) Use a management strategy that provides for conservation of the striped mullet resource and promotes sustainable harvest while considering the needs of all user groups.
2) Promote the protection, enhancement, and restoration of habitats and water quality necessary for the striped mullet population.
3) Minimize conflict among user groups, including non-fishing user groups and activities.
4) Promote research to improve the understanding of striped mullet population dynamics and ecology to improve management of the striped mullet resource.
5) Initiate, enhance, and/or continue studies to collect and analyze the socio-economic data needed to properly monitor and manage the striped mullet fishery.
6) Promote public awareness regarding the status and management of the North Carolina striped mullet stock.

4.1.3 Sustainable Harvest

Sustainable harvest will be achieved with a commercial fishing mortality threshold and target based on $F_{25\%}$ SPR and $F_{35\%}$ SPR. Fishing mortality has been at or below the target since 1999.

4.1.4 Management Strategy

The proposed management strategy for the striped mullet fisheries in North Carolina is to: 1) optimize resource utilization over the long-term; 2) reduce user group conflicts; and 3) promote public education. The first strategy will be accomplished by protecting critical habitats and monitoring stock status. To address user conflicts, a rule change will made to limit how much of a waterway may be block by runaround, drift, and other non-stationary gill nets. Specific user conflict issues will continue to be dealt with on a case-by-case basis and management actions will be implemented to address specific fishery related problems. The NCDMF will work to enhance public information and education.

4.1.5 Research Needs

4.1.5.1 NCDMF Data Gathering

- Increase sampling of the commercial bait mullet cast net fishery to improve the estimates of striped mullet and white mullet harvest (Low).
- Increase the number of age samples from both fisheries-dependent and fisheries-independent sources (Medium).
- Restart fishery-independent cast net sampling (NCDMF Program 121) to improve estimates of the proportion of striped mullet and white mullet in this fishery (Low).
- Initiate a fishery-independent adult striped mullet survey in the Core and Bogue sound areas where approximately 20% of the striped mullet harvest occurs (High).
- Analyze the data from the CRFL recreational cast net and seine survey to better characterize the recreational striped mullet fishery, including the social and economic elements (Low).

4.1.5.2 Biological

- Improve recreational fisheries statistics provided by the Marine Recreational Information Program (MRIP; formerly MRFSS) or some other program to reliably characterize the magnitude and length and age structure of recreational fisheries losses (Low).
- Develop a reliable fisheries-independent index of juvenile abundance (High).
- Investigate how catch-ability of striped mullet by NCDMF Program 146 is affected by variations in salinity and conductivity and expand survey to other coastal rivers and tributaries (Medium).
- Initiate a plankton survey covering all inlets to determine inlet use by striped mullet (Low).
- Initiate a tagging program to provide estimates of stock size, F, and M that are not dependent on assumptions about steepness (High).
- Initiate a study to estimate fecundity and update the current maturity schedule microscopically (Medium).
- Investigate the disappearance of males from the population after age-3 (300mm FL) (Low).
- Initiate an acoustic tagging study to determine spatial and temporal variations in habitat use throughout the state to help provide better indices for stock assessments (Low).

- Initiate a survey to estimate RCGL landings of striped mullet in order to estimate recreational landings, as well as the social and economic elements of the striped mullet fishery (Medium).

4.1.5.3 Education

- Implement public outreach on waste reduction of striped mullet in the commercial and recreational fisheries (Low).

4.1.5.4 Habitat and Water Quality

- Specific recommendations for habitat and water quality can be found in the CHPP (Deaton et al. 2010). The CHPP is currently undergoing revisions and is expected to be completed in 2015. Updated research recommendations for improving habitat and water quality can be found there once completed.

4.2 GENERAL PROBLEM(S) STATEMENT

4.2.1 Resolution of Newport River Gill Net Attendance

The management recommendation to have the "permanent shrimp line" in the Newport River located from the Hardesty Farm subdivision to Penn Point was unanimously supported during the 2006 Shrimp FMP and was implemented by adding it to the Trawl Net Prohibited Area (TNPA) rule. In 2011, the Newport River TNPA was added to the attended gill net areas in Rule 15A NCAC .03R .0112 (b) (1). Marine Patrol has been enforcing the attended gill net rule in a manner that only requires small mesh gill net attendance in the Newport River TNPA from May 1 through September 30, allowing the striped mullet fishery to occur. The Shrimp FMP Plan Development Team (PDT) recommended a rule change be pursued to remove the Newport River TNPA from the attended gill net areas in Rule 15A NCAC 03R .0112 (b) (1) but leave it subject to 03R .0112 (b) (5), which requires small mesh gill net attendance from May 1 through September 30.

4.2.2 User Conflicts

There are documented conflicts between boaters, commercial fishermen, shoreline residents, and recreational fishermen. The broad issue of user group conflicts affects many of the fisheries in North Carolina. Under the purview of Amendment 1 to the Striped Mullet FMP, is determining management measures to reduce conflicts occurring in confined creeks and in the vicinity of docks and marinas between shoreline residents, recreational hook-and-line fishermen, and commercial runaround gill net fishermen. New measures are not resource-related and should be considered only as conflict resolution measures.

4.2.3 Updating Management Framework for North Carolina Striped Mullet Stock

The original 2006 Striped Mullet FMP adopted a fishing mortality overfishing threshold of F25% spawning potential ratio (SPR) and a fishing mortality target of F30% SPR and determined overfishing was not occurring (NCDMF 2006). The FMP also established minimum and maximum commercial landings triggers that if exceeded would prompt a reassessment of the striped mullet stock before the normal five-year review outlined in statute as required by the Fisheries Reform Act. Amendment 1 considers updating the minimum and maximum commercial landings triggers (set two standard deviations above and below the average commercial landings using commercial landings from 1994–2011, raising the fishing mortality target to $F_{35\%}$ SPR, and implement adaptive management.

4.3 DEFINITION OF MANAGEMENT UNIT

Most tagging studies show limited distances between tagging and recapture locations for adult striped mullet (Idyll and Sutton 1951; Broadhead and Mefford 1956; Collins 1985a; Mahmoudi et al. 2001; McDonough 2001; Wong 2001). Ninety percent of recaptures occurred within 20 miles of the tagging location in Florida (Idyll and Sutton 1951; Broadhead and Mefford 1956), while 91% of recaptures were found within 52 miles of the release site in North Carolina (Wong 2001). Mahmoudi et al. (2001) noted that the majority of adults in Florida were recaptured in the same system in which they were tagged. Low percentages of out-of-state recaptures in North Carolina and South Carolina (1.8 and 9%) suggest that striped mullet stocks are fairly residential to native states. Therefore, the management unit for the North Carolina striped mullet FMP includes all striped mullet within the coastal and joint waters of North Carolina.

4.4 EXISTING PLANS, STATUTES, AND RULES

4.4.1 Plans

Currently, North Carolina and Florida are the only states along the U.S. Atlantic Coast that conduct stock assessments of striped mullet for management use.

4.4.2 Statutes

In 2006, the NCDMF Striped Mullet FMP was finalized for striped mullet in joint and coastal waters of North Carolina. The major 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. Statutes that have been applied to the striped mullet fishery include:

- It is unlawful to use a spotter plane directed at food fish, except in connection with a purse seine operation authorized by a rule of the MFC. G.S. 113-171.1(c)
- 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. G.S. 113-185(a)
- 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 MFC'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. G.S. 113-185(b)
- 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. G.S. 113-268(a)
- 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. G.S. 113-268(b)
- 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. G.S. 113-268(c)

4.4.3 Marine Fisheries Commission Rules

The following rules adopted by the MFC affect management of the striped mullet stock in North Carolina. The version of the rules shown below is taken from North Carolina Marine Fisheries Commission Rules effective June 1, 2013, including its April 1, 2014 supplement. These rules are codified in Title 15A (Environment and Natural Resources) Chapter 03 (Marine Fisheries) of the North Carolina Administrative Code (15A NCAC 03).

SUBCHAPTER 03I - GENERAL RULES

SECTION .0100 - GENERAL RULES

15A NCAC 03I .0108 OCEAN FISHING PIERS

(a) It is unlawful to fish with nets of any kind or from boats within the zone adjacent to any ocean fishing pier meeting the requirements of G.S. 113-185(a), if such zone is marked by one of the following methods or a combination of methods:

(1) Yellow range poles at least three inches in diameter and extending not less than six feet above the surface of the ground, and which are parallel to the pier and identified by signs with the name of the pier printed in letters at least three inches high; or

(2) Buoys, which shall be yellow in color and not less than nine inches in diameter and extend no less than three feet above the surface of the water.

(b) It is unlawful to define a zone that extends more than 750 feet from the pier. When a marking system defines a smaller area than authorized, the limitations on fishing activities shall apply within the marked zone. When the marking system does not include buoys placed seaward of the pier's offshore end, the zone protected under G.S. 113-185 shall be limited to the areas parallel to the sides of the pier and shall include no area seaward of the offshore end of the pier.

(c) Owners of qualifying ocean piers shall be responsible for complying with all applicable local, state and federal regulations for marking systems.

History Note: Authority G.S. 113-134; 113-181; 113-182; 143B-289.52;
Eff. January 1, 1991;
Recodified from 15A NCAC 3I .0008 Eff. December 17, 1996.

SUBCHAPTER 03J – NETS, POTS, DREDGES, AND OTHER FISHING DEVICES

SECTION .0100 – NET RULES, GENERAL

15A NCAC 03J .0101 FIXED OR STATIONARY NETS

It is unlawful to use or set fixed or stationary nets:

(1) In the channel of the Intracoastal Waterway or in any other location where it may constitute a hazard to navigation;

(2) So as to block more than two-thirds of any natural or manmade waterway, sound, bay, creek, inlet or any other body of water;

(3) In the middle third of any marked navigation channel;

(4) In the channel third of the following rivers: Roanoke, Cashie, Middle, Eastmost, Chowan, Little, Perquimans, Pasquotank, North, Alligator, Pungo, Pamlico, and Yeopim.

History Note: Authority G.S. 113-134; 113-182; 143B-289.52;
Eff. January 1, 1991.

15A NCAC 03J.0103 GILL NETS, SEINES, IDENTIFICATION, RESTRICTIONS

(a) It is unlawful to use a gill net:

(1) With a mesh length less than 2½ inches.

(2) In internal waters from April 15 through December 15, with mesh length of 5 inches or greater and less than 5 ½ inches.

(b) The Fisheries Director may, by proclamation, limit or prohibit the use of gill nets or seines in coastal waters, or any portion thereof, or impose any or all of the following restrictions on gill net or seine fishing operations:

(1) Specify area.

(2) Specify season.

(3) Specify gill net mesh length.

(4) Specify means/methods.

(5) Specify net number and length.

(c) It is unlawful to use fixed or stationary gill nets in the Atlantic Ocean, drift gill nets in the Atlantic Ocean for recreational purposes, or any gill nets in internal waters unless nets are marked by attaching to them at each end two separate yellow buoys which shall be of solid foam or other solid buoyant material no less than five inches in diameter and no less than five inches in length. Gill nets which are not connected together at the top line shall be considered as individual nets, requiring two buoys at each end of each individual net. Gill nets connected together at the top line shall be considered as a continuous net requiring two buoys at each end of the continuous net. Any other marking buoys on gill nets used for recreational purposes shall be yellow except one additional buoy, any shade of hot pink in color, constructed as specified in this paragraph, shall be added at each end of each individual net. Any other marking buoys on gill nets used in commercial fishing operations shall be yellow except that one additional identification buoy of any color or any combination of colors, except any shade of hot pink, may be used at either or both ends. The owner shall always be identified on a buoy on each end either by using engraved buoys or by attaching engraved metal or plastic tags to the buoys. Such identification shall include owner's last name and initials and if a vessel is used, one of the following:

(1) Owner's N.C. motor boat registration number, or

(2) Owner's U.S. vessel documentation name.

(d) It is unlawful to use gill nets:

(1) Within 200 yards of any flounder or other finfish pound net with lead and pound or heart in use, except from August 15 through December 31 in all coastal fishing waters of the Albemarle Sound, including its tributaries to the boundaries between coastal and joint fishing water, west of a line beginning at a point 36° 04.5184’ N - 75° 47.9095’ W on Powell Point; running southerly to a point 35° 57.2681’ N - 75° 48.399’ W on Caroon Point, it is unlawful to use gill nested within 500 yards of any pound net set with lead and either pound or heart in use.

(2) From March 1 through October 31 in the Intracoastal Waterway within 150 yards of any railroad or highway bridge.

(e) It is unlawful to use gill nets within 100 feet either side of the center line of the Intracoastal Waterway Channel south of in the entrance to Alligator-Pungo River canal near beacon “54” in Alligator River to the South Carolina line, unless such net is used in accordance with the following condition:

(1) No more than two gill nets per boat may be used at any one time;

(2) Any net used must be attended by the fisherman from a boat who shall at no time be more than 100 yards from either net; and

(3) Any individual setting such nets shall remove them, when necessary, in sufficient time to permit unrestricted boat navigation.

(f) It is unlawful to use drift gill nets in violation of 15A NCAC 03J .0101(2) and Paragraph (e) of this Rule.
(g) It is unlawful to use unattended gill nets with a mesh length less than five inches in a commercial fishing operation in the gill net attended areas designates in 15A NCAC 03R .0112(a).
(h) It is unlawful to use unattended gill nets with a mesh length less than five inches in a commercial fishing operation from May 1 through October 31 in the internal coastal and joint waters of the state designated in 15A NCAC 03R .0112(b).
(i) For gill nets with a mesh length of five inches or greater, it is unlawful:

(1) To use more than 3,000 yards of gill net per vessel in internal waters regardless of the number of individuals involved.

(2) From June through October, for any portion of the net to be within 10 feet of any point on the shoreline while set and deployed, unless the net is attended.

(j) For the purpose of this Rule and 15A NCAC 03R .0112, shoreline is defined as the mean high water line or marsh line, whichever is more seaward.

History Note: Authority G.S. 113-134; 113-173; 113-182; 113-221; 143B-289.52
Eff. January 1, 1991;
Amended Eff. August 1, 1998; March 1, 1996; March 1, 1994; July 1, 1993; September 1, 1991;
Temporary Amendment Eff. October 2, 1999; July 1, 1999; October 22, 1998;
Amended Eff. April 1, 2001.
Temporary Amendment Eff. May 1, 2001;
Amended Eff. April 1, 2009; December 1, 2007; September 1, 2005; August 1, 2004; August 1, 2002.

15A NCAC 03J.0110 SEINES

It is unlawful to use seines 30 feet or over in length for recreational purposes unless the net is marked by attaching to the corkline one floating buoy, any shade of hot pink in color, which shall be solid foam or other solid buoyant material no less than five inches in diameter and no less than five inches in diameter and no less than five inches in length. The owner shall always be identified on the buoy using engraved buoys or by attaching engraved metal or plastic tags to the buoy. Such identification shall include owner's last name and initials and if a vessel is used, one of the following:

(1) Gear owner's current motor boat registration number; or

(2) Owner's U.S. vessel documentation name.

History Note: Authority G.S. 113-134; 113-173; 113-182; 143B-289.52;
Temporary Adoption Eff. July 1, 1999;
Eff. August 1, 2000.

SECTION .0300 - POTS, DREDGES, AND OTHER FISHING DEVICES

15A NCAC 03J .0301 POTS

(a) It is unlawful to use pots except during time periods and in areas specified herein:

(1) In Coastal Fishing Waters from December 1 through May 31, except that all pots shall be removed from internal waters from January 15 through February 7. Fish pots upstream of U.S. 17 Bridge across Chowan River and upstream of a line across the mouth of Roanoke, Cashie, Middle and Eastmost Rivers to the Highway 258 Bridge are exempt from the January 15 through February 7 removal requirement. The Fisheries Director may, by proclamation, reopen

various waters to the use of pots after January 19 if it is determined that such waters are free of pots.

(2) From June 1 through November 30, north and east of the Highway 58 Bridge at Emerald Isle:

(A) In areas described in 15A NCAC 03R .0107(a);

(B) To allow for the variable spatial distribution of crustacea and finfish, the Fisheries Director may, by proclamation, specify time periods for or designate the areas described in 15A NCAC 03R .0107(b); or any part thereof, for the use of pots.

(3) From May 1 through November 30 in the Atlantic Ocean and west and south of the Highway 58 Bridge at Emerald Isle in areas and during time periods designated by the Fisheries Director by proclamation.

The Fisheries Director may, by proclamation authority established in 15A NCAC 03L .0201, further restrict the use of pots to take blue crabs.

(b) It is unlawful to use pots:

(1) in any navigation channel marked by State or Federal agencies; or

(2) in any turning basin maintained and marked by the North Carolina Ferry Division.

(c) It is unlawful to use pots in a commercial fishing operation unless each pot is marked by attaching a floating buoy which shall be of solid foam or other solid buoyant material and no less than five inches in diameter and no less than five inches in length. Buoys may be of any color except yellow or hot pink or any combination of colors that include yellow or hot pink. The owner shall always be identified on the attached buoy by using engraved buoys or by engraved metal or plastic tags attached to the buoy. Such identification shall include one of the following:

(1) gear owner's current motorboat registration number; or

(2) gear owner's U.S. vessel documentation name; or

(3) gear owner's last name and initials.

(d) Pots attached to shore or a pier shall be exempt from Subparagraphs (a)(2) and (a)(3) of this Rule.

(e) It is unlawful to use shrimp pots with mesh lengths smaller than one and one-fourth inches stretch or five-eighths-inch bar.

(f) It is unlawful to use eel pots with mesh sizes smaller than one inch by one-half inch unless such pots contain an escape panel that is at least four inches square with a mesh size of one inch by one-half inch located in the outside panel of the upper chamber of rectangular pots and in the rear portion of cylindrical pots, except that not more than two eel pots per fishing operation with a mesh of any size may be used to take eels for bait.

(g) It is unlawful to use crab pots in coastal fishing waters unless each pot contains no less than two unobstructed escape rings that are at least two and five-sixteenths inches inside diameter and located in the opposite outside panels of the upper chamber of the pot, except the following are exempt from the escape ring requirements:

(1) unbaited pots;

(2) pots baited with a male crab; and

(3) pots set in areas and during time periods described in 15A NCAC 03R .0118.

(h) The Fisheries Director may, by proclamation, exempt the escape ring requirements described in Paragraph (g) of this Rule in order to allow the harvest of mature female crabs and may impose any or all of the following restrictions:

(1) specify areas;

(2) specify time periods; and

(3) specify means and methods.

(i) It is unlawful to use more than 150 crab pots per vessel in Newport River.

(j) It is unlawful to remove crab pots from the water or remove crabs from crab pots between one hour after sunset and one hour before sunrise.

(k) User Conflicts:

(1) In order to address user conflicts, the Fisheries Director may by proclamation impose any or all of the following restrictions:
   (A) specify areas;
   (B) specify time periods; and
   (C) specify means and methods.

   The Fisheries Director shall hold a public meeting in the affected area before issuance of such proclamation.

(2) Any person(s) desiring user conflict resolution may make such request in writing addressed to the Director of the Division of Marine Fisheries, P.O. Box 769, 3441 Arendell St., Morehead City, North Carolina 28557-0769. Such requests shall contain the following information:
   (A) a map of the affected area including an inset vicinity map showing the location of the area with detail sufficient to permit on-site identification and location;
   (B) identification of the user conflict causing a need for user conflict resolution;
   (C) recommended solution for resolving user conflict; and
   (D) name and address of the person(s) requesting user conflict resolution.

(3) Upon the requestor's demonstration of a user conflict to the Fisheries Director and within 90 days of the receipt of the information required in Subparagraph (k)(2) of this Rule, the Fisheries Director shall issue a public notice of intent to address a user conflict. A public meeting shall be held in the area of the user conflict. The requestor shall present his or her request at the public meeting, and other parties affected may participate.

(4) The Fisheries Director shall deny the request or submit a proclamation that addresses the results of the public meeting to the Marine Fisheries Commission for their approval.

(5) Proclamations issued under Subparagraph (k)(1) of this Rule shall suspend appropriate rules or portions of rules under 15A NCAC 03R .0107 as specified in the proclamation. The provisions of 15A NCAC 03I .0102 terminating suspension of a rule pending the next Marine Fisheries Commission meeting and requiring review by the Marine Fisheries Commission at the next meeting shall not apply to proclamations issued under Subparagraph (k)(1) of this Rule.

(l) It is unlawful to use pots to take crabs unless the line connecting the pot to the buoy is non-floating.

(m) It is unlawful to use pots with leads or leaders to take shrimp. For the purpose of this Rule, leads or leaders are defined as any fixed or stationary net or device used to direct fish into any gear used to capture fish. Any device with leads or leaders used to capture fish is not a pot.

History Note: Authority G. S. 113-134; 113-173; 113-182; 113-221.1; 143B-289.52;
Eff. January 1, 1991;
Amended Eff. August 1, 1998; May 1, 1997; March 1, 1996; March 1, 1994; October 1, 1992; September 1, 1991;
Temporary Amendment Eff. July 1, 1999;
Amended Eff. August 1, 2000;
Temporary Amendment Eff. September 1, 2000;
Amended Eff. April 1, 2014; September 1, 2005; August 1, 2004; August 1, 2002.

SECTION .0400 – FISHING GEAR

15A NCAC 03J.0401 FISHING GEAR

(a) The Fisheries Director in order to address issues involving user conflict may, by proclamation, close the areas described in Paragraph (b) of this Rule to the use of specific fishing gear.

(b) It is unlawful to use fishing gear as specified by proclamation at the time and dates specified in the proclamation between the Friday before Easter through December 31 in the following areas when such areas have been closed by proclamation:

(1) All or part of the Atlantic Ocean, up to one-half mile from the beach;
(2) Up to one-half mile in all directions of Oregon inlet;
(3) Up to one-half mile in all directions of Hatteras Inlet;
(4) Up to one-half mile in all directions of Ocracoke Inlet;
(5) Up to one-half mile of the Cape Lookout Rock Jetty;
(6) Up to one-half mile in all directions of fishing piers open to the public;
(7) Up to one-half mile in all directions of State Parks;
(8) Up to one-half mile of marinas as defined by the Coastal Resources Commission.

(c) The Fisheries Director shall specify in the proclamation the boundaries of the closure through the use of maps, legal descriptions, prominent landmarks or other permanent type markers.

(d) The Fisheries Director shall hold a public meeting in the affected areas before issuance of proclamations authorized by this Rule.

History Note: Authority G.S. 113-133; 113-134; 113-182; 113-221; 143B-289.52
Eff. July 1, 1993;
Amended Eff. June 1, 1996; March 1, 1995; October 1; 1993.

15A NCAC 03J.0402 FISHING GEAR RESTRICTIONS

(a) It is unlawful to use commercial fishing gear in the following areas during dates and times specified for the identified areas:

(1) Atlantic Ocean - Dare County:
(A) Nags Head:
(i) Seines and gill nets may not be used from the North Town Limit of Nags Head at Eight Street southward to Gulf Street:
(I) From Wednesday through Saturday of the week of the Nags Head Surf Fishing Tournament held during October of each year the week prior to Columbus Day.
(II) From November 1 through December 15.
(ii) Commercial fishing gear may not be used within 750 feet of licensed fishing piers when open to the public.
(B) Oregon Inlet. Seines and gill nets may not be used from the Friday before Easter through December 31:
(i) Within one-quarter mile of the beach from the National Park Service Ramp #4 (35° 48.2500' N - 75° 32.7000' W) on Bodie Island to the northern terminus of the Bonner Bridge (35° 46.5000' N - 75° 32.3666' W) on Hwy. 12 over Oregon Inlet.
(ii) Within the area known locally as "The Pond", a body of water generally located to the northeast of the northern terminus of the Bonner Bridge.

(C) Cape Hatteras (Cape Point). Seines and gill nets may not be used within one-half mile of Cape Point from the Friday before Easter through December 31. The closed area is defined by a circle with a one half mile radius having the center near Cape Point at 35° 12.9000’ N - 75° 31.7166’ W.

(2) Atlantic Ocean - Onslow and Pender Counties. Commercial fishing gear may not be used during the time specified for the following areas:

A) Topsail Beach. From January 1 through December 31, that area around Jolly Roger Fishing Pier bordered on the offshore side by a line 750 feet from the end of the pier and on the northeast and southwest by a line beginning at a point on the beach one-quarter mile from the pier extending seaward to intersect the offshore boundary.

(B) Surf City:

(i) From January 1 to June 30, those areas around the Surf City Fishing Pier bordered on the offshore side by a line 750 feet from the end of the pier, on the southwest by a line beginning at a point on the beach one-quarter mile from the pier and on the northeast by a line beginning at a point on the beach 750 feet from the pier extending seaward to intersect the offshore boundaries.

(ii) From July 1 to December 31, those areas around the pier bordered on the offshore side by a line 750 feet from the end of the pier, on the southwest by a line beginning at a point on the beach 750 feet from the pier and on the northeast by a line beginning at a point on the beach one-quarter mile from the piers extending seaward to intersect the offshore boundaries.

(3) Atlantic Ocean - New Hanover County. Carolina Beach Inlet through Kure Beach. Commercial fishing gear may not be used during the times specified for the following areas:

(A) From the Friday before Easter to November 30, within the zones adjacent to the Carolina Beach and Kure Beach Fishing Piers bordered on the offshore side by a line 750 feet from the ends of the piers and on the north and south by a line beginning at a point on the beach one-quarter mile from the pier extending seaward to intersect the offshore boundary, except the southern boundary for Kure Beach Pier is a line beginning on the beach one mile south of the pier to the offshore boundary for the pier.

(B) From May 1 to November 30, within 900 feet of the beach, from Carolina Beach Inlet to the southern end of Kure Beach with the following exceptions:

(i) From one-quarter mile north of Carolina Beach Fishing pier to Carolina Beach Inlet from October 1 to November 30:

(I) Strike nets may be used within 900 feet of the beach;

(II) Attended nets may be used between 900 feet and one-quarter mile of the beach.

(ii) Strike nets and attended gill nets may be used within 900 feet of the beach from October 1 to November 30 in other areas except those described in Part (a)(3)(A) and Subpart (a)(3)(B)(i) of this Rule.

(iii) It is unlawful to use commercial fishing gear within 900 feet of the beach from Carolina Beach Inlet to a point on the beach 33° 55.0026’N - 77° 56.6630’ W near the former location of New Inlet during the October surf fishing tournament in Carolina Beach.

(4) Pamlico River – Beaufort County. Goose Creek State Park. Commercial fishing gear may not be used from the Friday before Easter through December 31 for the following areas:

(A) Within 150 feet of the shoreline within park boundaries;
(B) Within the marked channel from Dinah Landings to the mouth of Upper Goose Creek.

(b) It is unlawful to use gill nets or seines in the following areas during dates and times specified for the identified areas:

(1) Neuse River and South River, Carteret County. No more than 1,200 feet of gill net(s) having a stretched mesh of five inches or larger may be used:
   (A) Within one-half mile of the shore from Winthrop Point at Adams Creek to Channel Marker "2" at the mouth of Turnagain Bay.
   (B) Within South River.
(2) Cape Lookout, Carteret County:
   (A) Gill nets or seines may not be used in the Atlantic Ocean within 300 feet of the Rock Jetty (at Cape Lookout between Power Squadron Spit and Cape Point).
   (B) Seines may not be used within one-half mile of the shore from Power Squadron Spit south to Cape Point and northward to Cape Lookout Lighthouse including the area inside the "hook" south of a line from the COLREGS Demarcation Line across Bardens Inlet to the eastern end of Shackleford Banks and then to the northern tip of Power Squadron Spit from 12:01 a.m. Saturdays until 12:01 a.m. Mondays from May 1 through November 30.
(3) State Parks/Recreation Areas:
   (A) Gill nets or seines may not be used in the Atlantic Ocean within one-quarter mile of the shore at Fort Macon State Park, Carteret County.
   (B) Gill nets or seines may not be used in the Atlantic Ocean within one-quarter mile of the shore at Hammocks Beach State Park, Onslow County, from May 1 through October 1, except strike nets and attended gill nets may be used beginning August 15.
   (C) Gill nets or seines may not be used within the boat basin and marked entrance channel at Carolina Beach State Park, New Hanover County.
(4) Mooring Facilities/Marinas. Gill nets or seines may not be used from May 1 through November 30 within:
   (A) One-quarter mile of the shore from the east boundary fence to the west boundary fence at U.S. Coast Guard Base Fort Macon at Beaufort Inlet, Carteret County;
   (B) Canals within Pine Knoll Shores, Carteret County;
   (C) Spooners Creek entrance channel and marina on Bogue Sound, Carteret County; Harbor Village Marina on Topsoil Sound, Pender County; and Marina and entrance canals within Carolina Marlin Club property adjacent to Newport River, Carteret County.
(5) Masonboro Inlet. Gill nets and seines may not be used:
   (A) Within 300 feet of either rock jetty; and
   (B) Within the area beginning 300 feet from the offshore end of the jetties to the Intracoastal Waterway including all the waters of the inlet proper and all the waters of Shinn Creek.
(6) Atlantic Ocean Fishing Piers. At a minimum, gill nets and seines may not be used within 300 feet of ocean fishing piers when open to the public. If a larger closed area has been delineated by the placement of buoys or beach markers as authorized by G.S. 113-185(a), it is unlawful to fish from vessels or with nets within the larger marked zone.

(7) Topsail Beach, Pender County. It is unlawful to use gill nets and seines from 4:00 p.m. Friday until 6:00 a.m. the following Monday in the three finger canals on the south end of Topsail Beach.
(8) Mad Inlet to Tubbs Inlet – Atlantic Ocean, Brunswick County. It is unlawful to use gill nets and seines from September 1 through November 15, except that a maximum of four commercial gill nets per vessel not to exceed 200 yards in length individually or 800 yards in combination may be used.
(9) Spooners Creek, Carteret County. It is unlawful to use gill nets and seines between sunset and sunrise in Spooners Creek entrance channel in Bogue Sound, all of Spooners Creek proper and the adjoining tributary canals and channels.

History Note: Authority G.S. 113-133; 113-134; 113-182; 113-221; 143B-289.52;
Eff. March 1, 1996.
Amended Eff. October 1, 2004; August 1, 2004; April 1, 2001.

SUBCHAPTER 03M – FINFISH

SECTION .0100 – FINFISH, GENERAL

15A NCAC 03M .0101 MUTILATED FINFISH

It is unlawful to possess aboard a vessel or while engaged in fishing from the shore or a pier any species of finfish that is subject to a size or harvest restriction without having head and tail attached, except:

(1) mullet when used for bait;
(2) blueback herring, hickory shad and alewife when used for bait provided that not more than two fish per boat or fishing operation may be cut bait at any one time; and
(3) tuna possessed in a commercial fishing operation as provided in 15A NCAC 03M .0520.

History Note: Authority G.S. 113-134; 113-182; 143B-289.52;
Eff. January 1, 1991;
Amended Eff. January 1, 1991;
Temporary Amendment Eff. May 1, 2001;
Amended Eff. April 1, 2011; July 1, 2006; August 1, 2002.

15A NCAC 03M .0103 MINIMUM SIZE LIMITS

It is unlawful to possess, sell, or purchase finfish under four inches in length except:

(1) 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) bait in the finfish fishery with the following provisions:
(a) It is unlawful to possess more than 200 pounds of live finfish or 100 pounds of dead finfish; and
(b) Such finfish bait may not be transported outside the State of North Carolina;
(3) live finfish in aquaria, provided the finfish are not subject to other minimum size limits under the authority of Marine Fisheries Commission Rule; and
(4) menhaden, herring, gizzard shad, and pinfish.

Bait dealers who possess a valid finfish dealer license from the Division of Marine Fisheries are exempt from Sub-Items (2)(a) and (b) of this Rule. Tolerance of not more than five percent by number of species shall be allowed.

History Note: Authority G.S. 113-134; 113-185; 143B-289.52; Eff. July 1, 1993;
Amended Eff. April 1, 2014.

SECTION .0500 – OTHER FINFISH

15A NCAC 03M .0502 MULLET

(a) The Fisheries Director may, by proclamation, impose any or all of the following restrictions on the taking of mullet:

(1) Specify season,
(2) Specify areas,
(3) Specify quantity,
(4) Specify means/methods,
(5) Specify size.

(b) It is unlawful to possess more than 200 mullet per person per day for recreational purposes.

History Note: Authority G.S. 113-134; 113-182; 113-221; 143B-289.52;
Eff. January 1, 1991;
Amended Eff. July 1, 2006.

SUBCHAPTER 03R – DESCRIPTIVE BOUNDARIES

SECTION .0100 - DESCRIPTIVE BOUNDARIES

15A NCAC 03R .0112 ATTENDED GILL NET AREAS

(a) The attended gill net areas referenced in 15A NCAC 03J .0103(g) are delineated in the following areas:

(1) Pamlico River, west of a line beginning at a point 35° 27.5768' N - 76° 54.3612' W on Ragged Point; running southwesterly to a point 35° 26.9176' N - 76° 55.5253' W on Mauls Point;
(2) Within 200 yards of any shoreline in Pamlico River and its tributaries east of a line beginning at a point 35° 27.5768' N - 76° 54.3612' W on Ragged Point; running southwesterly to a point 35° 26.9176' N - 76° 55.5253' W on Mauls Point; and west of a line beginning at a point 35° 22.3622' N - 76° 28.2032' W on Roos Point; running southerly to a point at 35° 18.5906' N - 76° 28.9530' W on Pamlico Point;
(3) Pungo River, east of the northern portion of the Pantego Creek breakwater and a line beginning at a point 35° 31.7198' N - 76° 36.9195' W on the northern side of the breakwater near Tooleys Point; running southeasterly to a point 35° 30.5312' N - 76° 35.1594' W on Durants Point;
(4) Within 200 yards of any shoreline in Pungo River and its tributaries west of the northern portion of the Pantego Creek breakwater and a line beginning at a point 35° 31.7198' N - 76° 36.9195' W on the northern side of the breakwater near Tooleys Point; running southeasterly to a point 35° 30.5312' N - 76° 35.1594' W on Durants Point; and west of a line beginning at a point 35° 22.3622' N - 76° 28.2032' W on Roos Point; running southerly to a point at 35° 18.5906' N - 76° 28.9530' W on Pamlico Point;
(5) Neuse River and its tributaries northwest of the Highway 17 high-rise bridge;
(6) Trent River and its tributaries; and

(7) Within 200 yards of any shoreline in Neuse River and its tributaries east of the Highway 17 high-rise bridge and south and west of a line beginning on Maw Point at a point 35° 09.0407' N - 76° 32.2348' W; running southeasterly near the Maw Point Shoal Marker "2" to a point 35° 08.1250' N - 76° 30.8532' W; running southeasterly near the Neuse River Entrance Marker "NR" to a point 35° 06.6212' N - 76° 28.5383' W; running southerly to a point 35° 04.4833' N - 76° 28.0000' W near Point of Marsh in Neuse River. In Core and Clubfoot creeks, the Highway 101 Bridge constitutes the attendance boundary.

(b) The attended gill net areas referenced in 15A NCAC 03J .0103(h) are delineated in the following coastal and joint fishing waters of the state south of a line beginning on Roanoke Marshes Point at a point 35° 48.5015' N - 75° 44.1228' W; running southeasterly to a point 35° 44.1710' N - 75° 31.0520' W on Eagles Nest Bay to the South Carolina State line:

(1) All primary nursery areas described in 15A NCAC 03R .0103, all permanent secondary nursery areas described in 15A NCAC 03R .0104, and no-trawl areas described in 15A NCAC 03R .0106(2), (4), (5), (7), (8), (10), (11), and (12);

(2) In the area along the Outer Banks, beginning at a point 35° 44.1710' N - 75° 31.0520' W on Eagles Nest Bay; running northwesterly to a point 35° 45.1833' N - 75° 34.1000' W west of Pea Island; running southerly to a point 35° 40.0000' N - 75° 32.8666' W west of Beach Slough; running southeasterly and passing near Beacon "2" in Chicamicomico Channel to a point 35° 35.0000' N - 75° 29.8833' W west of the Rodanthe Pier; running southwesterly to a point 35° 28.4500' N - 75° 31.3500' W on Gull Island; running southerly to a point 35° 22.3000' N - 75° 33.2000' W near Beacon "2" in Avon Channel ; running southwesterly to a point 35° 19.0333' N - 75° 36.3166' W near Beacon "2" in Cape Channel; running southwesterly to a point 35° 15.5000' N - 75° 43.4000' W near Beacon "36" in Rollinson Channel; running southeasterly to a point 35° 14.9386' N - 75° 42.9968' W near Beacon "35" in Rollinson Channel; running southwesterly to a point 35° 14.0377' N - 75° 45.9644' W near a "Danger" Beacon northwest of Austin Reef; running southwesterly to a point 35° 11.4833' N - 75° 51.0833' W on Legged Lump; running southeasterly to a point 35° 10.9666' N - 75° 49.7166' W south of Legged Lump; running southwesterly to a point 35° 09.3000' N - 75° 54.8166' W near the west end of Clarks Reef; running westerly to a point 35° 08.4333' N - 76° 02.5000' W near Nine Foot Shoal Channel; running southerly to a point 35° 06.4000' N - 76° 04.3333' W near North Rock; running southwesterly to a point 35° 01.5833' N - 76° 11.4500' W near Beacon "HL"; running southerly to a point 35° 00.2666' N - 76° 12.2000' W; running southerly to a point 34° 59.4664' N - 76° 12.4859' W on Wainwright Island; running easterly to a point 34° 58.7853' N - 76° 09.8922' W on Core Banks; running northerly along the shoreline and across the inlets following the Colregs Demarcation line to the point of beginning;

(3) In Core and Back sounds, beginning at a point 34° 58.7853' N - 76° 09.8922' W on Core Banks; running northwesterly to a point 34° 59.4664' N - 76° 12.4859' W on Wainwright Island; running southerly to a point 34° 58.8000' N - 76° 12.5166' W; running southeasterly to a point 34° 58.1833' N - 76° 12.3000' W; running southwesterly to a point 34° 56.4833' N - 76° 13.2833' W; running westerly to a point 34° 56.5500' N - 76° 13.6166' W; running southwesterly to a point 34° 53.5500' N - 76° 16.4166' W; running northwesterly to a point 34° 53.9166' N - 76° 17.1166' W; running southerly to a point 34° 53.4166' N - 76° 17.3500' W; running southwesterly to a point 34° 51.0617' N - 76° 21.0449' W; running southwesterly to a point 34° 48.3137' N - 76° 24.3717' W; running southwesterly to a point 34° 46.3739' N - 76°

26.1526' W; running southwesterly to a point 34° 44.5795' N - 76° 27.5136' W; running southwesterly to a point 34° 43.4895' N - 76° 28.9411' W near Beacon "37A"; running southwesterly to a point 34° 40.4500' N - 76° 30.6833' W; running westerly to a point 34° 40.7061' N - 76° 31.5893' W near Beacon "35" in Back Sound; running westerly to a point 34° 41.3178' N -76° 33.8092' W near Buoy "3"; running southwesterly to a point 34° 39.6601' N - 76° 34.4078' W on Shackleford Banks; running easterly and northeasterly along the shoreline and across the inlets following the COLREGS Demarcation lines to the point of beginning;

(4) Within 200 yards of any shoreline in the area upstream of the 76° 28.0000' W longitude line beginning at a point 35° 22.3752' N - 76° 28.0000' W near Roos Point in Pamlico River; running southeasterly to a point 35° 04.4833' N - 76° 28.0000' W near Point of Marsh in Neuse River; and

(5) Within 50 yards of any shoreline east of the 76° 28.0000' W longitude line beginning at a point 35° 22.3752' N - 76° 28.0000' W near Roos Point in Pamlico River; running southeasterly to a point 35° 04.4833' N - 76° 28.0000' W near Point of Marsh in Neuse River, except from October 1 through November 30, south and east of Highway 12 in Carteret County and south of a line from a point 34° 59.7942' N - 76° 14.6514' W on Camp Point; running easterly to a point at 34° 58.7853' N - 76° 09.8922' W on Core Banks; to the South Carolina State Line.

History Note: Authority G.S. 113-134; 113-173; 113-182; 113-221.1; 143B-289.52;
Eff. August 1, 2004;
Amended Eff. June 1, 2013; April 1, 2011; April 1, 2009.

Detailed information regarding North Carolina's current commercial and recreational fishery regulations is available on the NCDMF website (http://portal.ncdenr.org/web/mf/rules-and-regulations).

5.0 STATUS OF THE STOCK

5.1 GENERAL LIFE HISTORY

A glossary of biological terms can be found in Appendix 1.

5.1.1 Background

Striped mullet (*Mugil cephalus*) occur worldwide in fresh, brackish, and marine waters, predominantly in tropical to sub-tropical latitudes, and have been noted as the most abundant inshore teleost in the world (Thomson 1963; Odum 1970; Bacheler et al. 2005). In the western Atlantic, striped mullet have been documented from Nova Scotia to Brazil (Able and Fahay 1998) with striped mullet occurring year-round from North Carolina southward (Bacheler et al. 2005). Striped mullet are of considerable economic importance both commercially and recreationally. In North Carolina, striped mullet are typically targeted for bait and roe. Besides being an economically important species, striped mullet are an ecologically significant detritivore linking energy flow between lower trophic levels with a wide variety of estuarine and marine fish, birds, and mammals (Mahmoudi et al. 2001; Bacheler et al. 2005). The striped mullet is also known as the 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, white mullet (*Mugil curema*), and mountain mullet (*Agonostomus monitcola*) are the three Mugilid species found in North Carolina. Striped mullet and white mullet are similar in appearance, but can be taxonomically distinguished by anal fin ray counts or pectoral fin measurements (Collins 1985a; Collins 1985b). Striped mullet possess 11 anal fin elements, 3 anal spines, and 8 anal fin rays, and the pectoral fins are 66 to 74% of the head length; white mullet possess 12 anal fin elements, 3 anal spines, and 9 anal fin rays, and the pectoral fin lengths are 77 to 84% of the head length (Collins 1985a; Collins 1985b). Striped mullet also develop longitudinal stripes along the body by its juvenile stage. White mullet lack stripes and possess a distinct gold spot on the opercle (gill cover). As juveniles, both striped and white mullet cohabitate in estuarine waters making differentiation difficult (Martin and Drewry 1978; NCDMF unpublished data). In North Carolina, white mullet demonstrate a seaward emigration during the fall months, presumably migrating to Florida or southwards (Collins 1985b). Adult white mullet (age 1+) rarely occur north of Florida and therefore are not associated with the commercial “roe” mullet fishery in North Carolina (Able and Fahay 1998). The mountain mullet is rare in North Carolina; known only from one specimen noted in Brunswick County, North Carolina (Rohde 1976).

All body lengths cited from scientific literature in this section are reported as standard length (SL), fork length (FL), or total length (TL; Figure 5.1).

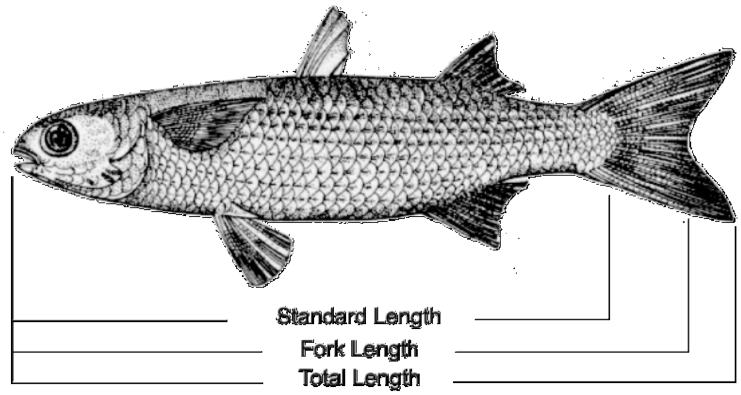

Figure 5.1. Common measurements of fish length; standard length, fork length, and total length.

5.1.2 Physio-chemical Tolerances and Preferences

5.1.2.1 Temperature

In a generalized summary of its worldwide distribution, Collins (1985a) suggested that striped mullet are not permanent residents in waters with temperatures below 16°C, or where waters fail to reach 18°C. However, minimum temperatures are otherwise reported between 4.5 to 9.0°C (Martin and Drewry 1978). Overwintering striped mullet were observed at less than 2°C in low salinity habitats (< 2 parts per thousand) in North Carolina (NCDMF unpublished data). Juveniles were observed (in poor condition) at water temperatures as high as 41°C in concrete culvert pools in Hawaii (Major 1977). In the laboratory, smaller striped mullet (< 50 mm) generally preferred higher water temperatures, 30.0 to 32.4°C, than larger fish, 19.5 to 29.0°C (Major 1977; Collins 1985a). Peak growth of juveniles of mixed *Mugil* spp. (striped mullet and white mullet) occurred at greater than 25°C in laboratory experiments (Peterson et al. 2000).

5.1.2.2 Salinity

The striped mullet is a classic euryhaline species (Collins 1985a; Hotos and Vlahos 1998). Field specimens have been collected in salinities ranging from 0 to 75 parts per thousand (ppt), but striped mullet prefer a median range of 20 ppt to 26 ppt (Collins 1985; Pattillo et al. 1999, Leard et al. 1995). Young-of-the-year (YOY) striped mullet are capable of full osmoregulation, and can tolerate freshwater to full seawater salinities by 40 mm (Nordlie et al. 1982). In a laboratory study Mohamadi et al (2013) demonstrated that low salinities are stressful for juvenile striped mullet by measuring variations in blood cortisol levels, a physiological indicator of stress. Specimens, as small as 30 mm, have been observed in freshwater creeks in North Carolina (NCDMF unpublished data). In the laboratory, no significant mortality occurred in YOY from abrupt salinity changes of 20 ppt to > 40 ppt. Furthermore, YOY acclimated to a maximum salinity of 126 ppt before behavioral and physical signs of stress and mortality occurred in the laboratory (Hotos and Vlahos 1998). Peak growth of juvenile *Mugil* spp. (striped mullet and white mullet) occurred at 17 ppt among three water temperatures in laboratory experiments (Peterson et al. 2000). Even though it has been shown that striped mullet can survive and mature in a range of salinities, the best production is reached when their gonads develop in salinities of 13 to 35 ppt (Tamaru et al. 1994).

5.1.2.3 Food/Feeding

The striped mullet is recognized as an important ecological bridge among a wide range of trophic levels. It connects base food chain items such as detritus, diatomaceous microalgae, phytoplankton, 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 dolphins (Breuer 1957; Thomson 1963; Collins 1985a; Barros and Odell 1995; Fertl and Wilson 1997; Bachelor et al. 2005; Kiszka et al. 2014). Carnivorous feeding (on copepods, mosquito larvae, and microcrustaceans) is common in striped mullet larvae and small juveniles (Harrington and Harrington 1961; DeSilva 1980), followed by a stronger dependence on benthic (bottom) detritus and sediment with increasing body size (DeSilva and Wijeyaratne 1977; Ajah and Udoh 2013; Bekova et al. 2013).

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 sp.*) 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 the gizzard-like pyloric stomach of the striped mullet (Thomson 1963). 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.

5.1.3 Reproductive Biology

5.1.3.1 Size at Maturity

Striped mullet are iteroparous, isochronal spawners (spawn many times over a lifetime, with one spawn per year). It has been shown that generally most immature mullet were sexually differentiated at 205 to 260 mm FL [8.1–10.2-in (Stenger 1959)] with some females as small as 175 mm FL showing differentiation. Bichy’s (2004) study of North Carolina striped mullet findings were consistent with Stenger (1959) with sexual differentiation occurring between 200 to 250 mm FL (7.9–9.8-in). Size at maturity has been found to range widely from 230 to 410 mm SL (9.1–16.1-in) with females maturing at a slightly smaller size than males (McDonough et al. 2003; Collins 1985a). In Louisiana, 50% of females and males are mature (L_{50}) at 230 and 220 mm FL, respectively [9.1 and 8.6-in. (Thompson et al. 1991)]. In Florida, female striped mullet reached L_{50} at 320 mm FL (12.4-in) and males at 297 mm FL [11.7-in. (Mahmoudi et al. 2001)], with smaller fish attaining maturity later in the spawning season (Greeley et al. 1987). In Georgia, Pafford (1983) showed the minimum size at maturity was 231 and 247 mm FL (9.1 and 9.7-in) for male and female striped mullet, respectively. In South Carolina, males reached sexual maturity between 248 to 300 mm TL (9.8–11.8-in) and females reached sexual maturity between 291 to 400 mm TL [11.5–15.7-in (McDonough et al. 2005)]. Striped mullet in North Carolina, in general, reach maturity at a greater length compared to other regions with males reaching maturity at a smaller size (L_{50}) then females, 283 mm and 324 mm fork length, respectively [11.1 and 12.8-in (Bichy 2004)]. Smaller North Carolina females also tended to spawn later in the season (Bichy 2000).

5.1.3.2 Age at Maturity

It has been shown that most (95%) immature striped mullet were sexually differentiated by the time of their first annular increment deposition [15–19 months (McDonough et al 2005)]. Most reports summarize the age at maturity as age 2, although a large amount of individual variation is reported (Thomson 1966; Moore 1973; Moore 1974; Martin and Drewry 1978; Pafford 1983). However, more recent works indicate that maturity often occurs earlier than age 2 (Collins 1985a; Bichy 2000). In North Carolina, the estimated age where 50% of striped mullet are mature (M_{50}) was age 1 for both males and females (Bichy 2000). In comparison to other studies, striped mullet mature at age 3 in Florida (Mahmoudi et al. 2001), and ages 2–3 in Louisiana (Thompson et al. 1991) and Georgia (Pafford 1983).

5.1.3.3 Sex ratio

Earlier male maturation appears to be a common trait of the striped mullet (Pafford 1983; Bichy 2000; Bichy 2004; McDonough et al 2005). Striped mullet are gonochoristic and their sex is genetically determined. 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 (Silva and De Silva 1981; Bichy 2000; McDonough 2001; McDonough et al. 2005). 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). In North Carolina, Bichy (2000) found the proportion of males to females varied by fish length with fish over 300 mm (11.8-in.) being predominately female. Below 300 mm (11.8-in), males dominated; however, the sex ratio is close to 1:1 (Bichy 2000).

5.1.3.4 Fecundity

Fecundity measures from a wide assemblage of studies range from 220,000 to 7.2 million eggs per individual; with fecundity positively related to body size (Broadhead 1953; Thomson 1963; Martin and Drewry 1978; Silva and De Silva 1981; Pafford 1983; Greeley et al. 1987; Bichy 2000; Wenner 2001; McDonough et al 2003). Recent studies have reported maximum fecundity around 0.5 to 4.2 million eggs per female (Whitfield and Blaber 1978; Pafford 1983; Render et al. 1995; Bichy 2000; Wenner 2001; Bichy and Taylor 2002; McDonough et al. 2003).

Reported estimates of relative fecundity have ranged between 648 to 2,616 eggs/gram of body weight (Shehadeh et al. 1973; Nash et al. 1974; Render et al. 1995; Bichy 2000).

5.1.3.5 Spawning Location

The striped mullet is considered a catadromous species due to its predictable migrations from freshwater habitats into marine spawning areas (Martin and Drewry 1978; Collins 1985a; Blaber 1987). The spawning location of striped mullet is largely based in theory and indirect evidence. The concentrated abundance of eggs and larvae in offshore collections support offshore waters as spawning grounds (Broadhead 1953; Anderson 1958; Arnold and Thompson 1958; Finucane et al. 1978; Martin and Drewry 1978; Powles 1981; Ditty and Shaw 1996; Able and Fahay 1998). Anecdotal, offshore observations of spawning behaviors and large, seaward migrations of spawning adults also indicate offshore spawning (Jacot 1920; Arnold and Thompson 1958). Anderson (1958) observed striped mullet larvae from lower Florida to North Carolina (from the 20 fathom line extending into the Gulf Stream). This supports other suggestions that striped mullet spawn offshore in and around the edge of the South Atlantic Bight (SAB; Collins and Stender 1989). However, in addition to offshore waters, spawning likely also occurs in nearshore coastal waters, lower estuarine areas and sounds (albeit less frequently), and perhaps in freshwater in extremely rare circumstances (Jacot 1920; Breder 1940; Johnson and McClendon 1969; Shireman 1975; Martin and Drewry 1978; Collins and Stender 1989; Bettaso and Young 1999). A striped mullet with hydrated oocytes was found 100 to 200 m from shore off Hatteras, North Carolina (Bichy 2000). Hydration occurs within one to two days before spawning (Martin and Drewry 1978). Observations suggest that spawning occurs at night, near the surface (Anderson 1958; Arnold and Thompson 1958). Larval abundance in Florida collections suggests that peak spawning occurs around new and full moon spring tides (Greeley et al. 1987).

5.1.3.6 Gonadosomatic Index and Spawning Period

Striped mullet in South Carolina, Georgia, and Louisiana displayed very high, mean, monthly gonadosomatic index (GSI) values of 20 to 25% (Pafford 1983; Render et al. 1995; McDonough 2001; Wenner 2001). GSI is the ratio of ovary weight to total body weight, multiplied by 100. GSI values increased with female size, yet asymptote at 357mm (14 in.) in Louisiana specimens (Render et al. 1995). The spawning period begins earlier in more northern latitudes, yet is otherwise very similar in duration and pattern in North Carolina, South Carolina, Georgia, and Louisiana. The spawning season in North Carolina spans from September to March, with peak spawning occurring in October and November (Jacot 1920; Bichy and Taylor 2002). North Carolina GSI values begin to rise rapidly in September (6%), peak in October (14%), remain high in November and December (~11%), diminish in January (4%), and decline to ~0% in April (Bichy and Taylor 2002). Although spawning may occur into March, limited microscopic examinations of gonads indicated that most gravid (egg carrying) females were re-absorbing atrectic (non-viable) oocytes after November. However, specimens with vitellogenic (viable) oocytes were noted into January (Bichy and Taylor 2002). In South Carolina and Georgia, GSI values indicated that spawning occurred from October through February, with a peak in November (Pafford 1983; McDonough 2001). Gonadosomatic Index values indicated peak spawning in December and January in Florida (Greeley et al. 1987). A very slight resurgence in GSI values roughly 3 months after the peak spawning period was noted in South Carolina, Georgia, and Louisiana (Pafford 1983; Render et al. 1995; McDonough 2001).

5.1.4 Age, Growth, and Development

5.1.4.1 Eggs

Spawning striped mullet broadcast transparent to straw-colored, buoyant, stenohaline (adapted to narrow salinity ranges) eggs (Kuo et al. 1973; Collins 1985a). Highest egg survival occurs between 28 to 33 ppt (Sylvester et al 1975). *In vitro* fertilization rate is 90%; *in vitro* hatching rate is 42% (Abraham et al. 1999). Fertilized egg diameters range between 0.60 to 0.98 mm (Martin and Drewry 1978; Kuo et al. 1973; Collins 1985a; Abraham et al. 1999). Individual, fertilized, eggs contain a single oil globule, ranging between 0.26 to 0.40 mm in diameter (Martin and Drewry 1978; Kuo et al. 1973; Collins 1985a). Optimum egg development occurs within the range of 21 to 24°C (Sylvester et al. 1975). Hatching occurs 36 to 38 hours after fertilization at 24°C, and 48 to 50 hours at 22°C (Kuo et al. 1973).

5.1.4.2 Yolk Sac Larvae

Larvae average 2.65 mm at hatching (Pattillo et al. 1999) and range between 2.2 to 3.6 mm (Martin and Drewry 1978). Larvae hatch with no mouth, paired fins, or branchial skeleton (Thomson 1963). A yolk sac with an ovoid to oblong-ellipsoidal oil globule is present on larvae for two to five days at 26°C (Martin and Drewry 1978). Typically, by four days, the mouth is formed, pectoral fins are developing, gill clefts have opened, and the yolk has been absorbed, although the oil globule is still present (Martin and Drewry 1978). Kuo et al. (1973) found little effect of temperature on yolk sac absorption rate; however, oil globule content persisted longer at lower temperatures. Steep growth occurs from yolk nutrition on day one; however, little to no growth occurs during the remainder of the yolk sac stage (four to five days; Kuo et al. 1973; Martin and Drewry 1978). Over 90% of larval mortality in the laboratory occurred during the initial 10 days of larval life (Martin and Drewry 1978; Kuo et al. 1973).

5.1.4.3 Larval Stage

Substantial growth occurs with the onset of feeding, beginning on the fifth to eighth day post-hatch, followed by intensification of feeding between the ninth and twelfth days (Kuo et al. 1973; Martin and Drewry 1978). Stomach, spleen, intestines, gall bladder, and swim bladder begin forming between 3.1 to 3.4 mm on approximately the fifth day (Martin and Drewry 1978). Gill filaments begin to form at 3.4 to 3.8 mm at eight days (Martin and Drewry 1978). Complete oil globule depletion occurs by 10 days at 24°C and 15 d at 22°C (Kuo et al. 1973). Gill lamellae are present at 3.85 to 5.7 mm at 14 to 15 d (Martin and Drewry 1978). Heavy pigmentation is scattered over the body by 5.4 to 6.6 mm, with a silver-white or silver-green color developing ventrally from the gill cover to anus (Martin and Drewry 1978). Eleven anal fin rays are present at 6 mm (Martin and Drewry 1978; Ditty and Shaw 1996), which is an important diagnostic tool for separating striped mullet and white mullet (Collins 1985a). Scales begin to develop at 8 to 10 mm (Martin and Drewry 1978). Striped mullet are approximately 11 mm at the end of the larval stage (24 to 28 days; Martin and Drewry 1978).

5.1.4.4 Pre-juveniles

Martin and Drewry (1978) recognize a pre-juvenile stage from 11 to 52 mm TL (0.4-in–2.0-in), with an approximate age of 30 to 90 days at its conclusion (Thomson 1966). The pre-juvenile stage is also referred to as the querimana stage (Thomson 1966). The 11 anal fin rays fuse into a complement of two anal spines and nine anal fin rays at 19 to 23 mm TL [0.7–0.9-in (Collins 1985a)]. The diagnostic count of three anal spines and eight anal fin rays is evident at 35 to 45 mm SL [1.4–1.8-in (Anderson 1958)]. Scales are absent on the second dorsal and anal fins, unlike white mullet (Able and Fahay 1998). Pre-juveniles from 16 to 40 mm TL (0.6–1.6-in) are brilliant silver ventrally and laterally, progressively more pigmented, tan, and brown on the dorsal surface (Able and Fahay 1998). Stripes become evident after 40 mm SL [1.6-in (Martin and Drewry 1978)]. The adipose eyelid is microscopically noticeable at 28 mm TL and macroscopically (visibly) noticeable by 42 mm TL [1.7-in (Martin and Drewry 1978)].

5.1.4.5 Juveniles

The juvenile stage encompasses a size range from 52 to 248 mm TL [2.0–9.8-in (Martin and Drewry 1978)]. Gill rakers increase from approximately 32 at 59 mm SL (2.3-in), to 48 at 117 mm SL [4.6-in (Martin and Drewry 1978)]. Juveniles and adults possess the same complement of fins (Martin and Drewry 1978). Striped mullet reach 50 mm TL (2.0-in) by five months (by their first March-May; Futch 1966). Striped mullet young of the year (YOY) have been observed arriving at Beaufort, North Carolina by mid-January. Little growth was noted until water temperatures reached 20°C in mid-April, and approximately 20 mm (08-in) of growth per month was estimated for May to October (Higgins 1927). Anderson (1958) estimated 5 mm (0.2-in) growth per month for Georgia YOY [~19 mm SL (0.7-in)] from November until January, followed by no growth during the coldest winter months. About 10 mm (0.4-in) growth occurred between February and March during rising water temperatures, followed by a growth rate of 17 mm (0.6-in) per month through next October (Anderson 1958). Anderson (1958) suggested that the longer periods of delayed YOY growth observed by Higgins (1927) in North Carolina was due to the extended winter season.

Two year-classes, separated by several months, were observed in North Carolina and Georgia (Jacot 1920; Higgins 1927; Anderson 1958). Anderson (1958) determined that by their second winter in Georgia, juveniles would fall into two average size groups, 197 and 122 mm TL (7.8–4.8-in), depending on the timing of spawning.

First annulus formation occurs at approximately 13 to 19 months, followed by successive annuli formations between April and August (Thompson et al. 1989; Thompson et al. 1991; Virgona et al. 1998; McDonough 2001; McDonough et al. 2005). Marginal increment analyses show that annulus formation occurs from May to June in North Carolina, South Carolina, and Georgia (Foster 2001; McDonough 2001; Wong 2001). Size at first annulus formation ranged from 120 to 200 mm FL (4.7–7.9-in). Lengths at annuli formations were varied among studies that used both scales and otoliths for ageing (Leard et al. 1995).

5.1.4.6 Adults

Adults grow at a rate of 38 to 64 mm per year [1.5–2.5-in. (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 (0.3-in) in each of the first and fourth quarters of the year, and averaged 16 and 19 mm (0.6–0.7-in) growth in the second and third quarters of the year in a Florida tagging study (Broadhead 1958).

Otolith growth is closely related to body growth for fishes (Helfman et al. 1997). Incremental otolith growth in striped mullet occurs primarily from July to November in Louisiana (Thompson et al. 1991) and June to October in North Carolina (Wong 2001). 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 marginal incremental growth in otoliths was observed for older striped mullet in August and September in North Carolina (Carmichael and Gregory 2001).

Males and females both grow rapidly in their first years and had similar length-at-age until about age 2, coinciding with maturation. After which growth is slowed considerably, but typically females grow larger and live longer (Table 5.1; Mahmoudi et al. 2001; NCDMF unpublished data). Large variability in size at early ages is seen in North Carolina, South Carolina, and Georgia stocks (Foster 2001; McDonough 2001; Wong 2001). North Carolina striped mullet appear to achieve larger mean lengths at earlier ages than in other parts of the southern United States (Bichy 2000; Wong 2001). For example, mean length for age 1 striped mullet (both sexes) in South Carolina was 257 mm (10.1-in), substantially smaller than males and females [317 and 346 mm, respectively (12.5 and 13.6-in) in North Carolina (McDonough 2001; Wong 2001). On average, age 2 males and females in South Carolina were 310 mm (12.2-in) compared to 344 mm and 394 mm (13.5–15.5-in) in North Carolina (McDonough 2001; Wong 2001). Since birth date is standardized as January 1 for ageing convention along the east coast of the United States, earlier spawning times in North Carolina may contribute to slightly larger mean lengths at young ages.

Table 5.1. Average length at age for North Carolina male and female striped mullet. FL = fork length; n = number of specimens: 1994–2011.

Males				Females			
Age	FL (mm)	FL (in)	n	Age	FL (mm)	FL (in)	n
0	236	9.3	99	0	245	9.6	41
1	292	11.5	857	1	315	12.4	896
2	311	12.2	1,252	2	349	13.7	2,872
3	340	13.4	156	3	390	15.4	1,557
4	372	14.6	44	4	421	16.6	664
5	375	14.8	11	5	442	17.4	251
6	396	15.6	3	6	447	17.6	101
7	440	17.3	3	7	462	18.2	39
8	452	17.8	5	8	431	17	14
9	478	18.8	2	9	423	16.7	3
10	412	16.2	1	10	480	18.9	6
11				11	363	14.3	1
12				12			
13	563	22.2	1	13	489	19.3	1
14	486	19.1	1	14			

5.1.4.7 Length-Weight Relationship

The length (L) – weight (W) relationship found in North Carolina striped mullet was expressed as $\ln(W) = -17.87 + 2.968 * \ln(L)$ (Wong 2001). Leard et al. (1995) summarized the relationships between length and weight for various studies.

5.1.4.8 Maximum Age and Maximum Size

The historical maximum age for striped mullet is reported as 13 years (Thomson 1963). However, male and female maximum ages of 14 and 13 were recorded in North Carolina research (Table 5.1). Maximum reported sizes ranged from 791 mm (31.1-in) in North Carolina to a 914 mm (36.0-in) specimen from India (Gopalakrishnan 1971; NCDMF unpublished data).

5.1.5 Movements and Migrations

5.1.5.1 Larval Transport and Migration

Striped mullet larvae are found during the winter and spring months over a range of offshore depths [9–914 m (30–3,000 ft)] in the SAB (Collins and Stender 1989). The greatest abundances of larvae occurred 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, (Ekman) drift, characteristic of southeast U.S. winter wind patterns (Powles 1981).

5.1.5.2 Young-of-the-year and Juvenile Movement

Larval and 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 (0.8–1.0-in) when they appear on outer beaches, 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 [0.9-in (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 that YOY and juveniles move into deeper waters with the adult migration in the fall.

5.1.5.3 Adult Movement and Migrations

Martin and Drewry (1978) reported that adults occupy shallow waters during a ‘trophic’ (feeding) phase from spring to summer/early fall between migration (spawning) periods. Adults generally do not move extensively during this trophic 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 aggregation 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. 2001; 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).

5.1.5.4 Tagging Studies

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 20 miles of the tagging location in Florida (Idyll and Sutton 1951; Broadhead and Mefford 1956), while 91% of recaptures were found within 52 miles 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 vast majority of tagged fish that were 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 two months but on a smaller scale (Bachelor et al. 2005). However, egg and larval transport occurs in a northward direction with the Florida current (Gulf Stream) along the southeast 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 (McDonough 2001; Wong 2001). Low percentages of out-of-state recaptures in North Carolina and South Carolina (1.8 and 9%) may suggest that striped mullet stocks are fairly residential to native states. Mahmoudi et al. (2001) noted that the majority of adults in Florida were recaptured in the same system in which they were tagged.

5.2 PRESENT STOCK STATUS

A population assessment of the North Carolina striped mullet stock (Appendix 2) was conducted by means of a statistical catch-at-age-analysis using Stock Synthesis 3 developed by Methot (2000; 2011; NFT 2011; Methot and Wetzel 2013). This population model is an age- and size-based forward projection analysis, incorporating both fishery-dependent and -independent data. Age-specific estimates of population abundance and commercial fishing mortality for each year covering an eighteen-year time series (1994–2011) were produced in the population model. Benchmark fishing mortality rates proposed as thresholds for sustainability, were calculated using life history and fishery information unique to the North Carolina striped mullet stock. Observed fishing mortality estimates from the population model were evaluated in relation to the fishing mortality threshold, to determine if overfishing is occurring on the stock.

Striped mullet inhabiting North Carolina coastal and joint waters comprise the unit stock in the assessment. The North Carolina striped mullet stock falls under the jurisdiction of the MFC. The NCDMF directly manages the stock under these two regulatory commissions. No inter-state management over the Atlantic coastal striped mullet population is in effect.

The North Carolina striped mullet commercial fishery is the largest along the U.S. Atlantic seaboard, averaging 1.94 million lb from 1994 to 2011. The commercial fishery is predominantly a fall, roe targeting gill net fishery. Rapid surges in roe value in the late 1980s, followed by rising commercial fishing effort and landings through the mid-1990s caused concern for the North Carolina stock. Recreational landings in North Carolina are presumed to be smaller than commercial landings, and are composed of two types of harvest: cast netted juveniles used for hook and line bait, and recreationally gill netted striped mullet. Annual estimates of recreational striped mullet harvest in North Carolina are difficult to obtain with current recreational surveys designed to target hook-and-line harvest.

The striped mullet stock was first recognized as a species of concern by the State of North Carolina in 1999. The first stock assessment included in the 2006 Striped Mullet FMP found the stock was not undergoing overfishing and the stock was reclassified as viable.

By definition, overfishing occurs when the fishing mortality rate exceeds the threshold F rate and the rate of removal of fish exceeds the ability of the stock to replenish itself (ASMFC 2004). The following benchmarks and thresholds are given as full year fishing mortality rates on fully recruited age classes (ages 2–5).

The threshold F rate for striped mullet was based on a level of fishing that conserves 25% of the spawning stock biomass (SSB) compared to a condition where no fishing mortality occurs (F = 0). This percentage of SSB is known as spawning potential ratio (SPR). This fishing mortality threshold of $F_{25\%}$ = 0.932 was considered a proxy for F at maximum sustainable yield (F_{msy}) for the stock. Adopting a threshold fishing mortality corresponding to SPR = 25% was primarily based on rapid growth to maturity, large annual age 0 recruitment, and greater than 100 years of historical commercial landings similar in magnitude to the current fishery, ostensibly indicating a long-term self-sustaining stock at this level of exploitation.

Although the stock is heavily exploited, overfishing is not occurring based on $F_{25\%}$ as the threshold fishing mortality rate. Fishing mortality in the terminal year (F_{2011} = 0.437) was below the fishing mortality threshold. Based on these results the striped mullet stock is not undergoing overfishing. A poor stock-recruit relationship resulted in unreliable biomass-based reference points and prevented determining if the stock is currently overfished.

The distinct pattern of very low commercial fishing mortality in January–June, combined with shifting fishery selectivity towards older fish in July–December, allows females to attain maturity before they face the full brunt of fishing mortality. Terminal stock abundance and age structure is most likely at sustainable levels, although model trends in SSB and recruitment were declining in the last few years of the assessment period. Although SSB and age structure likely sustain current harvest levels, reproduction comes heavily from younger age classes, requiring cautious management of the stock. A series of poor recruitment events could upset stock sustainability.

Given $F_{25\%}$ as a proxy for F_{msy}, the stock is currently fished below the maximum exploitation level that can maintain sustainability, thus leaving room for acknowledged uncertainty in data used in the assessment or against unpredictable future events such as recruitment failures. The typical management response to dealing with uncertainty is to adopt more conservative thresholds that are considered precautionary (Haigh and Sinclair 2000). A target of $F_{35\%}$ = 0.566 is recommended as a precautionary target for the striped mullet stock (see Appendix 2).

6.0 STATUS OF THE FISHERIES

6.1 COMMERCIAL FISHERY

6.1.1 History

The historic striped mullet fishery had a prominent role in the early 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. Its fishery importance is illustrated in the colloquial name of the Atlantic and North Carolina Railway, known as the 'Old Mullet Line', which connected coastal and piedmont North Carolina from the 1850s to 1950s (Little 2012). The mullet fishery operated at over 3 million lb annually during the late 1800's (Chestnut and Davis 1975). The fishery was highly seasonal, occurring primarily during the fall spawning migration (Taylor 1951). Enormous catches of greater than 1 million lb of striped mullet landings in a single day was not an uncommon event during these fall migrations (Smith 1907). Despite salting as a preservation method, these massive harvest pulses were larger than the market's distribution and holding capacity, well into the 1950s (Taylor 1951). Fifty-eight percent of the harvest was reported in "salted" condition in 1887 and 1888, while 76% of total harvest was "salted" between 1889 and 1897 (Chestnut and Davis 1975). By the mid-1900s, 95% of the harvest was sold fresh, while the rest were brine-cured, salted, or filleted and packaged (Taylor 1951). Peak landings of over 6.7 million lb and 5.1 million lb were harvested in 1902 and 1908, respectively (Chestnut and Davis 1975; Figure 6.1).

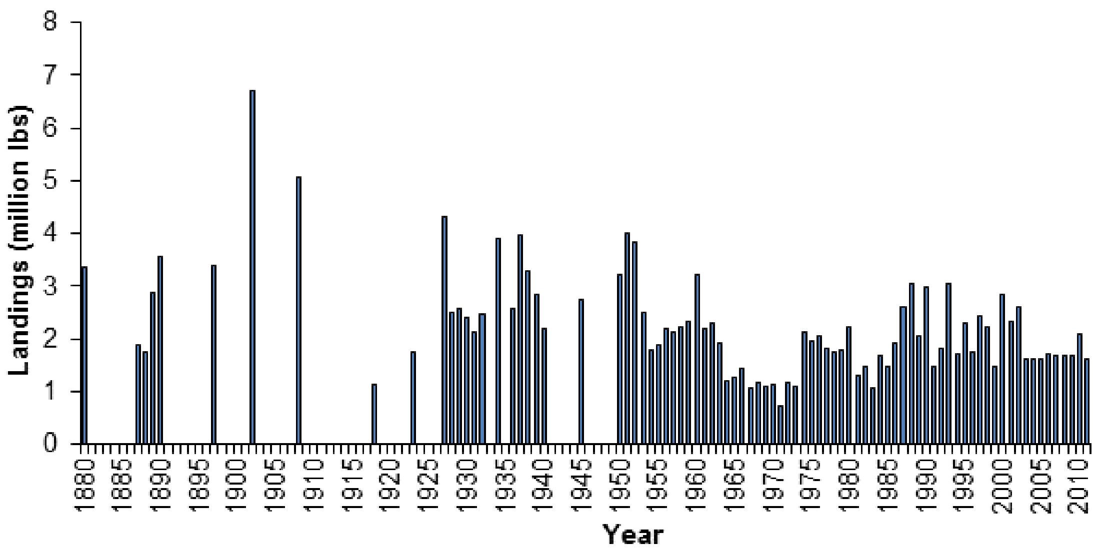

Figure 6.1. Historical landings of the North Carolina striped mullet fishery: 1880–2011. Landings data were not available for all years.

6.1.2 Collection of Commercial Statistics

Annual NC landings data for striped mullet exist from 1880 to present (Chestnut and Davis 1975). The National Marine Fisheries Service (NMFS) standardized the collection methods of landings statistics for U.S. South Atlantic fishery species in 1972. Landings were collected monthly from major seafood dealers, although reporting was not mandatory. The NCDMF and NMFS began a cooperative commercial fishery data collection program in 1978, maintaining the same methodology established in 1972; however, NCDMF assumed the primary role of data collection for the state and further improved data collection coverage with additional staff. Under-reported landings were a growing concern due to the reliance on voluntary program cooperation from seafood dealers. The rising perception of deteriorating attitudes towards fisheries management by North Carolina fishermen in the late 1980s and early 1990s contributed to the reform of the NCDMF/NMFS cooperative statistics program (Lupton and Phalen 1996). With the support of the commercial fishing industry, NCDMF instituted a mandatory, dealer-based, trip-level, reporting system known as the North Carolina Trip Ticket Program (NCTTP) for all commercial species in 1994, which greatly improved reporting compliance. Any transaction between a licensed fisherman and licensed dealer became mandatory by statute. The number of dealers with reported striped mullet landings increased by 79% (122 to 218) between 1993 and 1994. Improved collection methods beginning in 1994 should be considered when comparing pre-1994 landings with current landings.

6.1.3 Annual Landings and Value

The North Carolina striped mullet fishery changed markedly in the late 1980s. From 1972 to 1986, annual landings in the striped mullet fishery averaged 1.66 million lb, with a range of 1.07 to 2.22 million lb (Figure 6.2). Average annual landings from 1987 to 1993 were 2.44 million lb, with landings near or exceeding 3 million lb in 1988, 1990, and 1993. Strong demand from Asia for striped mullet roe and competing roe-exporting companies combined to create a highly profitable roe fishery in NC in 1988; that year landings exceeded 3 million lb for the first time in 28 years.

Value of the fishery increased even more noticeably than landings during the late 1980s. From 1987 to 1988, landings increased by 18%, yet value grew by 150%. Average November price of striped mullet increased from $0.24 per lb (all market grades) in 1987 to $0.86 in 1988 and $1.35 in 1989 (Figure 6.3). In contrast, the market value of striped mullet was often lower during peak spawning months (October and November) in previous years. Prices would often decline due to the glut caused by the high availability of large, migratory schools and little market demand. However, spawning female striped mullet graded as ‘red roe’ striped mullet suddenly fetched $1.00–$1.80/lb in the late 1980s. A depressed Asian economy in the late 1990s may have led to a decline in roe demand. Since the early 2000s landings in the striped mullet fishery have stabilized around 1.5 to 2.0 million lb annually.

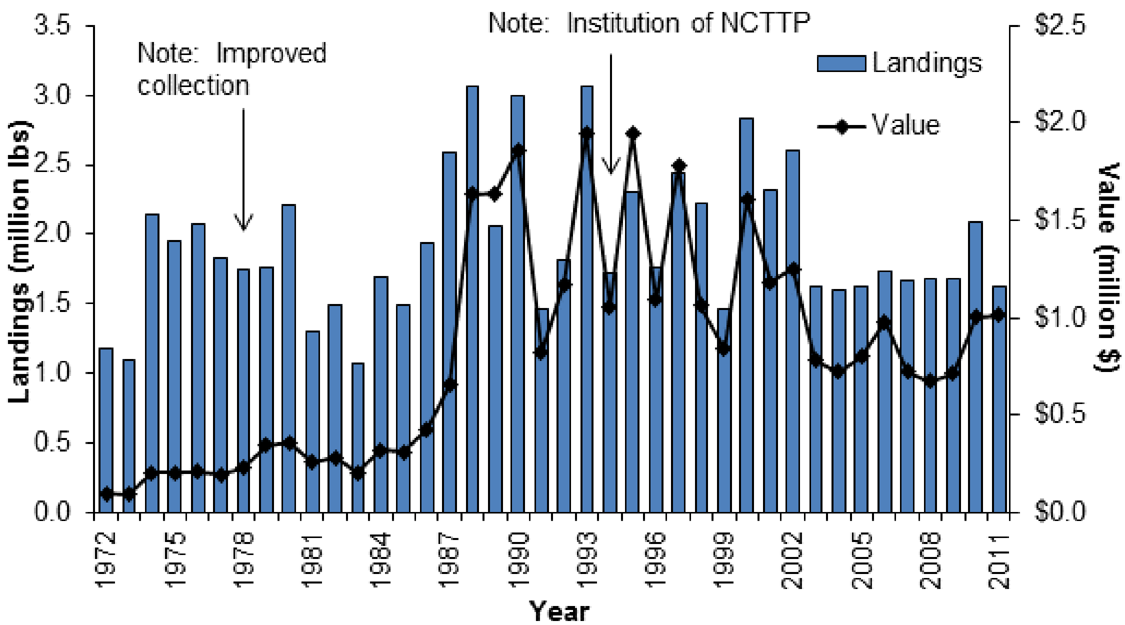

Figure 6.2. Annual landings and value of the North Carolina striped mullet fishery: 1972–2011. Note: values not adjusted for inflation.

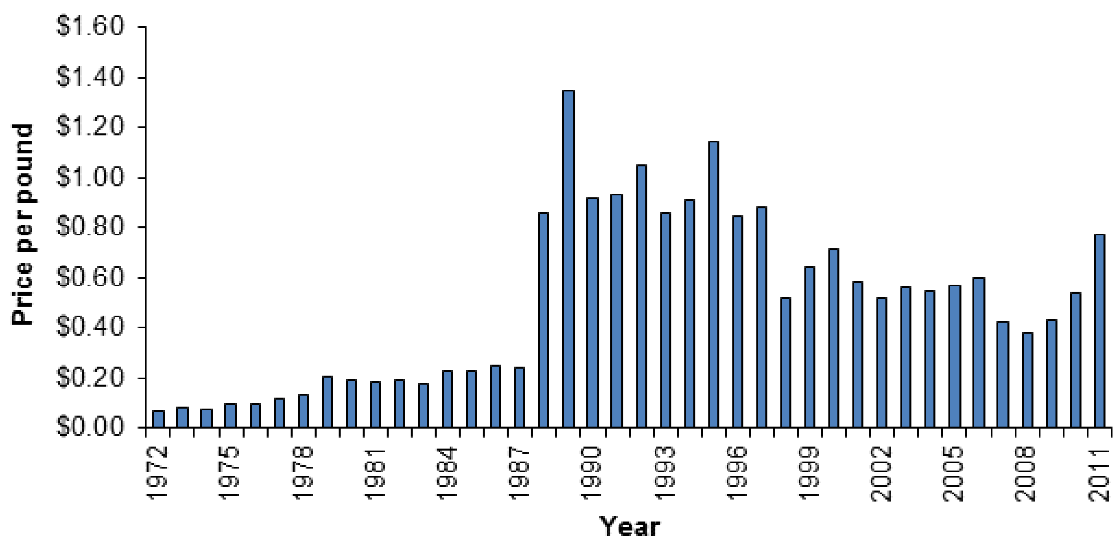

Figure 6.3. Average November price per lb in the North Carolina striped mullet fishery: 1972–2011. Averages include all market grades. Note: price not adjusted for inflation.

6.1.4 Landings by Season

The average market price for striped mullet was minimal and generally stable throughout the year from 1972 to 1987 (Figure 6.4). The sudden market demand for roe in 1988 caused the average market price to increase during the main months (October–December) of the spawning season. Roe prices remained at a consistently high level until 1998. Market price for roe striped mullet declined in 1998 and has remained much lower than what was observed in 1988–1997. A depressed Asian economy in the late 1990s may have led to a decline in roe demand. Also, the decline in market price was partially due to the fallout of some competing exporters, which created a more unified exporting industry (NCDMF 2006). The greatest intensity of harvest occurred in October and November (Figures 6.5 and 6.6), coinciding with the peak period of striped mullet spawning (Jacot 1920; Bichy and Taylor 2002).

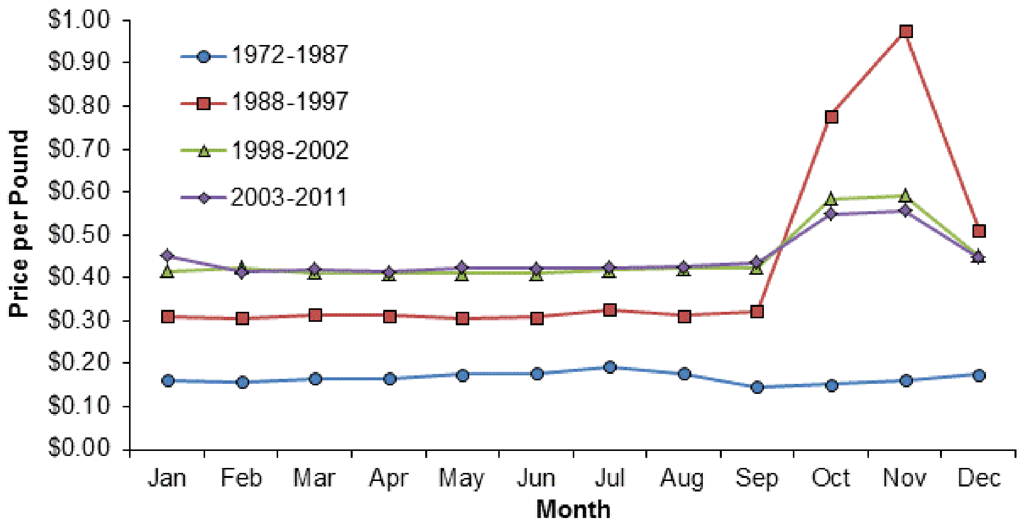

Figure 6.4. Average monthly price per lb in the North Carolina striped mullet fishery: 1972–1987, 1988–1997, 1998–2002, and 2003–2011. Averages include all market grades. Note: price not adjusted for inflation.

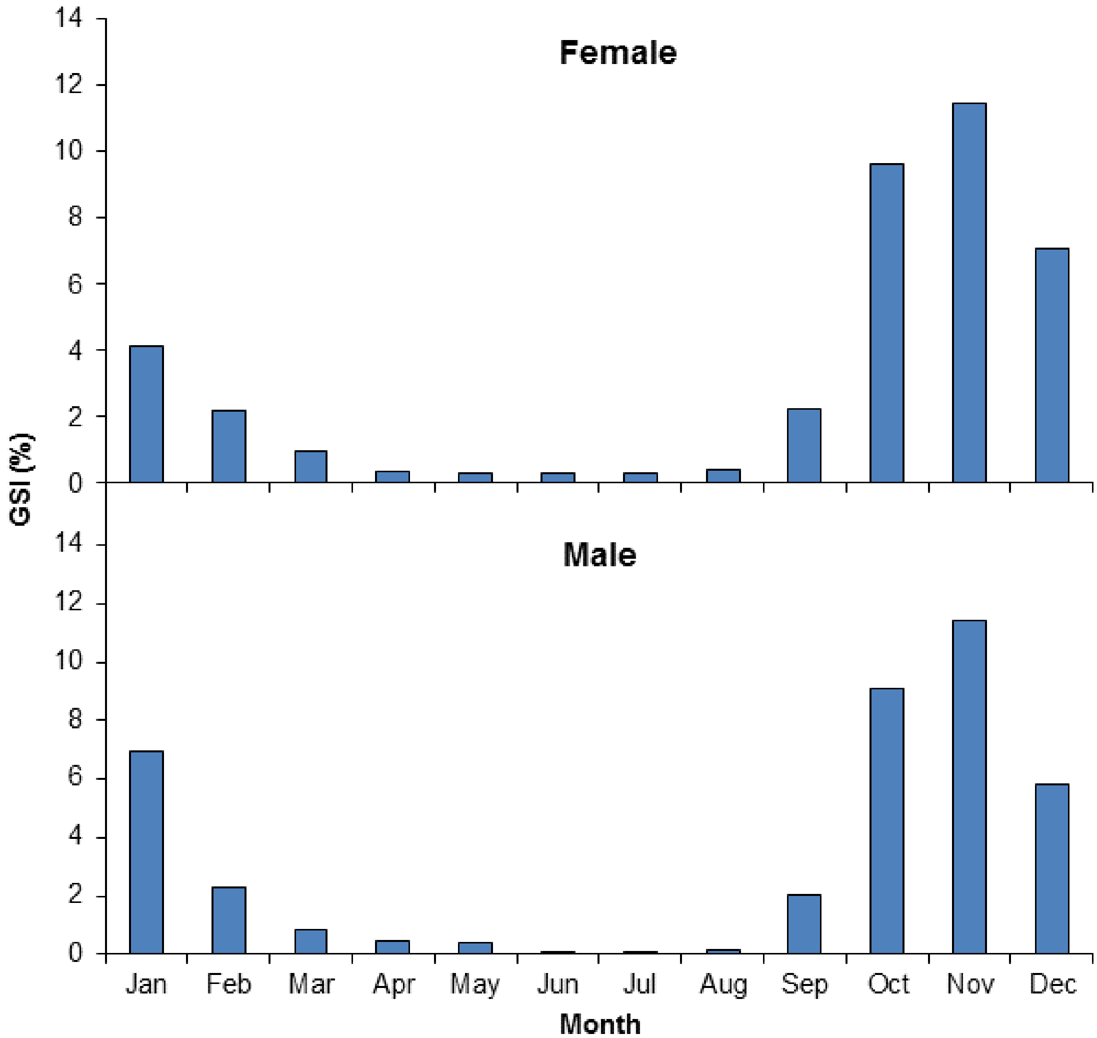

Figure 6.5. Average monthly gonadosomatic index (GSI) values for female and male striped mullet in North Carolina: 1994–2011.

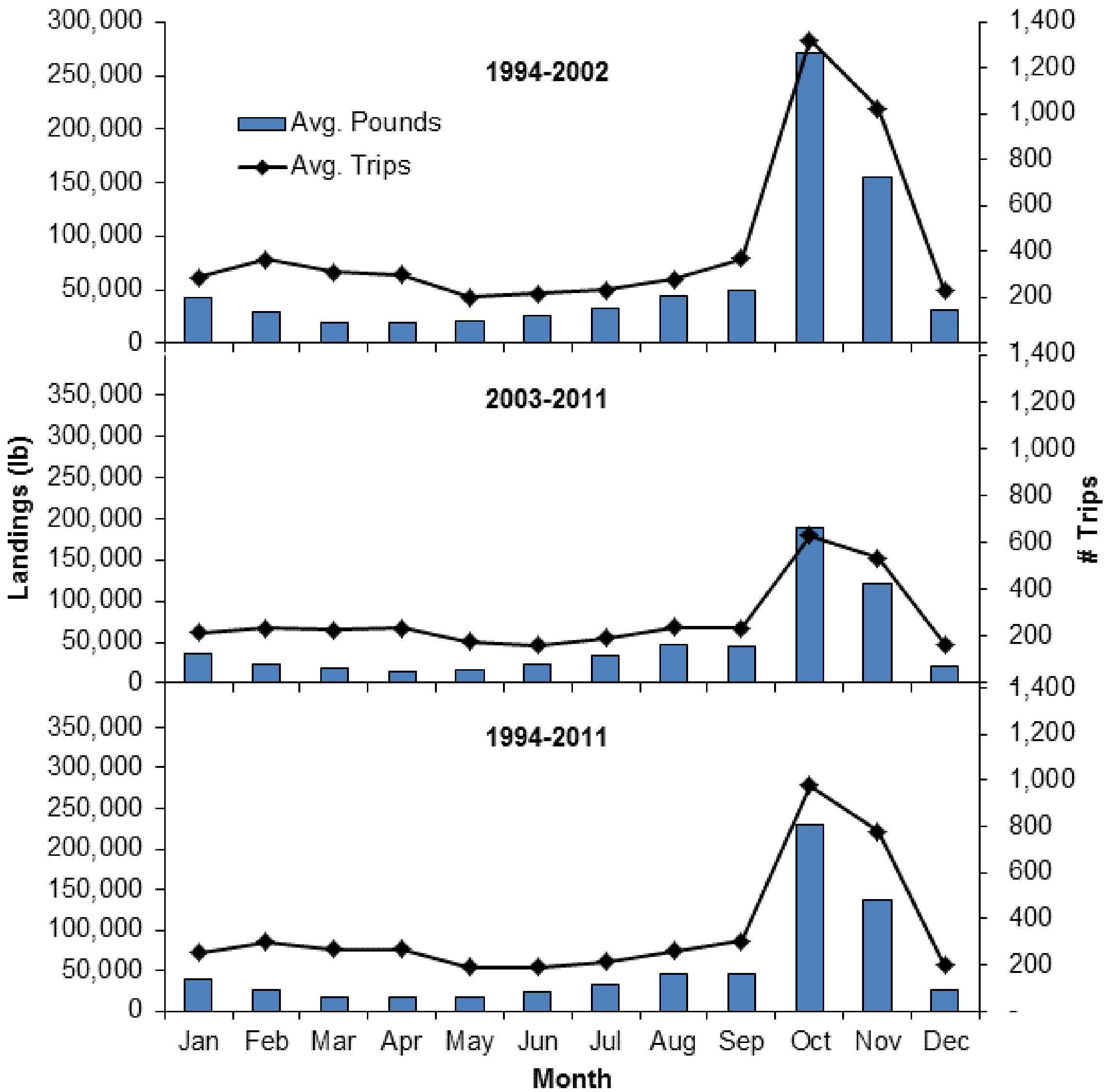

Figure 6.6. Average monthly landings and number of trips in the North Carolina striped mullet fishery: 1994–2011.

6.1.5 Landings by County

Forty percent of the total striped mullet harvest was landed in Carteret County from 1972–2011, roughly two and a half times the next closest landings value from Dare County (Table 6.1; Figure 6.7). The year-to-year proportion of total, statewide landings taken by Carteret County has fluctuated widely, between 21% and 66%, since 1972 (Figure 6.8). Carteret County harvest share peaked in 1990 (66%) and has since declined. A decline in landings from the beach seine fishery, which occurs in Bogue Banks, is responsible for much of the reduced harvest proportion taken by Carteret County. Dare County and Pamlico County harvests have increased over recent years (1994–2011) relative to the rest of the state (Table 6.2). In 2004, steadily rising landings in Dare County overtook landings in Carteret County and have remained higher since (Figure 6.8).

Table 6.1. Average annual landings by county in the North Carolina striped mullet fishery: 1972–2011.

County	Average Landings (lb)	Percent of Total Landings
Carteret	762,329	40%
Dare	295,808	15%
Pamlico	174,458	9%
Onslow	157,824	8%
Beaufort	92,796	5%
Pender	72,160	4%
Brunswick	64,848	3%
New Hanover	62,135	3%
Pasquotank	62,036	3%
Hyde	61,459	3%
Chowan	44,847	2%
Tyrrell	24,950	1%
Others (20)	48,993	3%

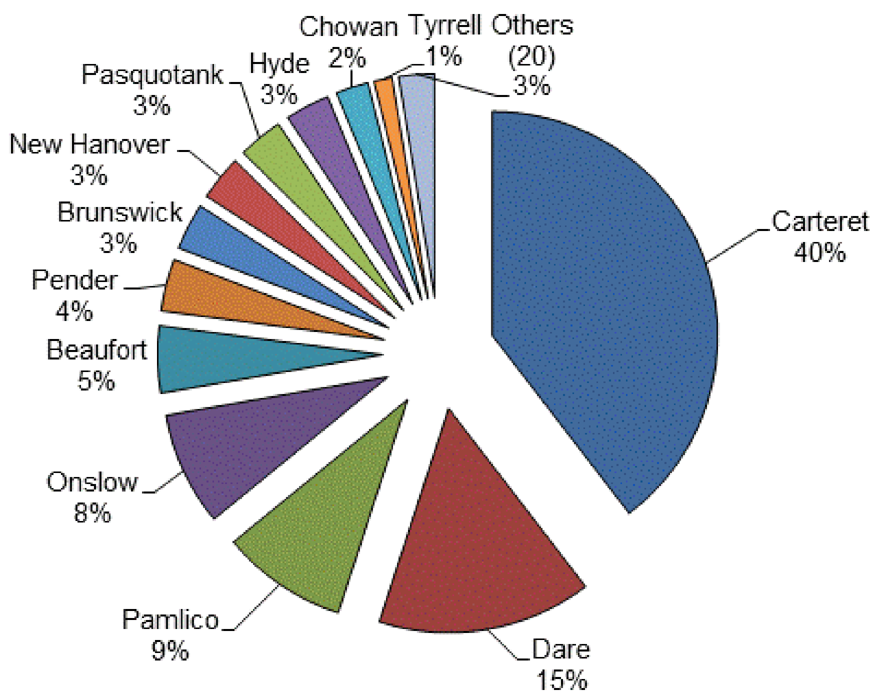

Figure 6.7. Percent of total landings by county in the North Carolina striped mullet fishery: 1972–2011.

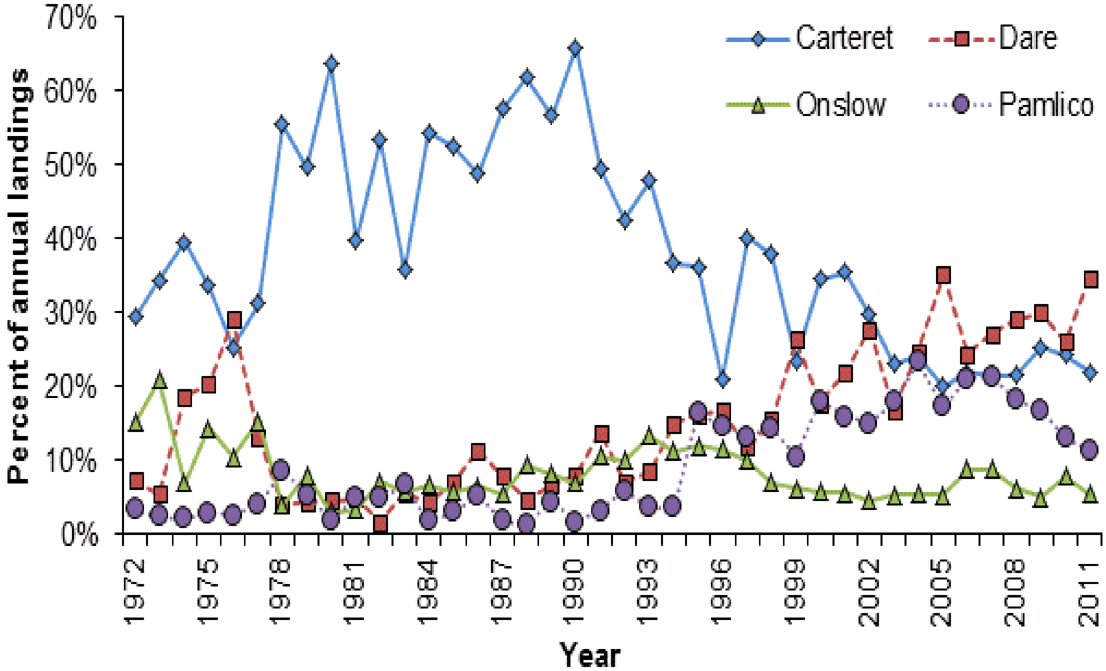

Figure 6.8. Annual percentage of total landings by major counties in the North Carolina striped mullet fishery: 1972–2011.

Table 6.2. Average annual landings by county in the North Carolina striped mullet fishery: 1972–1993, 1994–2002, and 2003–2011.

1972–1993			1994–2002			2003–2011		
County	Average (lb.)	Percent	County	Average (lb.)	Percent	County	Average (lb.)	Percent
Carteret	928,724	49%	Carteret	730,938	33%	Dare	469,444	28%
Dare	178,204	9%	Dare	409,648	19%	Carteret	386,977	23%
Onslow	169,230	9%	Pamlico	307,862	14%	Pamlico	301,883	18%
Pender	105,712	6%	Onslow	175,610	8%	Onslow	112,158	7%
Brunswick	103,179	5%	Chowan	98,685	5%	Beaufort	91,601	5%
Beaufort	94,414	5%	Beaufort	90,036	4%	Hyde	62,624	4%
New Hanover	80,360	4%	Pasquotank	89,261	4%	Pasquotank	60,793	4%
Pamlico	67,756	4%	Hyde	70,535	3%	Pender	45,275	3%
Hyde	57,270	3%	New Hanover	44,435	2%	New Hanover	35,286	2%
Pasquotank	51,407	3%	Perquimans	39,320	2%	Chowan	32,596	2%
Others (10)	73,895	4%	Others (16)	157,958	7%	Others (20)	103,165	6%

6.1.6 Landings by Waterbody

The majority of annual commercial harvest came from state-jurisdiction ocean waters (less than 3 miles) from 1972 to 1993 via the beach seine fishery. On average, 46% of the entire fishery was annually harvested from inshore ocean waters from 1972–1993 (Figure 6.9). A sharp decline in landings from ocean waters occurred in 1994, and annual landings have remained depressed. The proportions of landings from other major waterbodies have generally increased, compensating for the landings decline from the ocean. Current commercial landings from 1994 to 2011 are now harvested more evenly among Pamlico Sound (20%), Core Sound (14%), Neuse River (13%), Albemarle Sound (12%), Ocean less than 3 miles, South of Cape Hatteras (10%), Pamlico River (6%), Croatan Sound (4%), New River (3%), and Bogue Sound (3%; Figure 6.9).

6.1.7 Characterization of Striped Mullet Trips

Erratic yearly landings prior to 2003 may have resulted from fall hurricane effects (Figure 6.10). The slight decline in trips may have resulted from a lower price for roe striped mullet from 1998 to present (Figure 6.3).

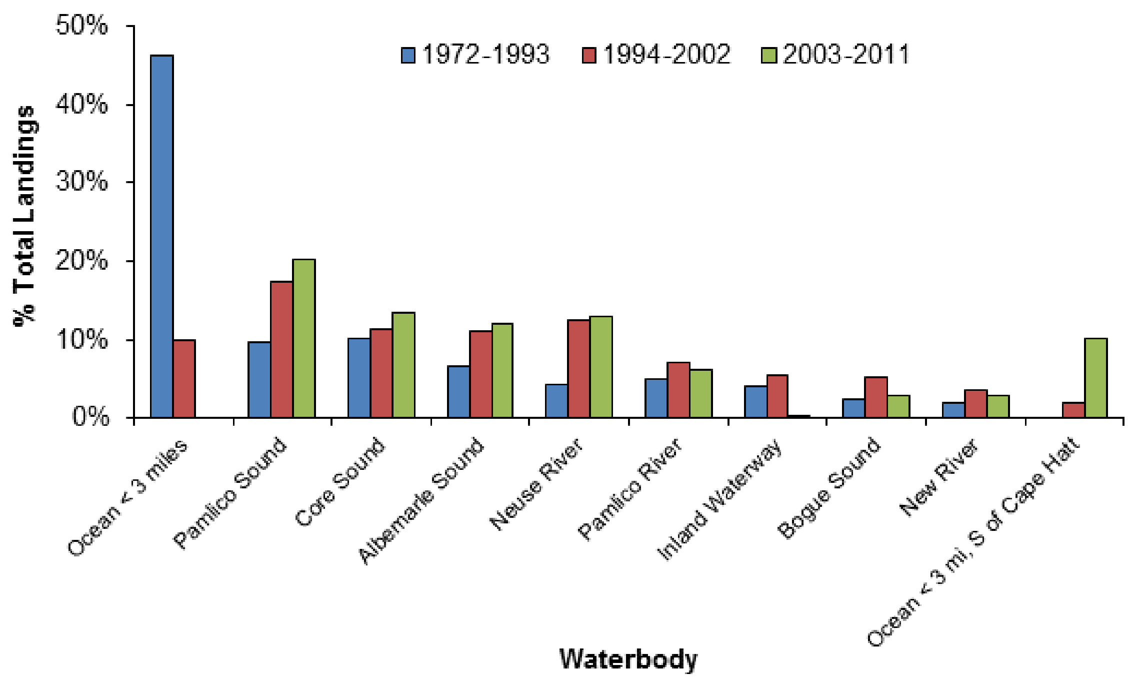

Figure 6.9. Percent of total landings by waterbody in the North Carolina striped mullet fishery: 1972–1993, 1994–2002, and 2003–2011.

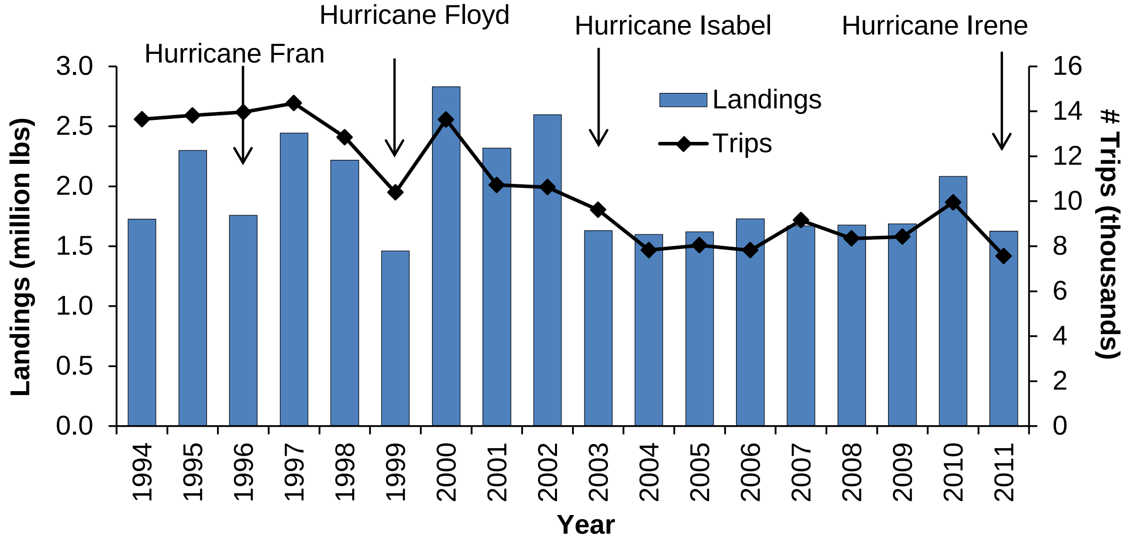

Figure 6.10. Annual landings and number of trips landing striped mullet in the North Carolina striped mullet fishery: 1994–2011.

Most documented trips in the striped mullet fishery are composed of small catches. Seventy percent of the total number of striped mullet trips from 1994 to 2011 was composed of catches with less than 100 lb of striped mullet (Figure 6.11). Small harvest trips (<100 lb) are less frequent in the peak months of October and November implying an increased directed effort for striped mullet during the fall spawning migration. Trips with less than 100 lb of striped mullet harvest accounted for approximately 9% of the total landings by weight from 1994 to 2011 (Figure 6.11). Furthermore, catches with less than five lb of striped mullet were the most common trip type, accounting for 23% of total trips (Figure 6.12). Incidental catches of five lb of striped mullet or less occur most frequently in the flounder pound net fishery and small mesh set gill net fisheries for spot, white perch, gizzard shad, bluefish, etc.

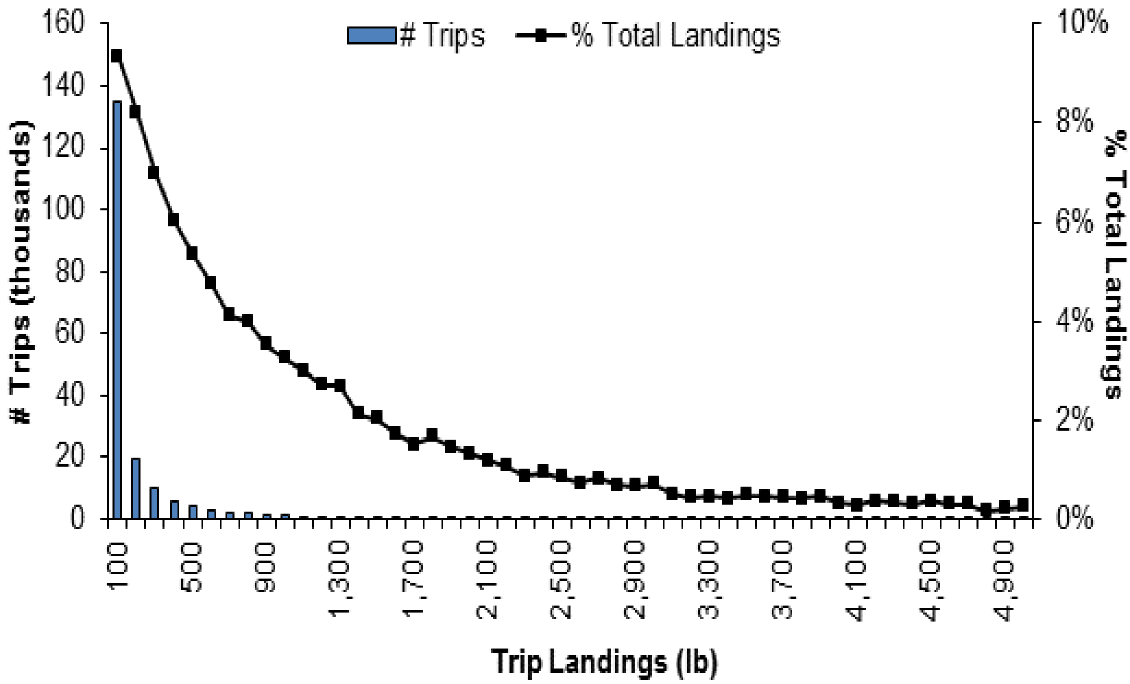

Figure 6.11 Total number of trips and percent of total landings in each 100 lb weight class of trip level landings in the North Carolina striped mullet fishery: 1994–2011. Note: the 100 lb weight class represents all trips with 1–100 lb landed.

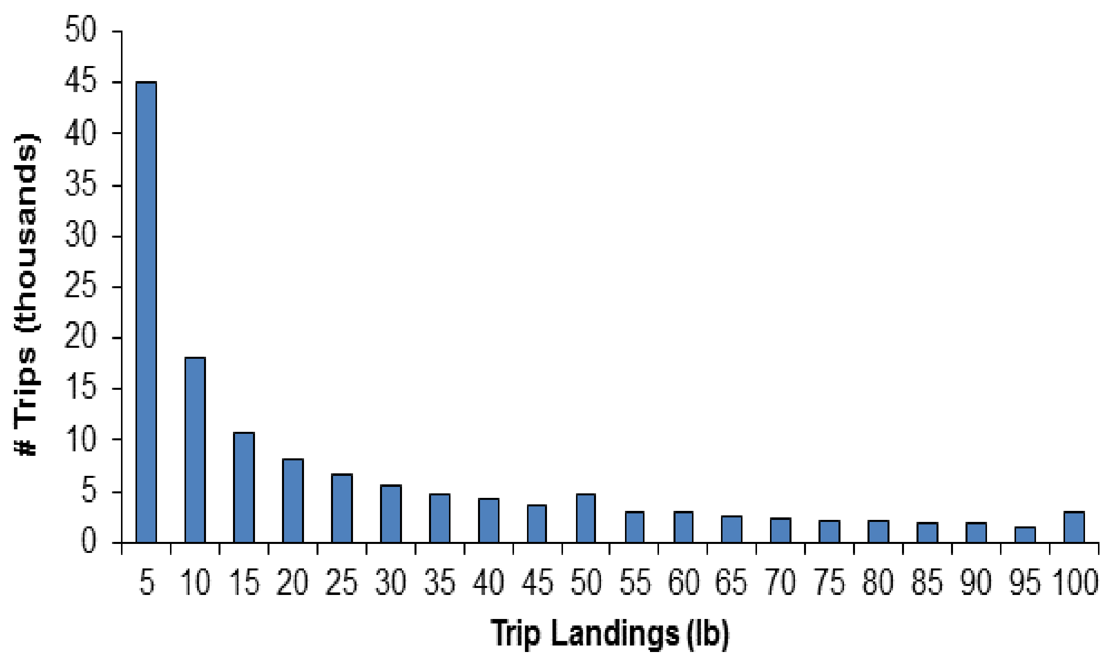

Figure 6.12. Total number of trips for each 5 lb weight class of landings for trips harvesting ≤ 100 lb in the North Carolina striped mullet fishery: 1994–2011. Note: the 5 lb weight class represents all trips with 1–5 lb landed.

6.1.8 Landings by Market Grade

Striped mullet harvest is categorized by size and roe grades when purchased by the seafood dealer from the fisherman. Striped mullet landings only began to be recorded by specific market grades on trip tickets in 1994 as extra-small, small, medium, large, jumbo, mixed, red roe, and white roe market categories. Ninety-seven percent of all striped mullet landings were sorted into either mixed (52%), red roe (39%), or white roe (spawning male striped mullet; 7%) market grades from 1994 to 2011 (Table 6.3; Figure 6.13).

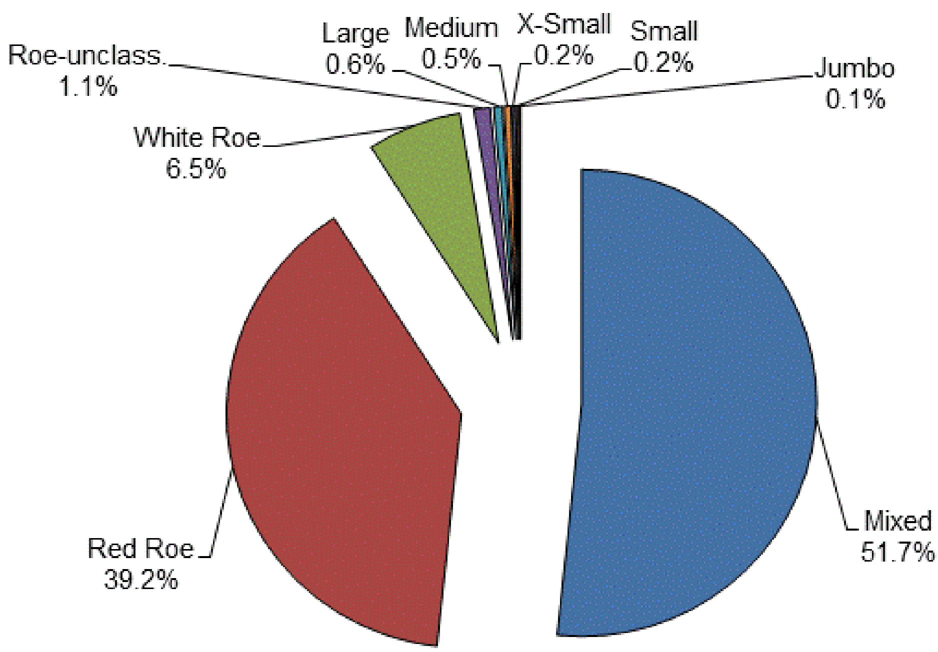

Figure 6.13. Percent of total landings by market grade in the North Carolina striped mullet fishery: 1994–2011.

Table 6.3. Average annual landings by market grade in the North Carolina striped mullet fishery: 1994–2002, 2003–2011, and 1994–2011.

1994–2002		2003–2011		1994–2011	
Market Grade	Average (lb.)	Market Grade	Average (lb.)	Market Grade	Average (lb.)
Mixed	1,081,857	Mixed	925,211	Mixed	1,003,534
Red Roe	908,461	Red Roe	614,101	Red Roe	761,281
White Roe	160,632	White Roe	91,228	White Roe	125,930
Roe	14,865	Roe	28,428	Roe	21,647
Large	7,246	Medium	15,648	Large	11,302
Small	4,793	Large	15,358	Medium	9,223
Medium	3,596	X-Small	6,632	X-Small	3,802
Jumbo	1,200	Small	2,795	Small	3,794
X-Small	972	Jumbo	2,378	Jumbo	1,833

Mixed market grade harvest occurs year-round, although more heavily in late summer to early fall and in January, probably associated with increased availability due to migratory schooling during these months (Figure 6.14; Leard et al. 1995; Collins 1985a; Bichy 2000). Ninety-eight percent of the annual red roe harvest and 95% of the white roe harvest occurs in October and November (Figure 6.14). Most spawning striped mullet will be graded as mixed after Thanksgiving, even though ripe fish are occasionally harvested into February–March. Typically, the roe market shifts from North Carolina to Florida in December.

Pronounced year-to-year fluctuations in red roe harvest are evident from 1994 to 2011 (Figure 6.15). Strong weather conditions (hurricanes, cold fronts) during the fall can profoundly affect landings from year-to-year. In addition to limiting fishing opportunities, hurricanes and hard winds can cause mature fish to exit inshore areas rapidly and prematurely. Hurricanes Fran (1996), Floyd (1999), Isabel (2003), and Irene (2011) likely caused fish to move offshore earlier than normal contributing to decreased landings in those years.

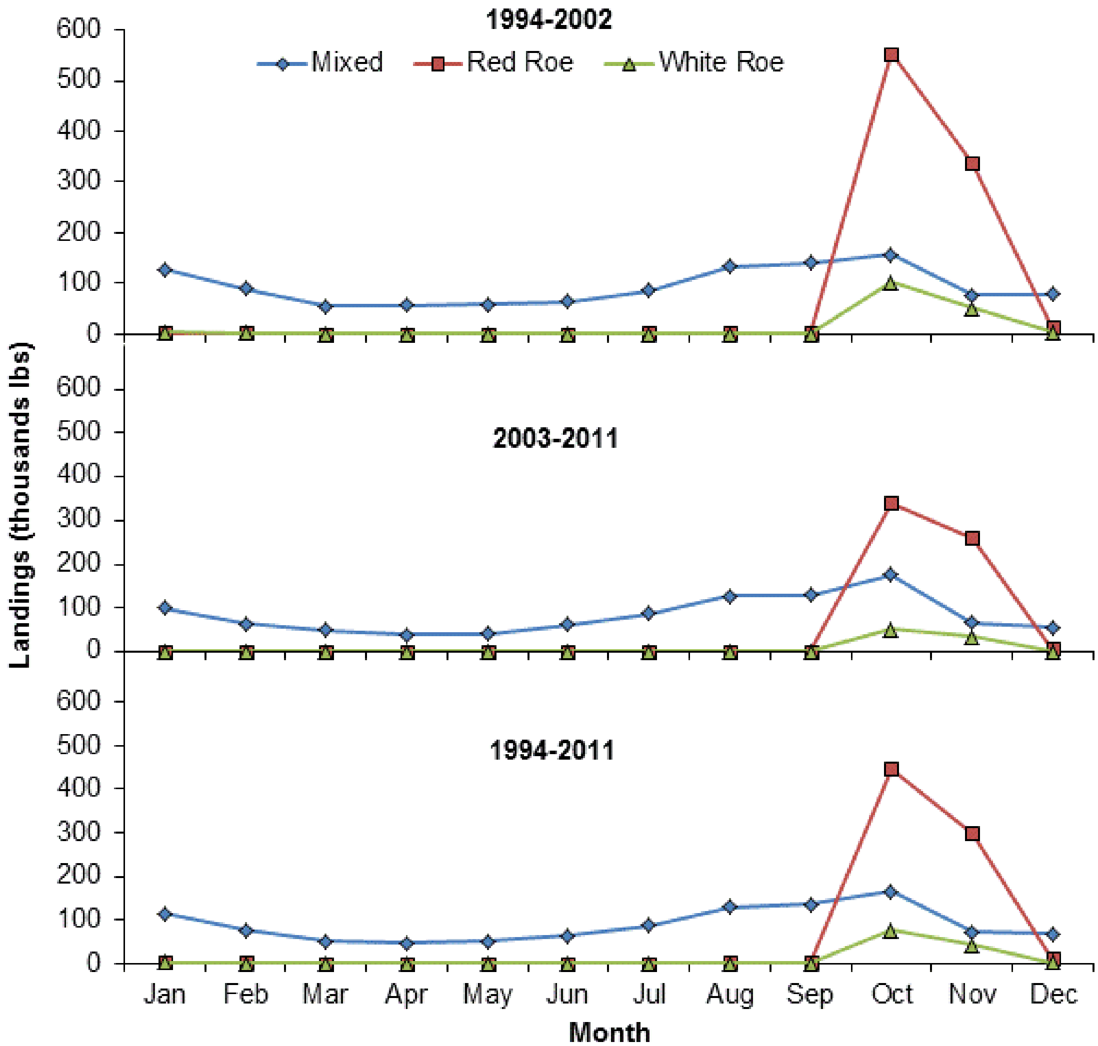

Figure 6.14. Average monthly landings for the three major market categories in the North Carolina striped mullet fishery: 1994–2002, 2003–2011, and 1994–2011.

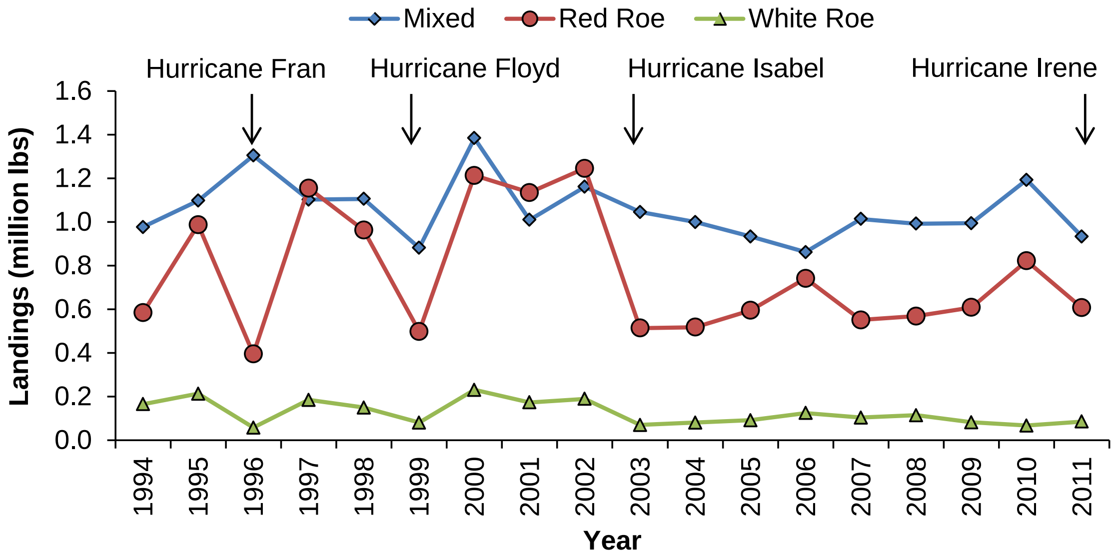

Figure 6.15. Annual landings for the three major market categories in the North Carolina striped mullet fishery: 1994–2011.

6.1.9 Landings by Gear

6.1.9.1 Historical

Seines and gill nets have been the two primary gear types involved in the fishery since the earliest landings documentation in 1887 (Figure 6.16). The seine fishery accounted for the majority of the commercial harvest for nearly a century, from 1887 to 1978. During this period, 60% of the total commercial harvest was landed by seines and 39% from gill nets. Gill net landings were larger than seine landings in only five of 50 years of available landings data during this time period (Chestnut and Davis 1975; NCDMF unpublished data). The seine fishery dominated early landings from 1887 to 1934, accounting for 61% of the total harvest (36% from gill nets). Total gill net landings exceeded seine landings (56% to 44%) for a short period, from 1937 to 1940. Seines again accounted for most of the fishery harvest (62% of total landings) from 1950 to 1978 (gill nets were responsible for 37% of total landings).

Gill nets replaced seines as the dominant gear type in the fishery in 1979 (Figure 6.16). The yearly proportion of the total fishery landings by gill nets has steadily increased through 1995 and has remained above 90%. By 2001, 94% of total landings were harvested by gill nets, 4% from seines, and 1% from cast nets.

More detailed landings data with respect to fishing gears became available in 1994 due to the creation of the NCTTP. The number of gears reported in the striped mullet fishery more than doubled between the periods of 1972–1993 and 1994–2002, from 16 to 34 different gear types. A maximum of three gears are recorded by the NCTTP for each paper trip ticket of landings (since 1994). However, the NCTTP does not allocate harvest weight to each individual fishing gear reported on the paper trip ticket when multiple gears are listed. In 2004, electronic reporting of trip tickets became more popular amongst commercial dealers and made it possible to associate a specific gear for each species reported. If more than one gear was listed for a trip, the gear most likely to have caught striped mullet was assigned to GEAR1 if it was reported as GEAR2 or GEAR3 and the reported GEAR1 gear was not an appropriate gear. Trips with gears commonly known to catch striped mullet as GEAR1 were not modified. The revised dataset was used to summarize striped mullet commercial landings data by gear between 1994 and 2011.

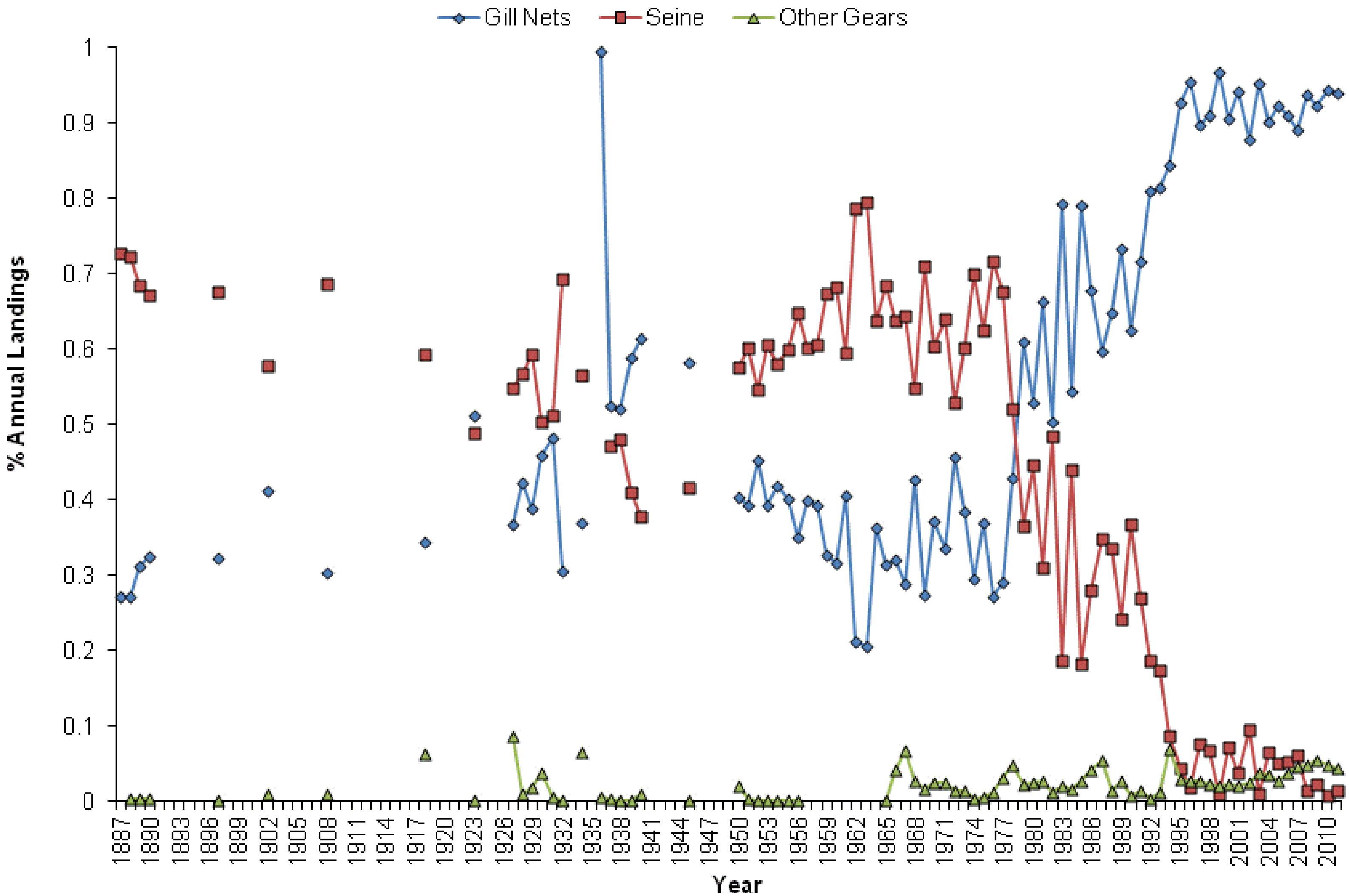

Figure 6.16. Annual percent of total landings trends for gill nets, seines, and other gears in the North Carolina striped mullet fishery: 1887–2011.

6.1.9.2 Current (1994–2011)

An average of 92% of all striped mullet landings have been harvested annually by gill nets (runaround, set, and drift nets) since 1994 (Figure 6.17). Runaround gill nets are responsible for the greatest, single proportion (55%) of total, annual landings in the striped mullet fishery (1994–2011; Table 6.4). Set gill nets (combined sinking, floating, large mesh, and small mesh) annually produced 37% of the harvest from 1994 to 2011. On average, beach seines were responsible for 5% of the annual harvest, and cast nets yielded 2% from 1994 to 2011.

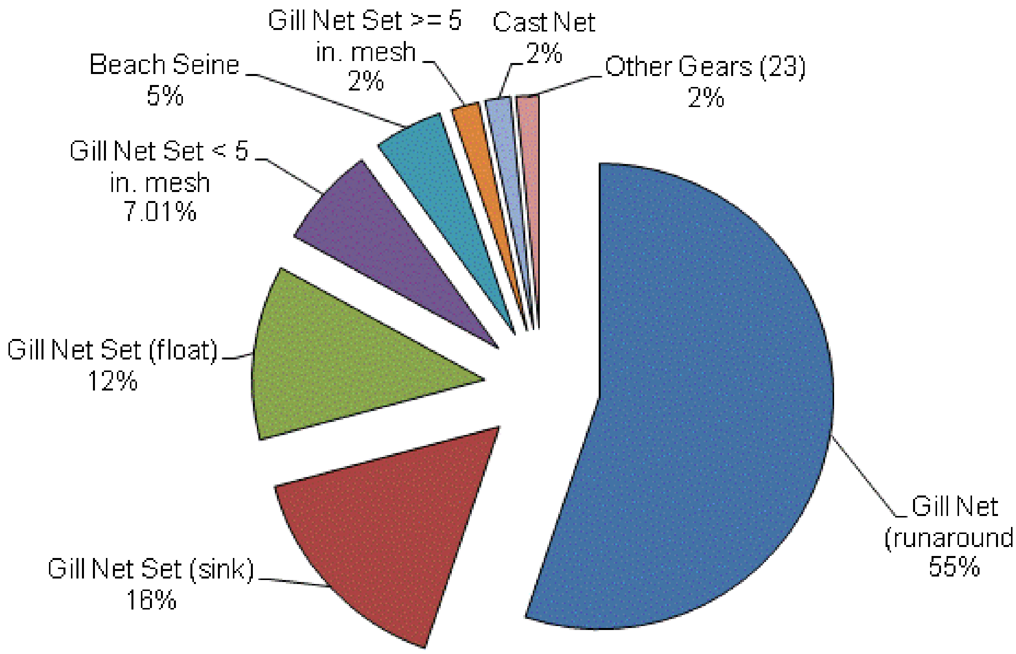

Figure 6.17. Average percent of annual landings by gear in the North Carolina striped mullet fishery: 1994–2011.

Table 6.4. Average annual landings by gear in the North Carolina striped mullet fishery: 1994–2002, 2003–2011, and 1994–2011.

1994–2002		2003–2011		1994–2011	
Gear	Average (lb.)	Gear	Average (lb.)	Gear	Average (lb.)
Gill Net (runaround)	1,047,177	Gill Net (runaround)	1,096,868	Gill Net (runaround)	1,072,022
Gill Net Set (sink)	506,827	Gill Net Set, <5-in mesh*	306,311	Gill Net Set, <5-in mesh*	306,311
Gill Net Set (float)	431,223	Gill Net Set (sink)	101,561	Gill Net Set (sink)	304,194
Beach Seine	130,001	Gill Net Set, ≥5-in mesh*	83,506	Gill Net Set (float)	235,706
Cast Net	24,242	Beach Seine	54,582	Beach Seine	92,292
Gill Net (drift)	15,037	Cast Net	44,287	Gill Net Set, ≥5-in mesh*	83,506
Pound Net	12,113	Gill Net Set (float)	40,188	Cast Net	34,265
Haul Seine	8,839	Pound Net	4,228	Gill Net (drift)	9,044
Swipe Net	2,109	Gill Net (drift)	3,051	Pound Net	8,171
Fyke Net	1,855	Fyke Net	2,715	Haul Seine	5,249
Others (16)	3,487	Others (15)	7,796	Others (20)	8,152

* Average landings only for 2004–2011, not a gear option on Trip Ticket until 2004

6.1.9.2.1 Runaround Gill Nets

Runaround gill net is a general term used to classify a style of fishing where a gill net is used to surround a school of fish and the net is then immediately retrieved. Gears typically referred to as “runaround gill nets” include strike nets, trammel nets, and drop nets. The importance of runaround gill nets has steadily increased since 1972 (Figure 6.18). Runaround gill netting was a major harvest producer in historic records during the late 1930s (59% of total harvest in 1939), although inconsistency in commercial sampling precludes a more detailed historical fishing gear analysis prior to 1972. The continuing surge in the mid-1990s in runaround gill net landings may have been buffeted by the 1995 gill net closure in Florida state waters. Anecdotal reports from North Carolina fishermen indicate an influx of Florida striped mullet fishermen into North Carolina and subsequent improvements in harvesting methods. More jet drive boats, spotting towers, night fishing, and runaround gill netting were reported by the mid-1990s. Also, expanded fishery rules requiring gill net attendance in additional areas for small mesh gill nets (less than 5 inches stretch mesh) began in 1998, which may have further prompted a shift from set nets to runaround fishing for striped mullet. However, the number of trips with runaround gill net landings has fluctuated since peaking in 1997 and landings have increased only slightly (Figure 6.19).

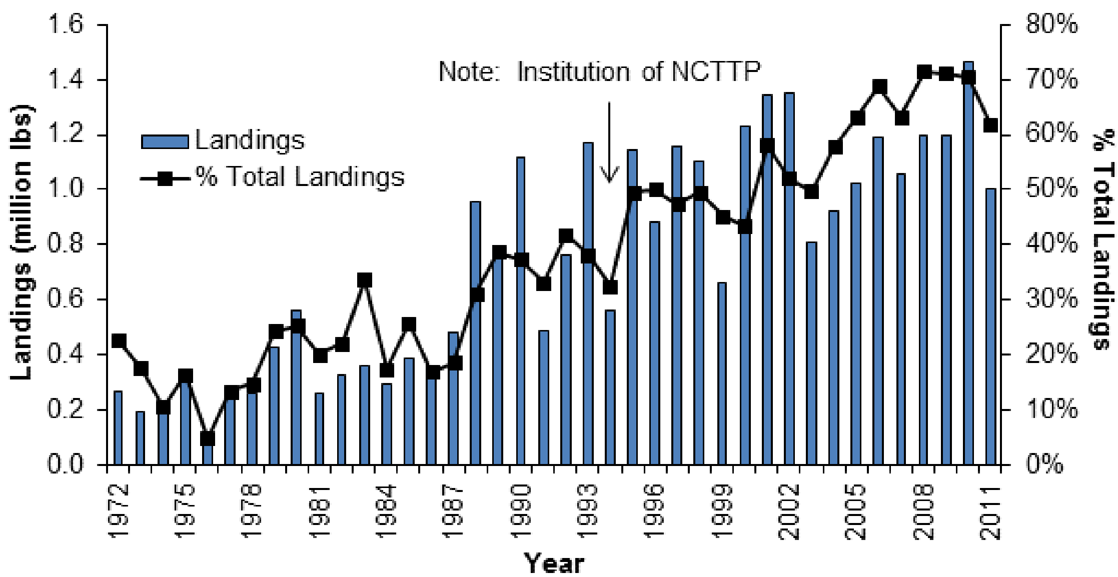

Figure 6.18. Annual landings and percent of total landings by runaround gill nets in the North Carolina striped mullet fishery: 1972–2011.

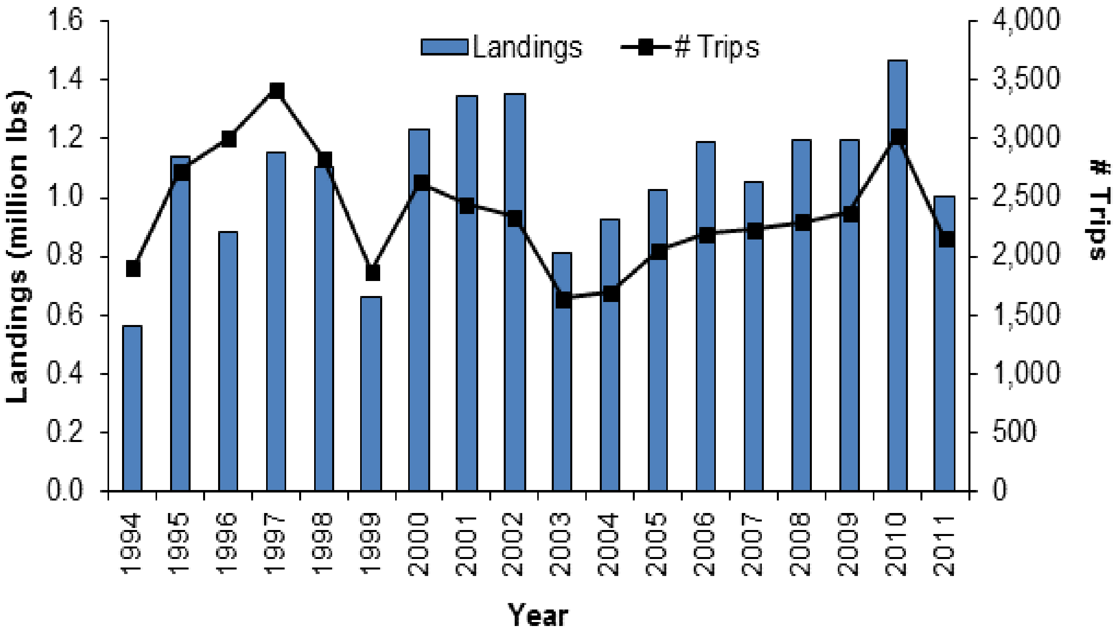

Figure 6.19. Annual landings and number of trips by runaround gill nets in the North Carolina striped mullet fishery: 1994–2011. Note: number of trips only includes trips that landed striped mullet.

Most runaround gill net trips and landings occur in October and November during the roe season (Figure 6.20). Mesh sizes range from 2 ¾-in to 5-in stretch mesh, although most runaround nets are between 3 1/8 and 4-in stretch mesh (NCDMF data). There was some concern effort may shift from set gill nets to runaround gill nets after the settlement of the sea turtle lawsuit in 2010, but landings and trips in 2010 and 2011 are similar to those seen from 2003 to 2009 (Figures 6.21 and 6.22).

Eighty-eight percent of runaround gill net landings are distributed among 10 waterbodies, with the largest contributions from Pamlico Sound (21%), Neuse River (17%), Core Sound (16%), and the ocean (7%; Table 6.5). Runaround gill netting has decreased considerably in the ocean since 1994, decreasing from 12% of the total runaround harvest in 1994 to 3% in 2011. Runaround landings from other waterbodies have fluctuated without much trend from 1994 to 2011 (Figure 6.23).

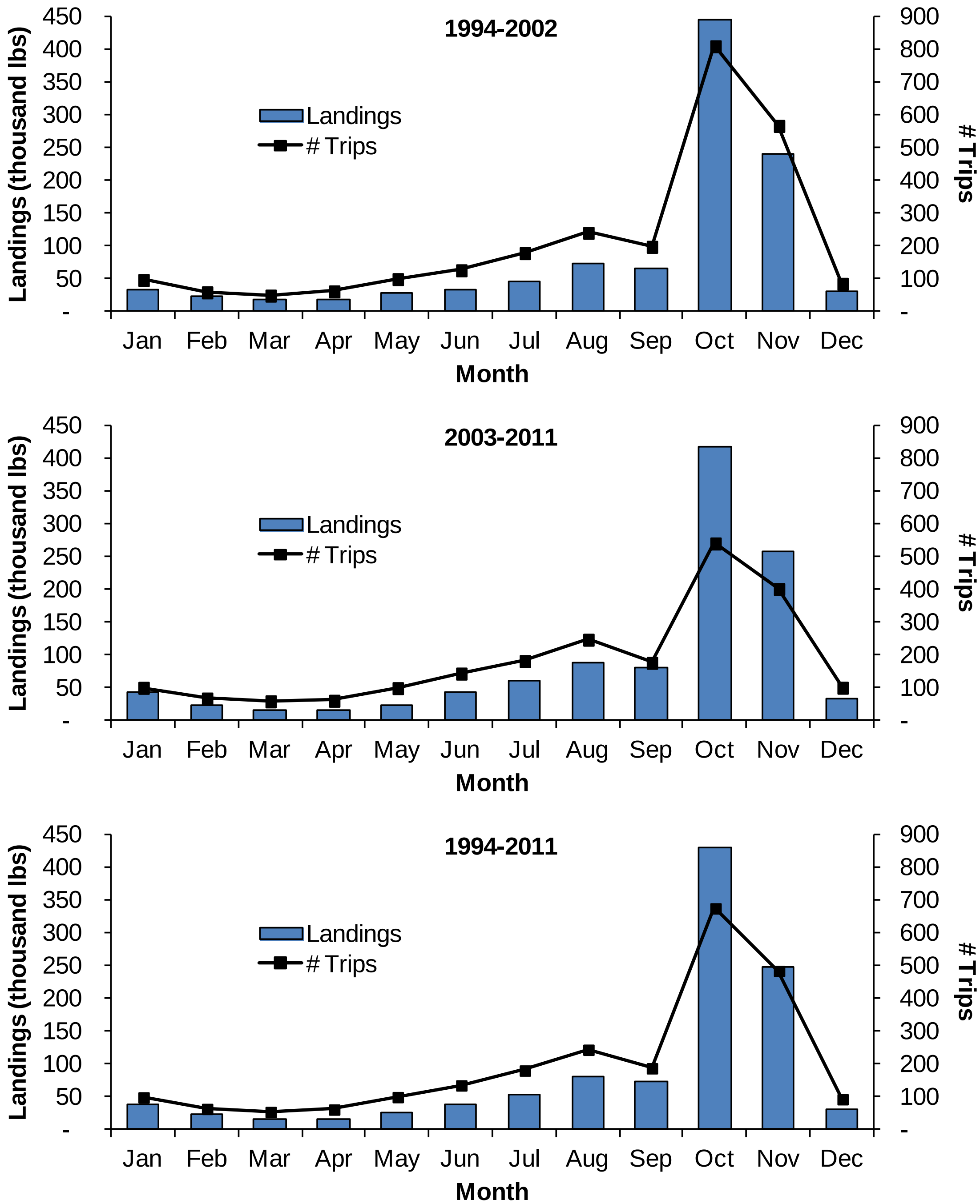

Figure 6.20. Average annual landings and number of trips by month for runaround gill nets in the North Carolina striped mullet fishery: 1994–2002, 2003–2011, and 1994–2011.

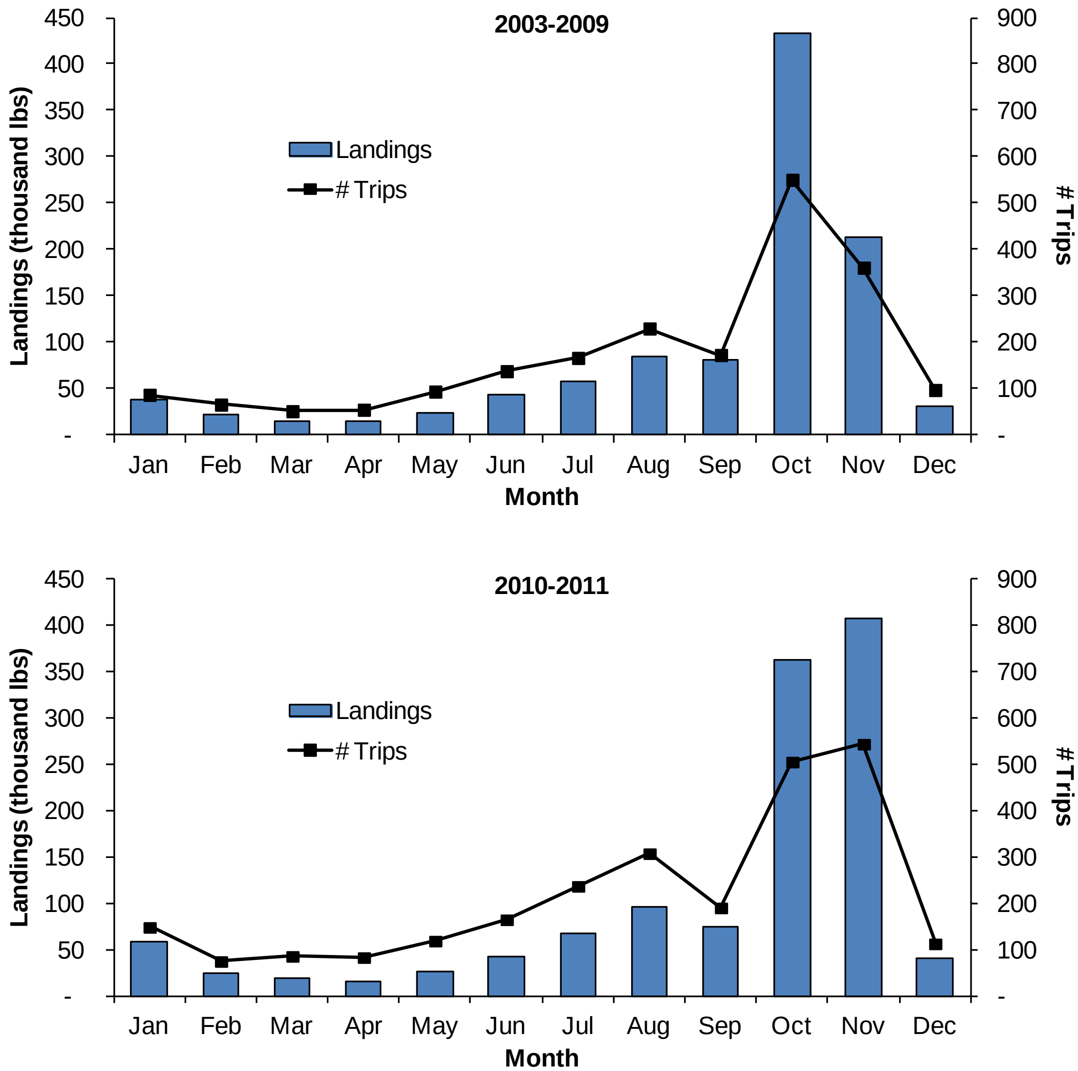

Figure 6.21. Average annual landings and number of trips by month for runaround gill nets in the North Carolina striped mullet fishery: 2003–2009 and 2010–2011.

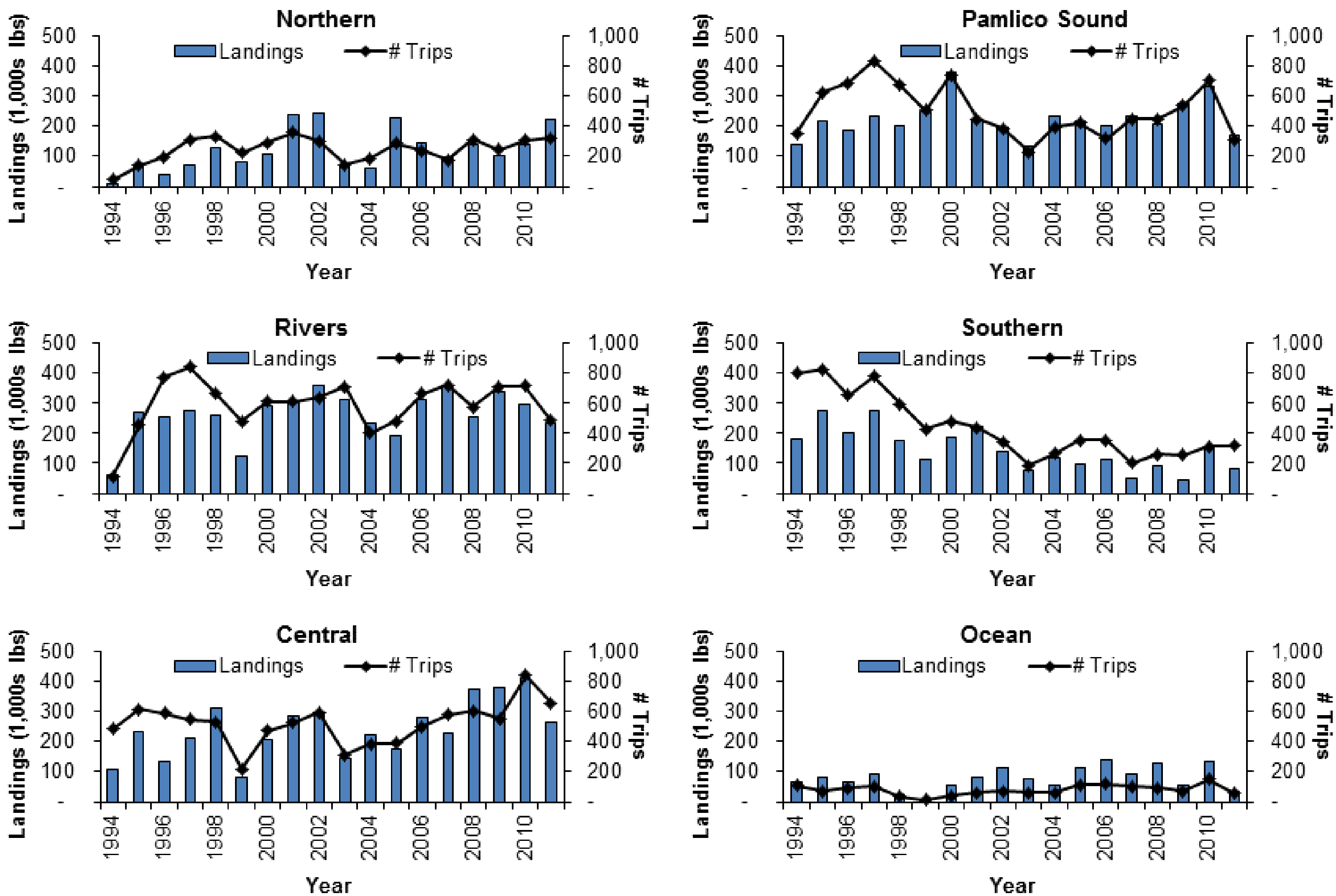

Figure 6.22. Annual landings and number of trips for runaround gill nets for six distinct areas in the North Carolina striped mullet fishery: 1994–2011. Note: only trips landing striped mullet included in trip count.

Table 6.5. Average annual landings by waterbody for runaround gill nets in the North Carolina striped mullet fishery: 1994–2002, 2003–2011, and 1994–2011.

1994–2002			2003–2011			1994–2011		
Waterbody	Average (lb.)	Percent	Waterbody	Average (lb.)	Percent	Waterbody	Average (lb.)	Percent
Pamlico Sound	224,313	21%	Pamlico Sound	223,420	20%	Pamlico Sound	223,866	21%
Neuse River	169,745	16%	Core Sound	217,773	20%	Neuse River	182,708	17%
Core Sound	120,327	11%	Neuse River	195,672	18%	Core Sound	169,050	16%
Inland Waterway	99,144	9%	Ocean 0–3 Miles	90,521	8%	Ocean 0–3 Miles	77,669	7%
Ocean 0–3 Miles	64,817	6%	Pamlico River	73,787	7%	Pamlico River	62,176	6%
Bogue Sound	60,528	6%	Croatan Sound	55,123	5%	Croatan Sound	55,365	5%
Croatan Sound	55,608	5%	Roanoke Sound	42,250	4%	Inland Waterway	52,684	5%
New River	54,449	5%	Bogue Sound	38,449	4%	Bogue Sound	49,488	5%
Pamlico River	50,565	5%	Albemarle Sound	32,949	3%	New River	38,403	4%
Albemarle Sound	30,875	3%	New River	22,357	2%	Albemarle Sound	31,912	3%
Others (17)	116,805	13%	Others (18)	104,567	9%	Others (19)	128,700	11%

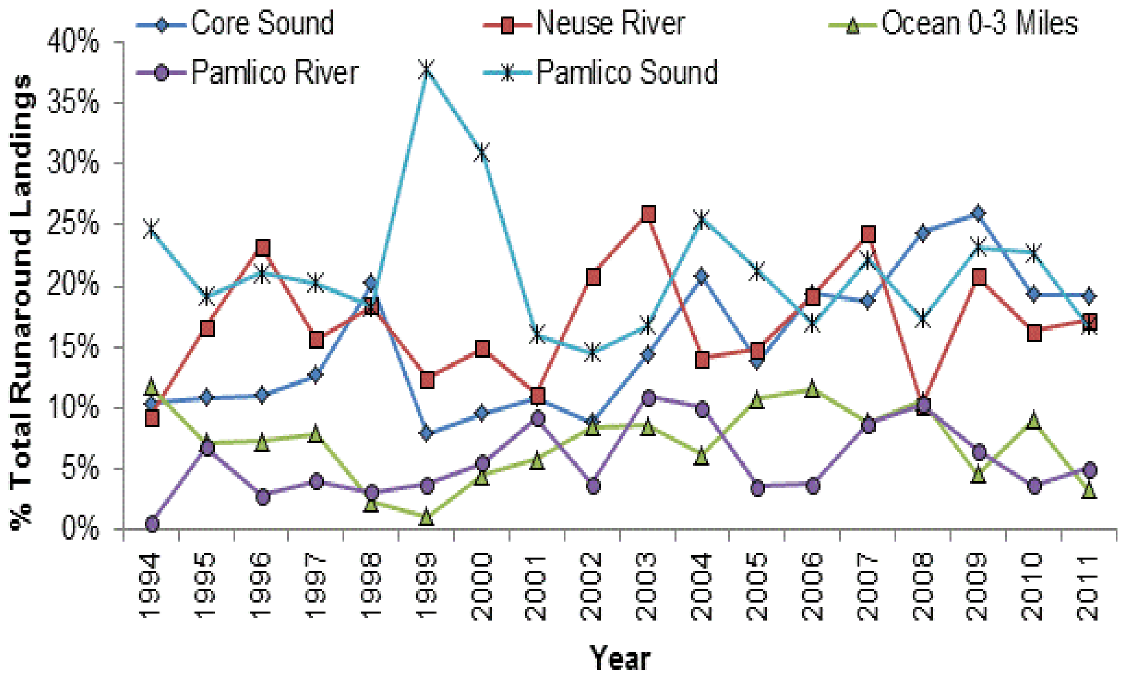

Figure 6.23. Annual percent of runaround gill net landings for major waterbodies in the North Carolina striped mullet fishery: 1994–2011.

6.1.9.2.2 Set Gill Nets

Set gill nets have also risen in importance since 1972, although its proportion of the total landings has not increased since the mid-1980s (Figure 6.24). Between 1994 and 2011, four types of set nets have been recorded by the NCTTP: floating, sinking, large mesh anchored, and small mesh anchored gill nets. Sinking set gill nets are defined as stationary gill nets with the top line below the surface of the water whereas floating gill nets have a top line at the surface of the water. In 2004, floating and sinking set gill nets were phased out and replaced by large mesh and small mesh anchored gill net codes in the NCTTP. Large mesh anchored gill nets have a stretched mesh size of five inches or greater and small mesh anchored gill nets have a stretched mesh size of less than five inches. Striped mullet landings from floating set nets began to decline in 2001, while sinking set nets have fluctuated without trend since 1994 (Figure 6.25). When the NCTTP codes for set gill nets changed in 2004, small mesh gill nets have accounted for the bulk of set gill net landings where landings from large mesh gill nets have been steady accounting for approximately 5% of annual striped mullet landings. Floating, sinking, large mesh, and small mesh set gill net landings are combined in the ensuing description of the set gill net fishery.

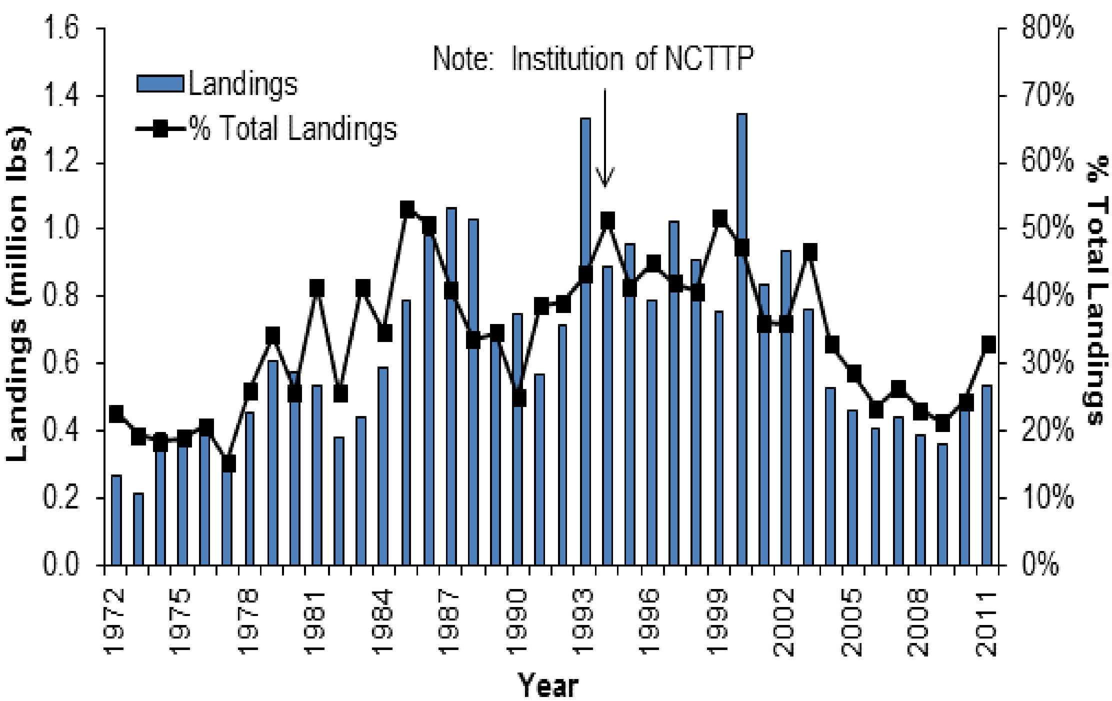

Figure 6.24. Annual landings and percent of total landings by set gill nets in the North Carolina striped mullet fishery: 1994–2011.

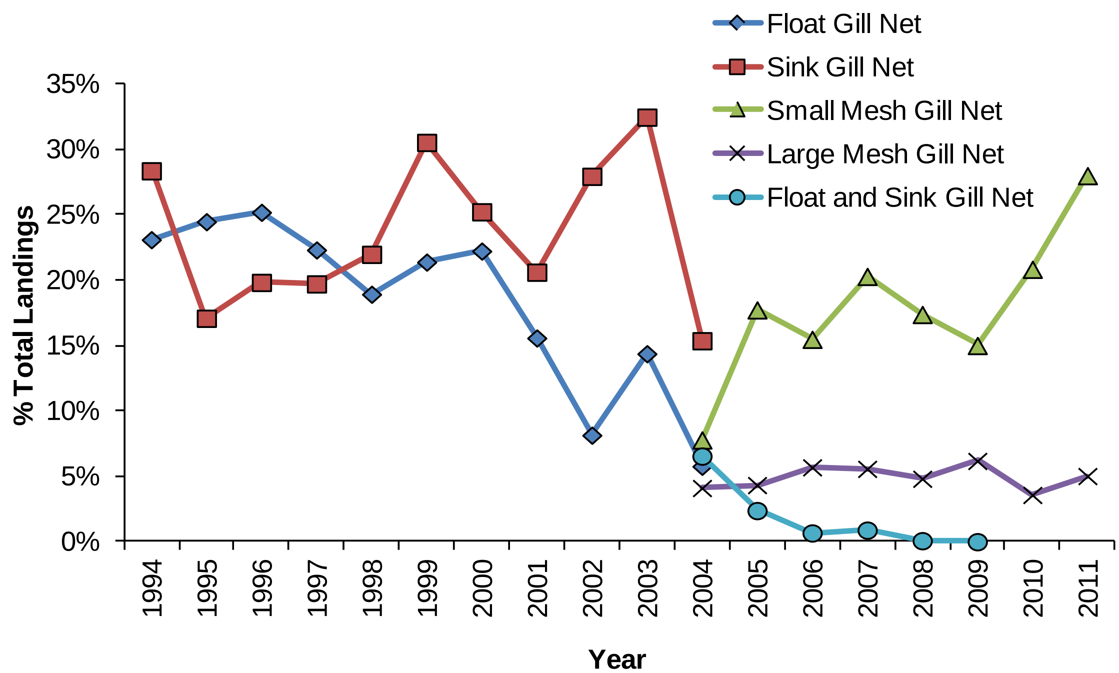

Figure 6.25. Percent of annual landings from float, sink, large mesh, and small mesh gill nets in the North Carolina striped mullet fishery: 1994–2011.

The number of trips with striped mullet landings harvested by set gill nets has declined from 1994 to 2002 (Figure 6.26). Annual landings from 1994 to 2011 have fluctuated but generally decreased during this period.

The number of set gill net trips with striped mullet harvest is greatest in October and November (Figure 6.27). The number of set gill net trips with landings of striped mullet is still elevated in winter and spring months (January to April) compared to runaround gill net trips. However, landings from set nets during the winter and spring are small, reflecting more incidental striped mullet capture in other non-targeted gill net fisheries. A wide range of set gill net mesh sizes (3 in–7-in diameter stretch) are found with striped mullet landings, also reflecting a wide array of different target fisheries (e.g., spot, flounder, white perch, bluefish, trout, and menhaden). There was some concern effort may shift from set gill nets to runaround gill nets after the settlement of the sea turtle lawsuit in 2010, but landings and trips in 2010 and 2011 are similar to those seen from 2003 to 2009 (Figures 6.28 and 6.29).

Eighty-six percent of set gill net landings of striped mullet were harvested in 10 waterbodies, with the largest contributions from Albemarle Sound (26%), Pamlico Sound (17%), Pamlico River (9%), Neuse River (9%), and Core Sound (8%). Landings from other waterbodies by set gill nets are shown in Table 6.6. Fluctuations in the share of landings taken in the above waterbodies by set gill nets are shown in Figure 6.30.

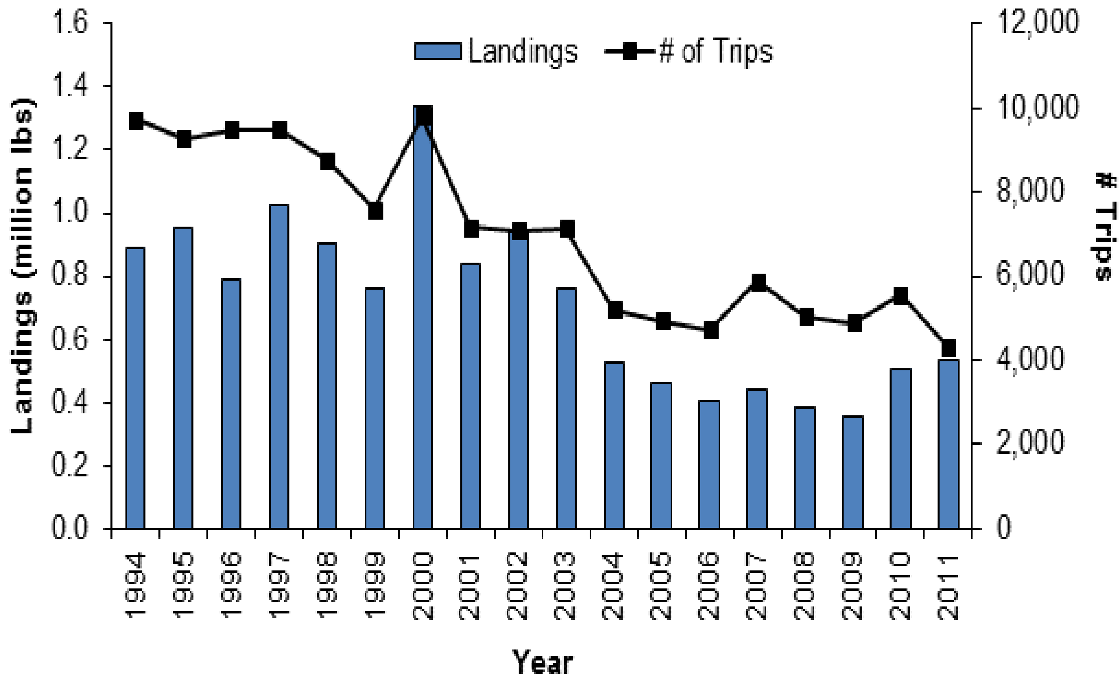

Figure 6.26. Annual landings and number of trips by set gill nets in the North Carolina striped mullet fishery: 1994–2011. Note: number of trips only includes trips that landed striped mullet.

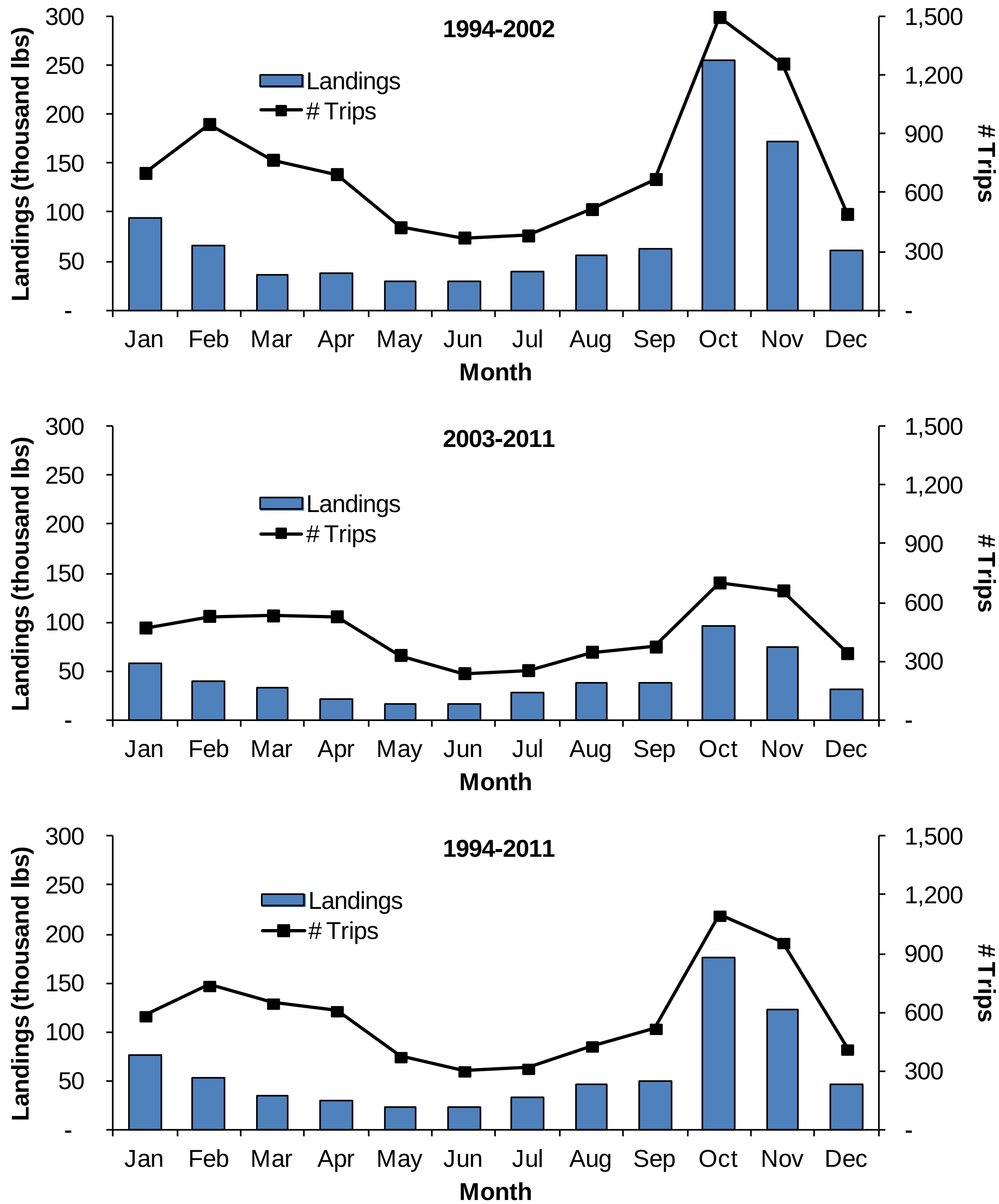

Figure 6.27. Average annual landings and number of trips by month for set gill nets in the North Carolina striped mullet fishery: 1994–2011.

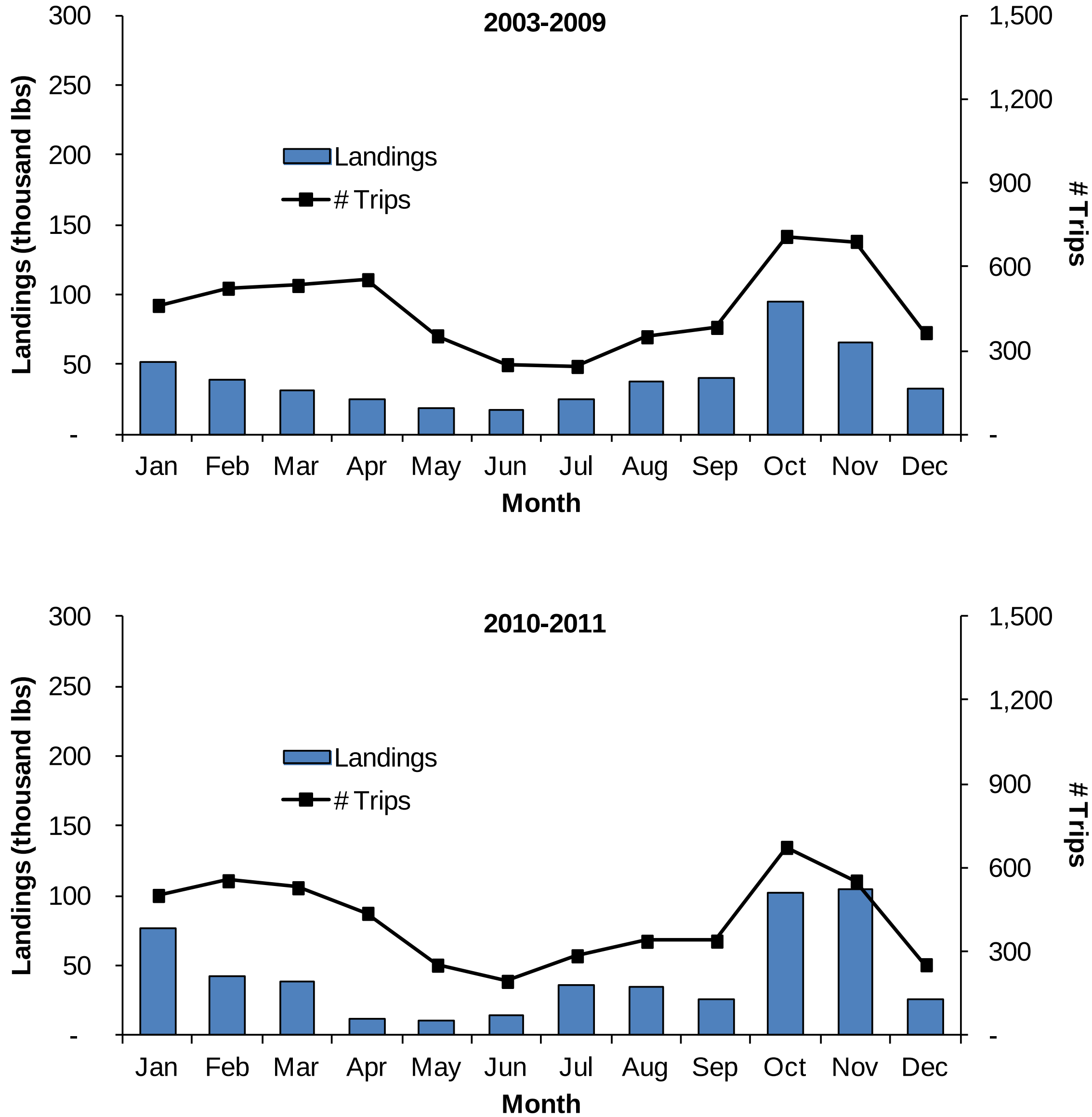

Figure 6.28. Average annual landings and number of trips by month for set gill nets for two distinct periods in the North Carolina striped mullet fishery: 2003–2009 and 2010–2011.

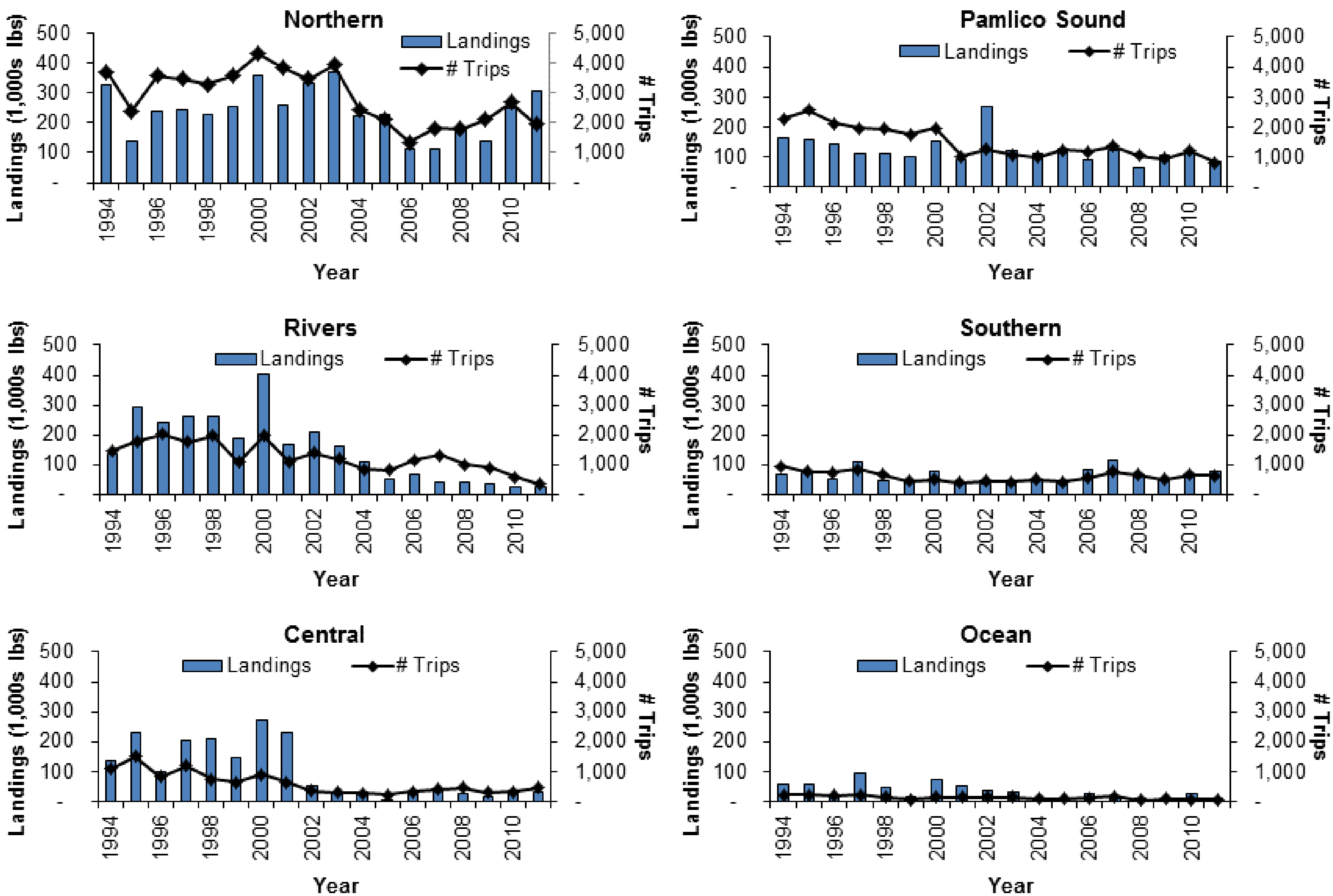

Figure 6.29. Annual landings and number of trips for set gill nets for six distinct areas in the North Carolina striped mullet fishery: 1994–2011.

Table 6.6. Average annual landings and percent total landings by water body for set gill nets in the North Carolina striped mullet fishery: 1994–2002, 2003–2011, and 1994–2011.

1994–2002			2003–2011			1994–2011		
Waterbody	Average (lb.)	Percent	Waterbody	Average (lb.)	Percent	Waterbody	Average (lb.)	Percent
Albemarle Sound	210,105	22%	Albemarle Sound	167,188	34%	Albemarle Sound	188,646	26%
Pamlico Sound	144,754	15%	Pamlico Sound	102,564	21%	Pamlico Sound	123,659	17%
Core Sound	105,982	11%	Pamlico River	29,810	6%	Pamlico River	67,093	9%
Pamlico River	104,376	11%	New River	28,924	6%	Neuse River	64,622	9%
Neuse River	102,965	11%	Neuse River	26,279	5%	Core Sound	58,378	8%
Ocean 0–3 Miles	50,724	5%	IWW (Onslow)	17,247	4%	Ocean 0–3 Miles	33,216	5%
Bogue Sound	49,000	5%	Currituck Sound	15,778	3%	Bogue Sound	29,490	4%
New River	22,266	2%	Ocean 0–3 Miles	15,709	3%	New River	25,595	4%
Inland Waterway	19,549	2%	Croatan Sound	12,446	3%	Currituck Sound	13,545	2%
Bay River	17,689	2%	Roanoke Sound	12,072	2%	Croatan Sound	12,609	2%
Others (21)	110,641	14%	Others (20)	60,236	13%	Others (21)	96,298	14%

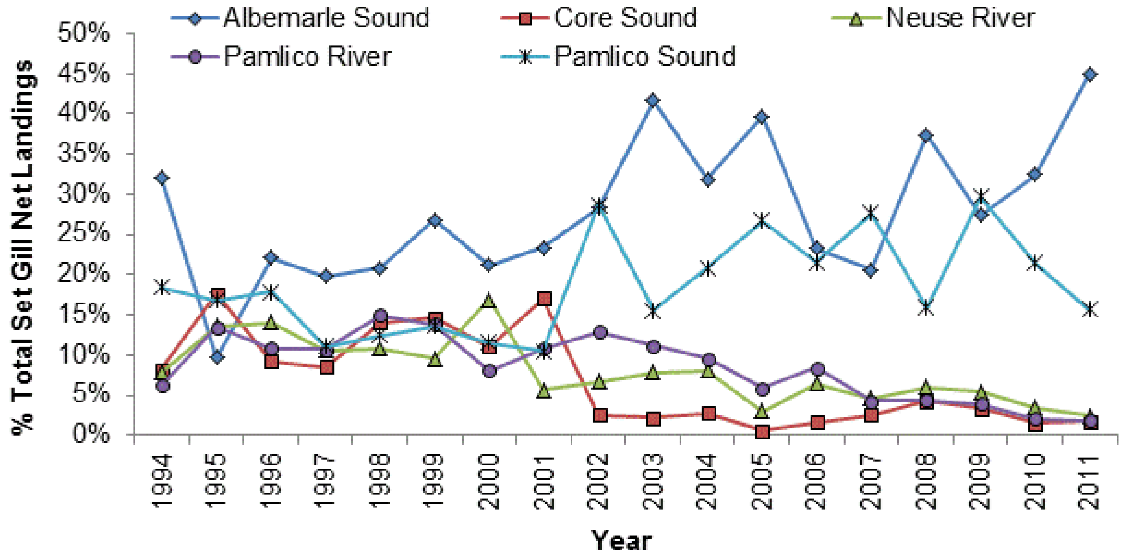

Figure 6.30. Annual percent of set gill net landings for major waterbodies in the North Carolina striped mullet fishery: 1994–2011.

6.1.9.2.3 Beach Seines

The historic striped mullet seine fishery was predominantly composed of beach crews scattered among established territories along the central coastline of North Carolina, from Ocracoke south along Core, Shackleford, and Bogue banks (Simpson and Simpson 1994). Spotters along the beach would alert boat crews of southwestward, ocean migrating striped mullet schools. A long seine was deployed by small boat or skiff to intercept the oncoming school. Striped mullet were hauled in by manpower, horses, oxen, or tractor in later years. Stop nets (stationary nets not intended to gill fish but used to impede the movement of schooling fish so that they can be harvested with a seine) were employed along Bogue Banks.

The harvest proportion of annual landings from the beach seine fishery has dwindled since 1972 (Figure 6.31) and landings have fluctuated but declined greatly since 1994 (Figure 6.32). Landings by beach seines occur almost entirely in October and November (Figure 6.33). Extremely poor landings in 1996, 1999, and 2003 were probably the result of fall hurricanes and strong weather conditions, which can have a particularly profound effect on stop net harvest because of its limited fishing season. Beach seine landings occur primarily in Carteret (90%), Dare (6%), Hyde (2%), and Onslow counties (2%; Table 6.7).

During the development of the original 2006 Striped Mullet FMP, two issues involving the striped mullet beach seine fishery were developed: 1) Pier, stop net, and gill net fishing conflicts in the Atlantic Ocean, and 2) Management implications of proposed NMFS beach seine and stop net regulations for bottlenose dolphins (NCDMF 2006).

The issue of user conflicts in the Atlantic Ocean striped mullet beach seine fishery, which has existed along Bogue Banks since the 1980s, involved resource allocation issues between commercial gill netters and stop net crews, and among ocean pier owners, pier patrons, and stop net crews. The initial recommendation from the NCDMF was to move current gill net restrictions on Bogue Banks currently in proclamation into rule. The restrictions put in place by proclamation (M-12-2001) in the fall of 2001 included a maximum gill net length of 160 yards, an exclusion zone from 150 yards off the beach to 350 yards offshore in which no gill net can be set, a 750 feet minimum distance between fishing piers and gill nets, and a minimum distance of 450 yards east from where a deployed stop net is set to where gill nets were permitted. However, due to the changing nature of the beach seine striped mullet fishery and impending NMFS Bottlenose Dolphin Take Reduction Plan restrictions, the NCDMF subsequently recommended the restrictions remain in effect by proclamation and not be adopted into rule (NCDMF 2006). In the fall of 2006, after completion of the 2006 Striped Mullet FMP, stop net and gill net representatives agreed upon new restrictions to address user conflicts. The new restrictions were put in place by proclamation (M-14-2006) and included an exclusion zone measuring 660 yards east of a deployed stop net as measured from where the stop net connects to shore and 250 yards south of the mean high water mark as measured along the adjacent 660 yard dimension in which no gill net can be set, stop net crews must mark the 660 yard zone with two stakes on shore set so as to indicate a range line, stop net crews must mark the prohibited gill net zone with three orange buoys, and the unauthorized or absence of marking buoys shall not serve to open the 660 by 250 yard zone east of the deployed stop net. These restrictions have been in place since 2006 and prevented the reoccurrence of problems thus far.

Management implications of proposed NMFS beach seine and stop net regulation for bottlenose dolphins were addressed in the 2006 Striped Mullet FMP because the specific stop net mesh sizes and placement agreed upon by NCDMF staff, ocean fishing pier operators, and striped mullet beach seine/stop net crews in 1994 would be illegal under the proposed rule by NMFS. Initially, NCDMF recommended fishermen explore the possibility of federal funding sources for the conversion of the Bogue Banks striped mullet stop nets from the minimum eight- and six-inch mesh size construction to the thought to be soon-to-be-legal maximum of four inch. However, following public meetings and the presentation to the Joint Legislative Commission on Seafood and Aquaculture, the NCDMF recommendation was changed to determine what the federal regulations resulting from the Bottlenose Dolphin Take Reduction Plan were and react accordingly (NCDMF 2006). Therefore, the minimum six- and eight-inch mesh size construction continued to be implemented by proclamation until 2013 when the minimum mesh size was changed to six inches by proclamation (M-27-2013) following passage of the federal rule.

The stop net fishery accounted for approximately 74% of the landings in the current striped mullet seine fishery from 2000–2002. The stop net fishery has operated under fixed seasons, and net and area restrictions since 1993. Stop nets are limited in number (four), length (400 yards), and mesh sizes (minimum eight inches–outside panels, six inches–middle section). Stop nets are only permitted along Bogue Banks (Carteret County) in the Atlantic Ocean from October 1 to November 30.

Landings from the other, smaller seine fisheries are harvested in ocean waters (<3 miles), primarily in Carteret, Dare, and Hyde counties. Typically, monofilament gill nets (200–300 yards) are used to intercept ocean schooling striped mullet and hauled onto the beach as functional seines. Ninety-two percent of the striped mullet landings in this fishery occur in October and November during the fall spawning migration (Leard et al. 1995; Collins 1985a; Bichy 2000). Outside of October and November, much of this seine fishery targets non-striped mullet species. Seines for spot, spotted seatrout, sea mullet, etc. along the Outer Banks accounts for most of the trips shown from December to September (Figure 6.33).

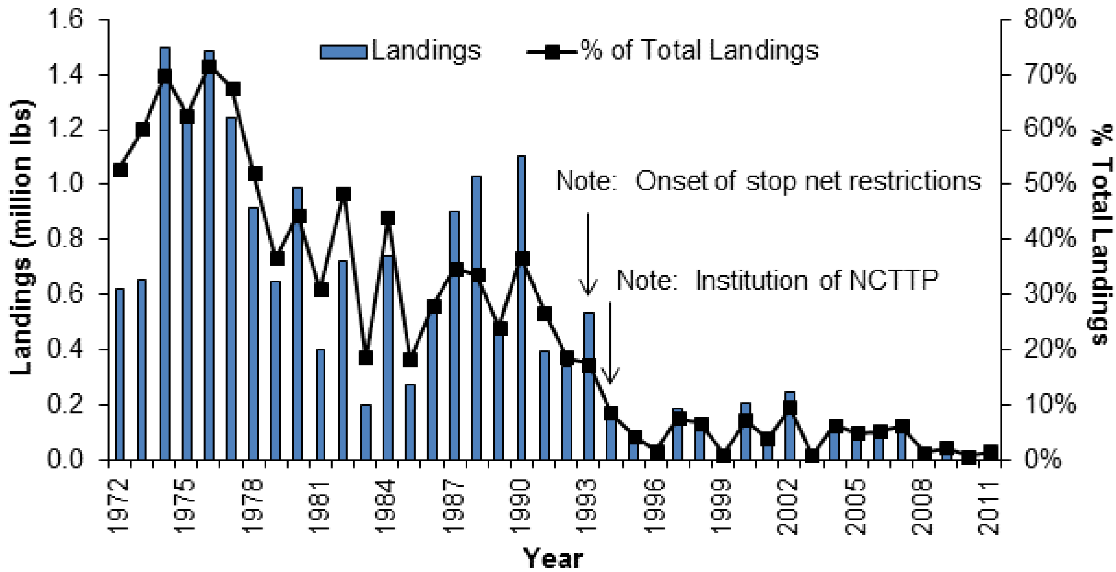

Figure 6.31. Annual landings and percent of total landings by beach seines in the North Carolina striped mullet fishery: 1972–2011.

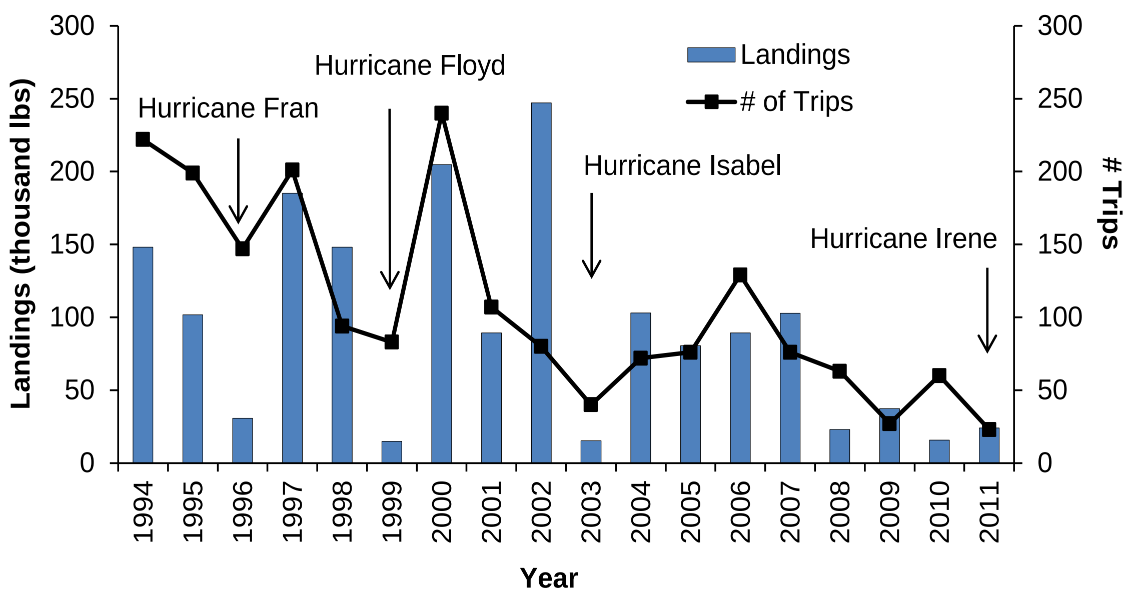

Figure 6.32. Annual landings and number of trips by beach seines in the North Carolina striped mullet fishery: 1994–2011.

Table 6.7. Average annual landings and percent total landings by waterbody for beach seines in the North Carolina striped mullet fishery: 1994–2002, 2003–2011, and 1994–2011.

1994–2002			2003–2011			1994–2011		
Waterbody	Average (lb.)	Percent	Waterbody	Average (lb.)	Percent	Waterbody	Average (lb.)	Percent
Ocean 0–3 miles, South of Cape Hatteras	98,428	76%	Ocean 0–3 miles, South of Cape Hatteras	52,935	97%	Ocean 0–3 miles, South of Cape Hatteras	75,681	82%
Ocean >3 miles	25,499	20%	Ocean 0–3 miles, North of Cape Hatteras	1,648	3%	Ocean >3 miles	12,749	14%
Ocean 0–3 miles, North of Cape Hatteras	3,115	2%				Ocean 0–3 miles, North of Cape Hatteras	2,382	3%
Bogue Sound	2,787	2%				Bogue Sound	1,393	2%
Core Sound	153	0%				Core Sound	76	0%
Pamlico Sound	20	0%				Pamlico Sound	10	0%

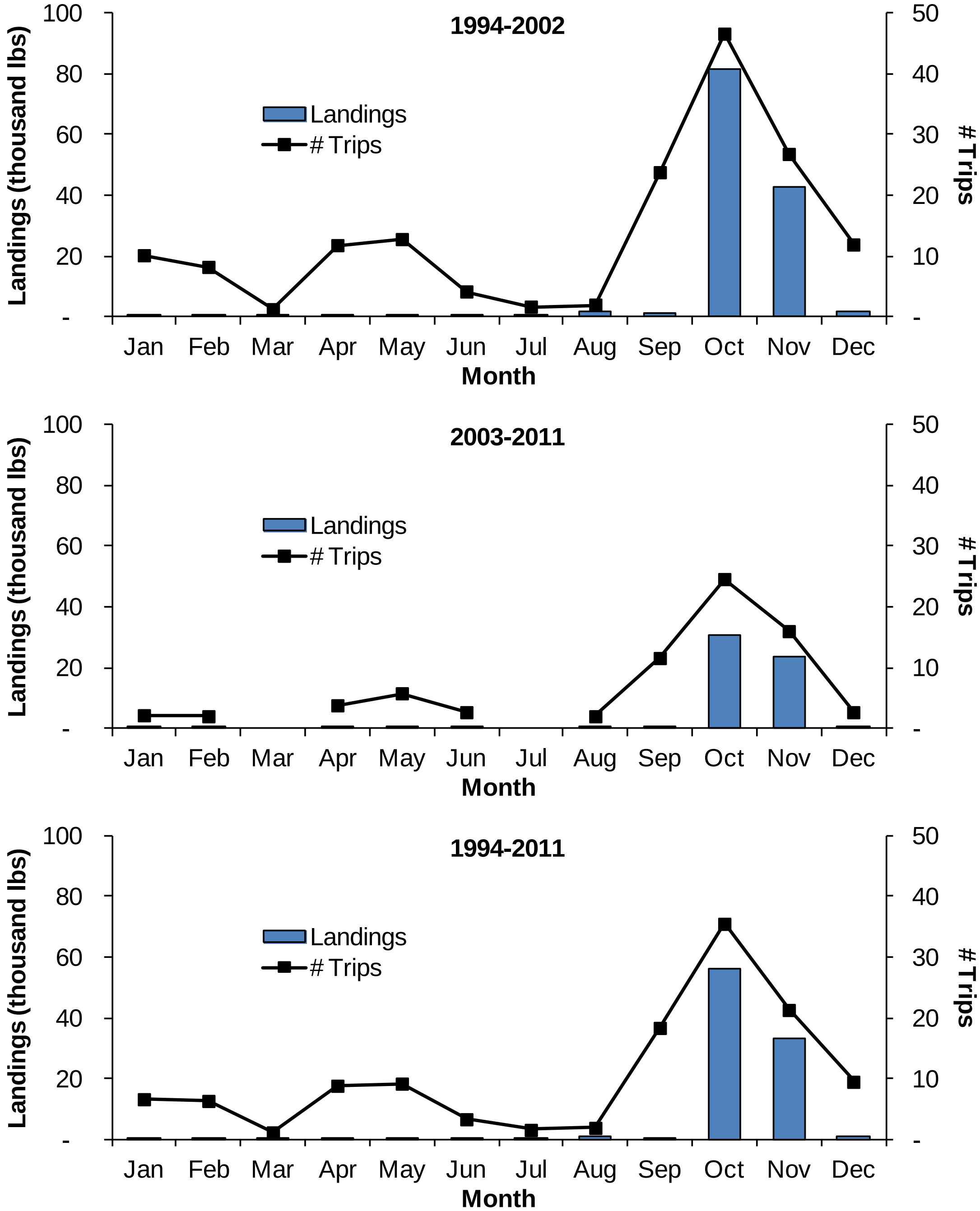

Figure 6.33. Average annual landings and number of trips by month for beach seines in the North Carolina striped mullet fishery: 1994–2002, 2003–2011, 1994–2011.

6.1.9.2.4 Cast Nets

Cast net harvest is predominantly sold as bait. The NCTTP began recording landings of striped mullet landings from cast nets began in 1994. Cast net landings only represent 2% of the total striped mullet landings from 1994 to 2011, yet show a slight upward trend (Figure 6.34).

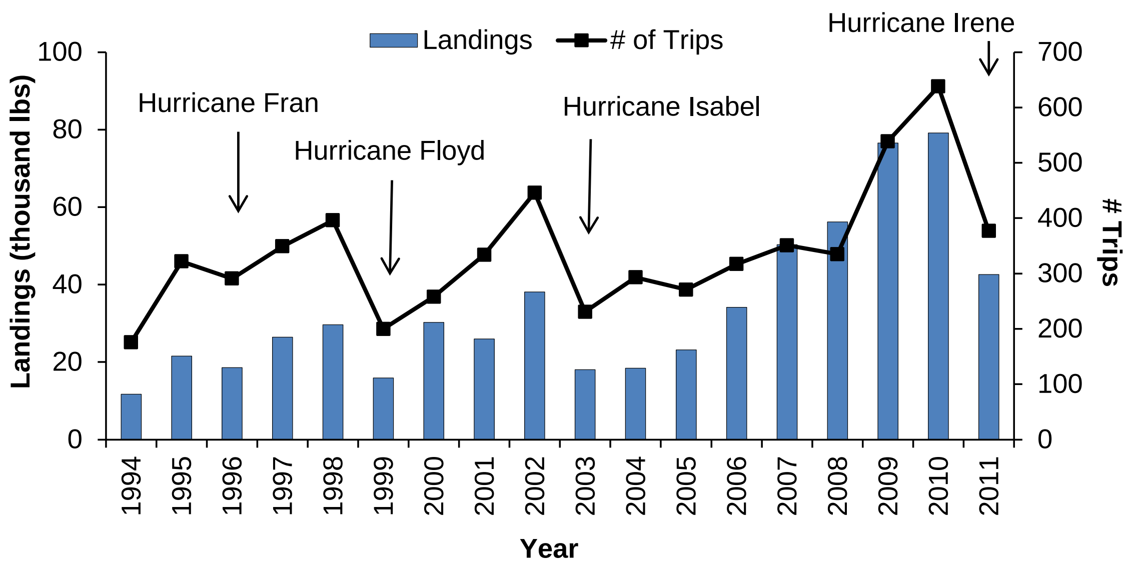

Figure 6.34. Annual landings and number of trips by cast nets in the North Carolina striped mullet fishery: 1994–2011. Note: a single harvest is sometimes sold to multiple dealers, which increases the total number of cast net trips relative to other gear types.

Cast net striped mullet landings and the number of trips landing striped mullet from cast nets are sharply seasonal. Seventy-four percent of the annual cast net harvest occurs in September and October (Figure 6.35). Cast net landings coincide with the large, September ocean migration of white mullet. Monthly cast net landings decline to 12% of the yearly total in November. NCDMF research indicated that >95% of September and October cast net bait harvest was comprised of white mullet. Conversely, nearly all bait mullet landed in November were identified as striped mullet.

The fall cast net fishery primarily targets mullets that will be used as bait, either as cut, whole (frozen), or live bait, much unlike other mullet fisheries that almost exclusively target roe fish during this period.

Most of the total landings are occurred in state jurisdiction ocean waters (< 3 miles; 57%), Pamlico Sound (29%), and Bogue Sound (3%). The remaining 10% of the landings were harvested among 20 other waterbodies.

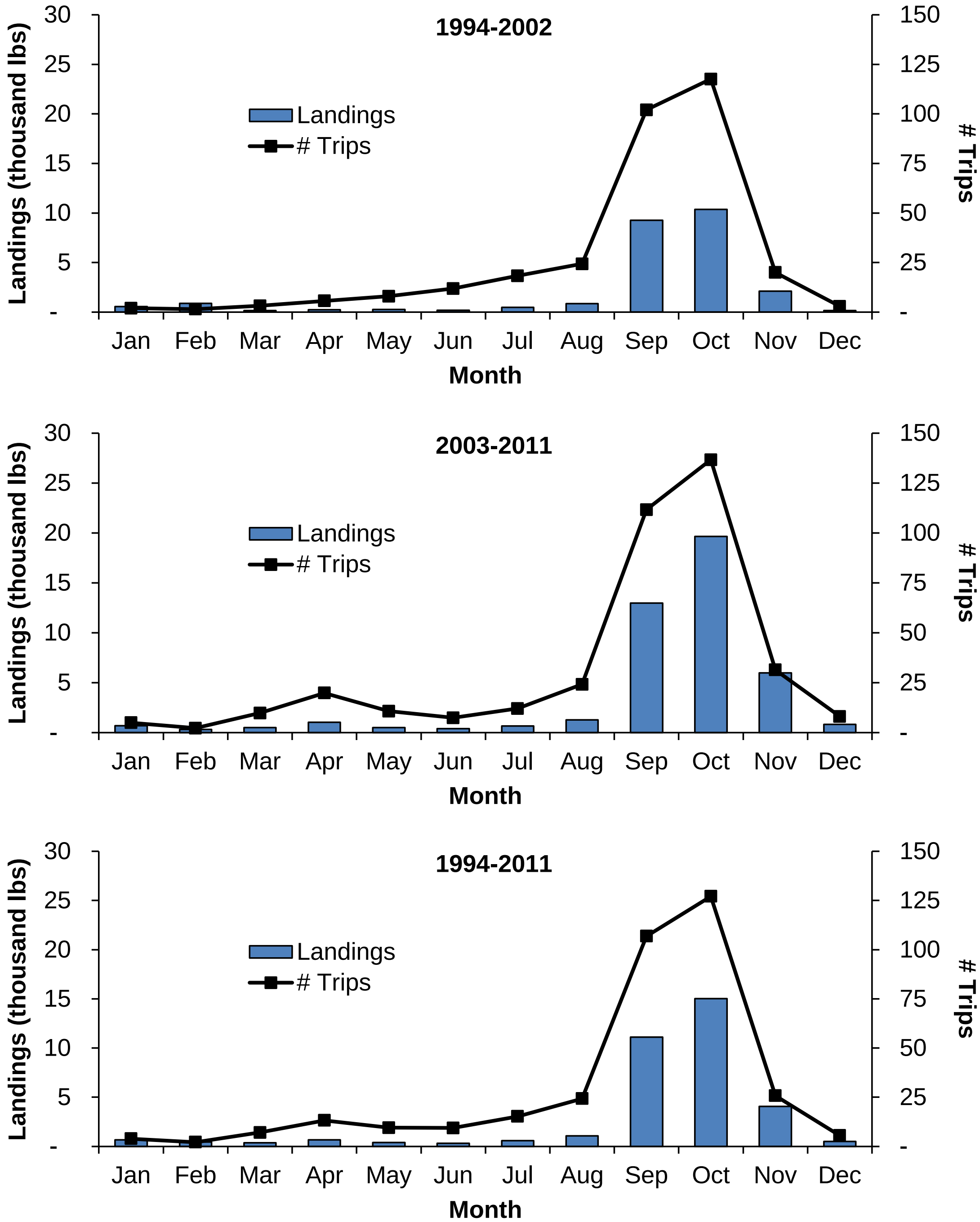

Figure 6.35. Average annual landings and number of trips by month for cast nets in the North Carolina striped mullet fishery: 1994–2011.

Table 6.8. Average annual landings and percent total landings by waterbody for cast nets in the North Carolina striped mullet fishery: 1994–2002, 2003–2011, and 2010–2011.

1994–2002			2003–2011			1994–2011		
Waterbody	Average (lb.)	Percent	Waterbody	Average (lb.)	Percent	Waterbody	Average (lb.)	Percent
Ocean 0–3 Miles	15,658	65%	Ocean 0–3 Miles	23,710	54%	Ocean 0–3 Miles	19,684	57%
Pamlico Sound	5,046	21%	Pamlico Sound	15,087	34%	Pamlico Sound	10,067	29%
White Oak River	1,160	5%	Bogue Sound	1,890	4%	Bogue Sound	1,153	3%
North River/Back Sound	555	2%	Neuse River	741	2%	White Oak River	627	2%
Bogue Sound	416	2%	Masonboro Sound	570	1%	North River/Back Sound	457	1%
Roanoke Sound	335	1%	Cape Fear River	390	1%	Masonboro Sound	391	1%
Masonboro Sound	211	1%	North River/Back Sound	359	1%	Neuse River	371	1%
Newport River	203	1%	Albemarle Sound	314	1%	Roanoke Sound	282	1%
Croatan Sound	180	1%	Roanoke Sound	229	1%	Albemarle Sound	233	1%
Inland Waterway	164	1%	Newport River	214	<1%	Cape Fear River	231	1%
Others (9)	313	<1%	Others (13)	783	1%	Others (13)	769	3%

6.1.9.2.5 Hook and Line

In March 2010, the MFC requested NCDMF staff to broadly examine issues related to the feasibility of hook-and-line as a commercial gear statewide, irrespective of species. As a result of information presented by staff, in November 2010 the MFC decided to study more specifically the implications of a commercial hook-and-line sector on a fishery-by-fishery basis as each FMP came up for review. The Striped Mullet FMP Amendment I is the first time the Striped Mullet FMP has been eligible for this review.

Currently there are no restrictions on the commercial harvest of striped mullet using hook-and-line gear (i.e., rod-and-reel, trolling, trotline, etc.). Historically, hook-and-line gear has not contributed a significant amount of landings for the commercial sector (Figure 6.36). The highest annual harvest occurred in 2005 with 3,720 lb of striped mullet harvested by hook-and-line gear.

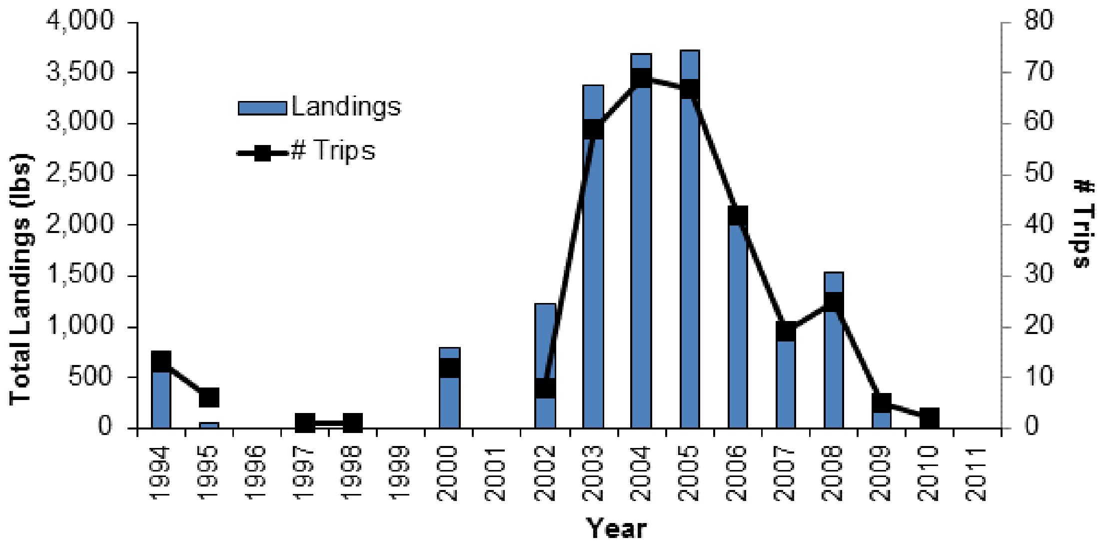

Figure 6.36. Annual landings and number of trips by commercial hook-and-line gear in the North Carolina striped mullet fishery: 1994–2011.

The harvest of striped mullet with hook-and-line gear is likely largely influenced by the biology of the species. Larval and juvenile striped mullet feed largely on micro-invertebrates and transition to herbivorous detritivores as adults (Harrington and Harrington 1961; DeSilva and Wijeyaratne 1977; DeSilva 1980). Anecdotal reports of adults feeding on mid-water polychaetes, *Nereis succinea*, and live bait of anglers also indicate opportunistic, carnivorous feeding by adults (Bishop and Miglarese 1978). There is a niche recreational hook-and-line fishery that uses highly specialized techniques to target striped mullet which likely make it impractical for directed commercial harvest.

6.1.10 Striped Mullet Bycatch

Fishery managers continually face the issue of bycatch and discards in fisheries throughout the world (Gray 2002). Discards impact fishery yields and fishery managers' ability to accurately assess fish stocks (Fennessy 1994; Hall 1999). Bycatch is defined by the ASMFC as "the portion of a catch taken incidentally to the targeted catch because of non-selectivity of the fishing gear to either species or size differences" (ASMFC 1994). Bycatch can be divided into two components: incidental catch and discarded catch. Incidental catch refers to retained or marketable catch of non-target species, while discarded catch is that portion of the catch returned to the sea as a result of regulatory, economic, or personal considerations.

The issue of striped mullet bycatch in North Carolina commercial fisheries was originally explored in the 2006 Striped Mullet FMP (NCDMF 2006). Covered fisheries included the large (≥5-in stretch) and small (<5-in stretch) mesh gill net fisheries, as well as hard crab and peeler pot, crab trawl, and shrimp trawl fisheries, and ghost pots. The results below have been updated where appropriate from the previous FMP and are summarized below.

<u>6.1.10.1 Set Gill Nets</u>

There were very few roe mullet or white roe observed (n = 1 in 2001 and n = 7 in 2002) in large mesh gill net fisheries. Striped mullet were the primary species landed from observed small mesh gill nets. They represented 46% and 68% of the total catch that was kept from 2001 and 2002, respectively. In both years of small mesh gill net observations there were numerous roe striped mullet observed. There were 868 and 1,436 roe striped mullet caught in each year, respectively. White roe were only observed (n = 216) in small mesh nets in 2001.

Striped mullet bycatch trends were assessed for large and small mesh gill nets in 2001 and 2002 based on number of trips, total yards observed, mean soak hour, and by fish disposition (kept, discard…). Out of the 121,239 yards of large mesh gill net observed in 2001, there were five striped mullet caught and only one discarded. From the 46,353 yards of small mesh gill net observed in 2001, there were 2,237 striped mullet caught with only four discarded (0.18%). By weight, there were 3.7 kg of striped mullet discarded from small mesh gill nets in 2001.

From the 224,405 yards of large mesh gill net observed in 2002, there were few striped mullet caught (n = 14). There was one discard from large mesh gill net observations representing 7% of the total striped mullet catch. There were numerous striped mullet (n = 3,908) observed from the 22,390 yards of small mesh gill net observed in 2002. Of the 3,908 striped mullet landed in small mesh nets, there were two discards representing 0.05% of the total striped mullet caught.

Combining years and mesh sizes, there were 414,927 yards of gill net observed. From these there were 6,164 striped mullet caught. Out of 6,164 striped mullet caught (kept, unmarketable discard, red roe, and white roe), there were eight discards representing 0.13% of the total striped mullet catch. By weight, out of 6,575 kg of striped mullet caught there was 5.7 kg (0.09%) discarded.

From these two years of commercially dependent gill net sampling in traditional fishing grounds along the Outer Banks and mainland side of Pamlico Sound, the following conclusions are apparent regarding the catch and bycatch of striped mullet in gill nets. Few striped mullet (n = 19 out of 6,164 captures or 0.31%) are captured in large mesh (>5-in stretch) gill nets compared to small mesh (<5-in stretch) gill nets. Additionally, striped mullet captured in large mesh gill nets are typically marketable and kept as such. Consequently, by number striped mullet discards represent 10.5% of the total striped mullet catch in large mesh gill nets and 0.1% of the total striped mullet catch in small mesh gill nets.

From 2003–2011, there were 456 small mesh gill net trips (with onboard observers) of which 158 trips caught striped mullet. From these trips a total of 2,317 striped mullet were caught and seven discards were observed (0.3%). Live or dead disposition of the observed discards was not recorded. During this same period, there were 2,266 large mesh gill net trips (with onboard observers) of which 111 trips caught striped mullet. From these trips, a total of 508 striped mullet were caught and 28 discards were observed (5.5%). As with small mesh discards, live or dead disposition was not recorded. Since there are currently no commercial harvest restrictions for striped mullet, most striped mullet caught are kept and sold, because of this; set gill nets do not appear to be a significant source of bycatch for striped mullet.

6.1.10.2 Hard Crab and Peeler Pots

Since its inception in 1994, the NCTTP has allowed for more accurate estimates of total fishing effort, target, and incidental catches in the blue crab, *Callinectes sapidus*, pot fishery. In 1999 a Fishery Resource Grant (FRG) was funded to examine bycatch in hard and peeler pots in the Neuse River, North Carolina (Doxey 2001).

Annual landings of the marketable portion of incidental finfish bycatch from hard crab pots have averaged 40,164 lb since 1996 (NCTTP, 1996–2011, single gear trips). Striped mullet are the sixth most common finfish species landed from this fishery. Annual landings of striped mullet from hard crab pots average 1,081 lb. Sixty-three percent of the landed striped mullet are captured from August through October. Striped mullet landings from hard crab pots have been reported from 21 waterbodies. Albemarle Sound accounts for the majority (68%) of the landings, followed by the Pungo River (8%), Roanoke Sound (7%), Pamlico Sound (6%), and Pamlico River (4%). On average 96,924 hard crab pot trips are reported each year (NCTTP, 1996–2011, single gear trips). Striped mullet are landed on average from only 36 (0.04 %) of these trips.

Reported average annual finfish landings from peeler pots are 939 lb (NCTTP, 1996–2011, single gear trips). From 1996 through 2011, peeler pots landed a total of 187 lb of striped mullet.

Four crab pot fishermen kept records of bycatch in their hard and peeler pots from March through October 1999 (Doxey 2001). Hard crab pot data was collected from 283 trips during which 149,649 hard crab pots were fished. Peeler pot data was collected from 11 trips taken in May during which 1,950 peeler pots were fished.

Doxey (2001) examined bycatch in hard and peeler pots. From 1,950 trips and 149,649 hard crab pots, 15 striped mullet were captured in hard crab pots, and three in peeler pots. All fish were alive at the time of capture and released in good condition. The average size of mullet in the hard crab pots was 293 mm (11.5-in) and ranged from 147 mm to 406 mm (5.8-in–16-in). The three striped mullet captured in peeler pots were 152, 179, and 203 mm (6-, 7-, and 8-in) in length.

Similar to gill net fisheries, crab pots do not appear to be a source of significant bycatch for striped mullet. Through the NCTTP, and various studies assessing the bycatch in hard crab and peeler pot fisheries, very few striped mullet were observed. Specifically, striped mullet represented only 3% of the finfish bycatch in hard crab pots, and only 187 lb of striped mullet total (average 12 lb annually) were observed out of an average of 939 lb of finfish bycatch annually from peeler pots.

6.1.10.3 Ghost Pots

Ghost crab pots are defined as those pots that either through abandonment or loss (float lines cut by boats, storm events, etc.) continues to catch crabs and finfish. Concern stems from the significant increase in the numbers of crab pots, the long life of vinyl coated pots, and the pot's ability to continue to trap crabs and finfish. The number of crab pots used in North Carolina has increased from 350,379 in 1983 to 1,285,748 in 2000. There have been annual reported estimates of 14% crab pot loss for Pamlico and Pungo Rivers (McKenna and Camp 1992). In a 1999 survey of crab license holders in North Carolina, statewide pot loss in 1998 for hard crab pots was 17% while peeler pot loss was reported at 11%. Total pot use for the same time frame was 853,766 hard crab pots and 163,151 peeler pots (NCDMF unpublished data 1998). Estimated crab pot loss for 1998 was 145,140 hard crab pots and 17,947 peeler pots. Reported crab pot loss in North Carolina due to Hurricanes Dennis and Floyd was 111,247 (NCDMF unpublished data).

While data exist on the fate and quantity of blue crabs in ghost pots, little information is available on finfish bycatch since dead fish are quickly consumed by blue crabs, leaving only bones and fins (Guillory 1993, NCDMF unpublished data 1993). Due to this lack of finfish bycatch data from ghost pots, the NCDMF initiated studies in 2002 to: 1) identify species composition in ghost blue crab pots; 2) determine the length of time that blue crabs and finfish can survive in ghost pots; 3) identify the method and placement of release sites on crab pots to minimize ghost fishing mortality; 4) find a degradable material that will allow for the escapement of blue crabs and finfish from crab pots after a predetermined length of time; and 5) test escapement panels and biodegradable material under commercial conditions. At present, no bycatch or discard data are available for striped mullet.

A ghost pot study was conducted by NCDMF from 2002–2005 (NCDMF 2008). Ghost pots were simulated in the Alligator River (n = 18), Pamlico River (n = 24), Bogue Sound (n = 24), and Middle Sound (n = 24). Over the course of the study only 20 striped mullet were captured in these ghost pots. The majority came from Bogue Sound (n = 11) and the rest were from Middle Sound (n = 5), and the Pamlico River (n = 4). This study indicates there is likely little impact to the striped mullet population from ghost pots.

6.1.10.4 Crab Trawl Fishery

In North Carolina's internal coastal waters there are very few (less than 25) trawlers that harvest blue crabs exclusively. Since 1994, fishermen that reported crab trawls as at least one of the fishing gears used has ranged from 179 to 418 vessels, and averaged about 290 vessels (NCTTP data 1994–2011). The majority (54%) of the effort in the crab trawl industry, based on number of trips, occurs between March and June.

Crab trawl headrope lengths for double-rigged vessels range from 30 to 45 feet, while twin-rigged vessels usually pull four nets in the 30-foot range. Tow times vary depending on temperature and the amount of biomass encountered. Tow times generally decrease as biomass and/or temperature increases.

The crab trawl fishery has received a large amount of attention due to concern over the bycatch of finfish (mainly southern flounder) and sublegal crabs. To assess this, a study was conducted by NCDMF in the Pamlico-Pungo river complex to examine this problem (McKenna and Camp 1992).

Finfish landings by crab trawl average 52,897 lb per year (NCTTP data 1994–2011). The main species landed is southern flounder accounting for 80% of the total finfish landed by crab trawls. Striped mullet landings from crab trawls average 44 lb per year.

Peeler crab trawl landings have been recorded separately from crab trawls since 2010. From 2010–2011, no finfish landings have been reported from peeler crab trawls.

McKenna and Camp (1992) assessed the finfish bycatch in the crab trawl fishery. During this study, 15 trips were made aboard commercial crab trawlers. The mean number of tows made during a trip was 3.3, and ranged from one to five. Tow times ranged from one to four hours and averaged 2.87 hours. An average trip consisted of 9.46 hours of towing. In 50 tows observed only one striped mullet was captured.

NCTTP data and studies assessing striped mullet bycatch (marketable and unmarketable) in trawl fisheries depicted minimal and insignificant catches of striped mullet (i.e., 44 lb striped mullet out of > 52,897 lb total finfish bycatch per year). Considering these results, the bycatch of striped mullet, both marketable and unmarketable, does not appear to be a significant problem in the inshore trawl fisheries.

6.1.10.5 Shrimp Trawl Fishery

Conventional two-seam otter trawls are used for the bottom-hugging pink and brown shrimp, while four seam and tongue trawls with floats on the headrope are used for the white shrimp. In Pamlico Sound, large vessels stay out four or five days and tow from one to three hours, often working day and night. Smaller vessels make daily trips and employ shorter tow times. In the Core Sound area, the fishery occurs mainly at night, with trips lasting one night. In the southern area, fishing is conducted on a day-trip basis, mostly during daylight hours.

On average 314,924 lb of finfish are landed by shrimp trawls annually. Striped mullet landings from this gear average 163 lb per year (1994–2011). Since 2003 striped mullet landings by shrimp trawls have averaged 136 lb per year. Forty-six percent of the striped mullet landed by shrimp trawls occurred in 1994–1995.

In 1999 and 2000, shrimp trawl catches from the Neuse River and Core Sound were examined for bycatch (Johnson 2003). Of the 56 catches sampled, 44 striped mullet were captured in three tows.

6.1.10.6 Other Gears

Other gears with reported commercial striped mullet landings are; drift gill net, pound nets, long haul seine, swipe net, fyke net, crab pot, gigs, fish pot, hook-and-line, skimmer trawl, shrimp trawl, crab trawl, trotline, flounder trawl, channel net, eel pot, bull rakes, common seine, turtle pot, clam kicking, and peeler pots. Combined, these gears contribute 2% to the total striped mullet harvest. It is very unlikely that there is significant total striped mullet discard from these fisheries.

6.2 RECREATIONAL FISHERY

Few anglers target striped mullet by hook and line. However, striped mullet and white mullet are a popular bait fish for anglers targeting a variety of inshore and offshore fish species. Mullets are used as live, strip, cut and trolling baits (Nickerson 1984). Anglers using cast nets often catch YOY mullets, commonly known as finger mullet. At the end of each fishing trip, anglers typically discard dead and unused bait mullet. Cast netting for mullet generally occurs during the summer and fall, with the majority caught in September and October coinciding with the southward migration of YOY striped and white mullet.

6.2.1 Recreational Fishing Data Collection

North Carolina currently conducts three surveys that collect data on the recreational finfish harvest. The Marine Recreational Information Program (MRIP) is the primary survey used to collect data on angler harvest from the ocean 0–3 miles from the coast and inside waters from the Virginia boarder south to the South Carolina border excluding the Albemarle Sound. From 2002–2008, the Recreational Commercial Gear License (RCGL) Survey was conducted by NCDMF to collect data from recreational fishermen who are allowed to harvest recreational limits of finfish while using commercial gear if they possess a RCGL. The third survey, which began in November 2010, is a monthly mail survey conducted to determine participation and effort of Coastal Recreational Fishing License (CRFL) holders in recreational cast net and seine use. The results of this survey are preliminary and will not be included in this FMP but the data will be invaluable to future assessments and FMPs.

6.2.2 Marine Recreational Information Program

The MRIP provides the primary data used to estimate the impact of marine recreational fishing on marine resources in North Carolina. The MRIP evolved from the Marine Recreational Fisheries Statistics Survey (MRFSS) which was initiated in 1981 by the National Marine Fisheries Service (NMFS) to gather information from recreational fishing community to provide estimates of catch and effort at a regional level (NRC 2006). NCDMF began conducting the dockside survey in 1987 and by 1989 had increased sample sizes significantly in order to provide better regional estimates and estimates useable at the state level. The data from 2004 through 2012 has been adjusted using new science that was applied to the previous surveying methodology.

The MRIP consists of two components, the Access-Point Angler Intercept Survey (APAIS) and the Coastal Household Telephone Survey (CHTS). The CHTS utilizes a random digit dialing (RDD) telephone survey approach to collect marine recreational fishing effort information from residential households located in coastal counties. APAIS, an onsite intercept survey conducted at fishing access-sites, is used for collection of individual catch and discard data for calculation of catch rate at the species level. Creel clerks collect intercept data from January through December (in two-month waves) by interviewing anglers completing fishing trips in one of the four fishing modes (man-made structures, beaches, private boats, and for-hire vessels). In 2005, the MRIP began at-sea sampling of headboat (party boat) fishing trips. Data derived from the telephone survey are used to estimate the number of recreational fishing trips (effort) for each stratum. The intercept and at-sea headboat data are used to estimate catch-per-trip for each species encountered. The estimated number of angler trips is multiplied by the estimated average catch-per-trip to calculate an estimate of total catch for each survey stratum.

Accurate recreational harvest estimates of striped mullet are difficult to obtain. The MRIP is used to estimate the recreational harvest of marine finfish in North Carolina. The survey is designed to sample anglers who primarily use rod and reel. However, the majority of the striped mullet sampled by MRIP creel clerks are caught with cast nets. It is difficult for fishermen to accurately estimate the number of striped mullet harvested as bait with cast nets. Non-reporting of bait is also a potential problem in the survey. The lack of discrimination between striped mullet and white mullet is another major limitation of the MRIP survey. It is likely that white mullet are often misidentified and added in the harvest estimates for striped mullet. In the MRIP time series, white mullet harvest estimates are only available for a few years. Mullets released by anglers are not observed by MRIP creel clerks and therefore cannot be identified to the species level. Therefore, MRIP discard estimates for mullet will not be included in this section.

The number and weight of mullets harvested by anglers from 1982–2011 is presented in Table 6.9 and Figure 6.37. The precision and reliability of estimates produced by MRIP are measured by the proportional standard error (PSE). Precision is inversely related to the PSE with small PSEs indicating a more precise estimate and larger PSEs indicating imprecise measurements. Estimates of catch with PSEs greater than 20% should be used with a great deal of caution. The PSEs for estimated mullet catch were well above 20% for almost all of the time series and approached 100%. These estimates were not used for the stock assessment of striped mullet. In 2001, the MRIP made improvements in striped mullet data collection, so data prior to 2001 will not be used in the following summary.

North Carolina harvest of mullet species (striped and white) has fluctuated slightly in the early 2000s with the peak (877,595 lb) in 2003 and exhibited a steep decrease from 2003 through 2007 (63,655 lb) when a slight increase occurred and continued to decreased with the exception of peaks in 2010 (52,093 lb; Table 6.9 and Figures 6.38).

Table 6.9. North Carolina recreational harvest of mullets (striped and white) by anglers: 2001–2011.

	Harvest Number		Harvest Weight	
Year	Number	PSE	Pounds (lb)	PSE
1982	264,187	43.7	301,475	46.5
1983	150,288	61.0	50,505	64.2
1984	291,687	49.3	90,477	52.0
1985	254,473	45.5	133,599	45.8
1986	31,431	72.3	15,780	70.4
1987	843,754	46.7	114,661	41.1
1988	292,594	44.7	135,301	83.4
1989	98,357	33.0	90,448	31.3
1990	77,501	41.4	94,651	44.8
1991	17,242	42.2	12,437	55.9
1992	395,190	81.4	417,828	91.9
1993	81,773	33.2	39,408	42.4
1994	79,018	38.2	175,288	38.9
1995	35,437	64.0	24,545	47.4
1996	15,150	49.9	4,438	63.1
1997	25,135	54.4	40,290	70.8
1998	2,985	55.4	1,860	62.3
1999	3,341	62.2	1,548	74.1
2000	33,722	52.6	18,696	84.5
2001	879,544	20.2	680,298	25.8
2002	1,541,249	15.0	448,875	24.0
2003	1,057,769	25.1	877,595	39.8
2004	2,169	103.4	1,588	103.4
2005	4,310	73.4	4,665	73.2
2006	3,996	52.6	3,190	50.1
2007	98,352	78.3	63,655	80.3
2008	1,895	63.0	1,237	64.4
2009	9,545	69.1	5,458	52.3
2010	37,485	34.7	52,093	48.3
2011	25,295	29.0	10,958	32.1

*PSE, or proportional standard error, is automatically included in all outputs. It expresses the standard error of an estimate as a percentage of the estimate and is a measure of precision.

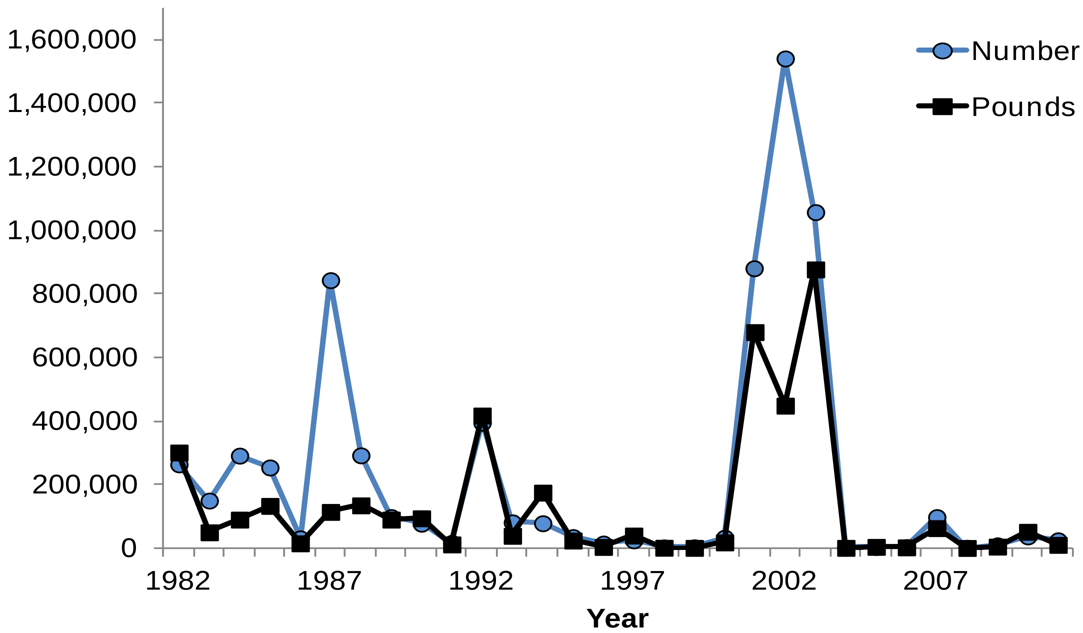

Figure 6.37. North Carolina recreational harvest of mullets (striped and white) by anglers: 1982–2011.

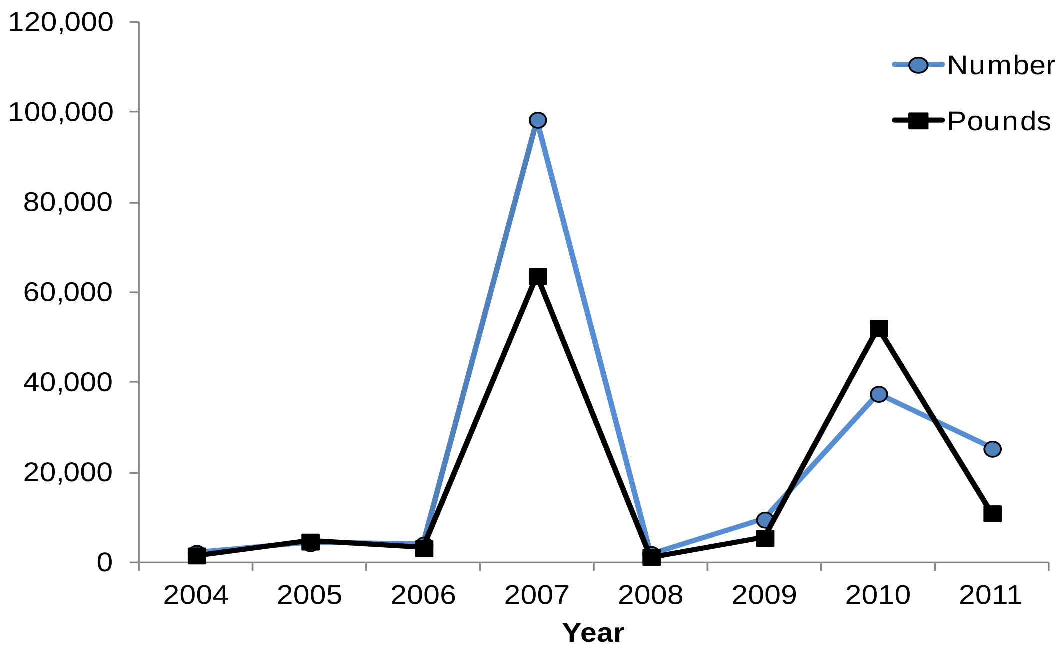

Figure 6.38. North Carolina recreational harvest of mullets (striped and white) by anglers: 2004–2011.

6.2.3 Recreational Commercial Gear License Survey

North Carolina has long allowed the recreational use of commercial fishing gears in its coastal waters. Participation in this activity prior to July 1999 required the possession of a Commercial Fishing Vessel License. A licensing restructure mandated by the North Carolina Fisheries Reform Act of 1997 and implemented in July 1999 established a new license, the RCGL, solely for the recreational use of commercial gears. The RCGL Survey, which was conducted from 2002–2008, is another source of recreational landings of striped mullet information

The NCDMF surveyed RCGL holders from 2002 through 2008 with the purpose of obtaining catch and effort estimates for the RCGL user group. The survey questionnaires were distributed monthly to 30% of the randomly selected RCGL population from each county requesting data such as waterbodies commonly fished, types and amounts of gear used, number and weight of individual species kept, and number of individual species discarded at sea. Approximately 45% of questionnaires distributed were completed and returned to the NCDMF. Demographic information obtained at the time the licenses were sold was used to examine if the returned surveys were representative of the RCGL population to ensure the samples taken could be used to generalize about the total RCGL population. Additionally, the survey responses for total catch and number of trips were examined for possible outliers using standard statistical methods. Monthly effort and catch reported by the survey respondents were extrapolated to the total RCGL population. This survey did not capture individual lengths or weights of fish reported.

Extrapolation of the sample to the total RCGL population requires three components: 1) the percent of individuals actively using each type RCGL gear from the sample, 2) the mean catch for each individual species by each gear type, and 3) the total number of RCGL holders. The summation of the multiplication of these items for each gear type yields the estimated total catch and effort for an individual species for the entire RCGL population. To provide a measure of reliability (precision), PSE was calculated for effort and catch estimates for each species. Small mesh gill nets (less than 5 inch stretched mesh), large mesh gill nets, seines, and crab pots were the only RCGL authorized gear that encountered striped mullet.

6.2.3.1 RCGL Harvest Estimates

From 2002 to 2008, RCGL reported a total of 38,555 trips with a harvest of 290,586 lb of striped mullet. The RCGL trips and harvest for mullet decreased significantly from 2002 (10,043 trips and 64,213 lb) to 2003 (4,223 trips and 24,774 lb). From 2003 to 2008 trip numbers and harvest remained at relatively stable low numbers (Table 6.10 and Figure 6.39).

Table 6.10. Estimated catch statistics for mullets (striped and white) in RCGL holders: 2002–2008.

		Trips		Harvest Number		Harvest Pounds (lb)		Discard Number	
Year	Month	Number	Percent	Number	Percent	Number	Percent	Number	Percent
2002	Jan.	231	2.3	218	0.3	180	0.3	0	0.0
	Mar.	1,311	13.1	2,305	3.5	2,266	3.5	442	6.7
	May	665	6.6	6,421	9.7	7,972	12.4	201	3.1
	June	1,359	13.5	7,020	10.6	6,493	10.1	1,087	16.6
	July	865	8.6	10,695	16.1	10,037	15.6	787	12.0
	Aug.	1,403	14.0	10,294	15.5	9,130	14.2	1,243	19.0
	Sept.	1,281	12.8	6,532	9.9	6,303	9.8	552	8.4
	Oct.	1,988	19.8	16,298	24.6	15,762	24.5	1,608	24.6
	Nov.	840	8.4	4,182	6.3	3,758	5.9	495	7.6
	Dec.	101	1.0	2,340	3.5	2,311	3.6	135	2.1
	All	10,043	100.0	66,305	100.0	64,213	100.0	6,549	100.0
2003	Jan.	50	1.2	992	3.4	592	2.4	42	1.2
	Feb.	83	2.0	505	1.8	291	1.2	0	0.0
	Mar.	243	5.8	1,302	4.5	1,446	5.8	210	6.0
	April	192	4.5	1,108	3.9	1,220	4.9	325	9.2
	May	296	7.0	2,127	7.4	1,834	7.4	0	0.0
	June	546	12.9	1,926	6.7	2,345	9.5	628	17.9
	July	455	10.8	5,146	17.9	3,718	15.0	420	12.0
	Aug.	395	9.4	4,081	14.2	3,659	14.8	1,254	35.7
	Sept.	410	9.7	3,809	13.2	3,286	13.3	297	8.5
	Oct.	1,115	26.4	4,529	15.8	3,512	14.2	339	9.6
	Nov.	416	9.8	3,121	10.9	2,793	11.3	0	0.0
	Dec.	22	0.5	112	0.4	78	0.3	0	0.0
	All	4,223	100.0	28,757	100.0	24,774	100.0	3,514	100.0
2004	Feb.	59	1.3	59	0.2	60	0.2	0	0.0
	Mar.	67	1.5	674	1.9	684	1.9	0	0.0
	April	85	1.9	128	0.4	71	0.2	43	1.5
	May	277	6.1	2,473	7.1	2,026	5.6	74	2.6
	June	471	10.4	3,237	9.3	2,825	7.9	301	10.5
	July	853	18.8	8,652	24.9	9,561	26.6	1,914	66.6
	Aug.	625	13.8	7,392	21.3	6,646	18.5	36	1.2
	Sept.	408	9.0	2,603	7.5	2,607	7.3	0	0.0
	Oct.	978	21.5	5,263	15.2	6,926	19.3	446	15.5
	Nov.	587	12.9	2,147	6.2	2,259	6.3	62	2.2
	Dec.	135	3.0	2,107	6.1	2,281	6.3	0	0.0
	All	4,545	100.0	34,736	100.0	35,947	100.0	2,875	100.0
2005	Jan.	12	0.3	160	0.4	184	0.5	0	0.0
	Feb.	38	0.9	203	0.6	220	0.6	0	0.0
	Mar.	13	0.3	336	0.9	403	1.1	0	0.0
	April	102	2.3	1,002	2.8	988	2.7	0	0.0
	May	134	3.0	671	1.9	463	1.3	0	0.0
	June	517	11.7	5,333	14.9	4,038	11.1	2,014	57.7
	July	618	14.0	5,112	14.2	4,751	13.1	153	4.4
	Aug.	985	22.4	12,352	34.4	13,588	37.4	627	18.0
	Sept.	284	6.4	1,451	4.0	1,523	4.2	63	1.8
	Oct.	1,022	23.2	5,398	15.0	5,211	14.3	227	6.5
	Nov.	490	11.1	1,718	4.8	1,717	4.7	220	6.3
	Dec.	188	4.3	2,151	6.0	3,229	8.9	188	5.4
	All	4,405	100.0	35,888	100.0	36,314	100.0	3,492	100.0
2006	Jan.	45	0.8	605	1.6	432	1.2	51	1.0

Year	Month	Trips		Harvest Number		Harvest Pounds (lb)		Discard Number	
		Number	Percent	Number	Percent	Number	Percent	Number	Percent
	Feb.	49	0.9	2,014	5.3	1,855	5.0	0	0.0
	Mar.	22	0.4	108	0.3	129	0.3	93	1.7
	April	110	2.0	304	0.8	258	0.7	162	3.0
	May	239	4.4	1,006	2.6	919	2.5	173	3.2
	June	476	8.7	1,860	4.9	2,065	5.5	337	6.3
	July	685	12.5	5,155	13.5	5,134	13.7	140	2.6
	Aug.	495	9.0	5,670	14.9	5,315	14.2	231	4.3
	Sept.	1,057	19.3	6,985	18.3	6,926	18.5	521	9.7
	Oct.	1,700	31.0	7,303	19.1	8,450	22.6	3,171	59.2
	Nov.	467	8.5	3,429	9.0	3,575	9.6	282	5.3
	Dec.	134	2.5	3,735	9.8	2,328	6.2	192	3.6
	All	5,479	100.0	38,175	100.0	37,385	100.0	5,352	100.0
2007	Jan.	32	0.7	147	0.4	131	0.3	319	4.3
	Feb.	34	0.7	424	1.2	426	1.1	20	0.3
	Mar.	86	1.8	700	2.0	744	1.9	219	2.9
	April	273	5.6	793	2.2	715	1.8	806	10.8
	May	173	3.5	555	1.6	543	1.4	402	5.4
	June	511	10.4	3,780	10.7	3,297	8.2	470	6.3
	July	546	11.2	4,695	13.2	5,093	12.7	914	12.3
	Aug.	662	13.5	6,414	18.1	7,964	19.8	423	5.7
	Sept.	637	13.0	6,943	19.6	7,872	19.6	395	5.3
	Oct.	1,090	22.3	4,962	14.0	6,026	15.0	654	8.8
	Nov.	632	12.9	3,660	10.3	4,743	11.8	350	4.7
	Dec.	217	4.4	2,400	6.8	2,615	6.5	2,477	33.3
	All	4,893	100.0	35,472	100.0	40,168	100.0	7,449	100.0
2008	Jan.	62	1.2	800	1.6	886	1.7	0	0.0
	Feb.	27	0.5	14	0.0	55	0.1	27	0.3
	Mar.	47	1.0	392	0.8	343	0.7	406	4.4
	April	227	4.6	1,422	2.8	1,397	2.7	161	1.8
	May	315	6.3	4,506	8.8	3,839	7.4	129	1.4
	June	380	7.7	4,654	9.0	5,011	9.7	493	5.4
	July	476	9.6	7,377	14.3	8,691	16.8	497	5.4
	Aug.	837	16.8	7,970	15.5	8,282	16.0	2,057	22.3
	Sept.	816	16.4	7,374	14.3	7,875	15.2	4,668	50.7
	Oct.	996	20.1	10,821	21.0	10,768	20.8	550	6.0
	Nov.	604	12.2	5,226	10.2	3,707	7.2	194	2.1
	Dec.	180	3.6	909	1.8	931	1.8	26	0.3
	All	4,967	100.0	51,465	100.0	51,785	100.0	9,207	100.0
All	Jan.	432	1.1	2,922	1.0	2,404	0.8	411	1.1
(2002–	Feb.	290	0.8	3,219	1.1	2,906	1.0	48	0.1
2008)	Mar	1,791	4.6	5,816	2.0	6,016	2.1	1,369	3.6
	April	989	2.6	4,757	1.6	4,649	1.6	1,497	3.9
	May	2,100	5.4	17,758	6.1	17,596	6.1	979	2.5
	June	4,260	11.0	27,809	9.6	26,074	9.0	5,329	13.9
	July	4,497	11.7	46,833	16.1	46,985	16.2	4,825	12.6
	Aug.	5,402	14.0	54,172	18.6	54,583	18.8	5,870	15.3
	Sept.	4,892	12.7	35,698	12.3	36,393	12.5	6,496	16.9
	Oct.	8,889	23.1	54,575	18.8	56,655	19.5	6,995	18.2
	Nov.	4,035	10.5	23,484	8.1	22,552	7.8	1,603	4.2
	Dec.	979	2.5	13,753	4.7	13,774	4.7	3,018	7.9
	All	38,555	100.0	290,797	100.0	290,586	100.0	38,439	100.0

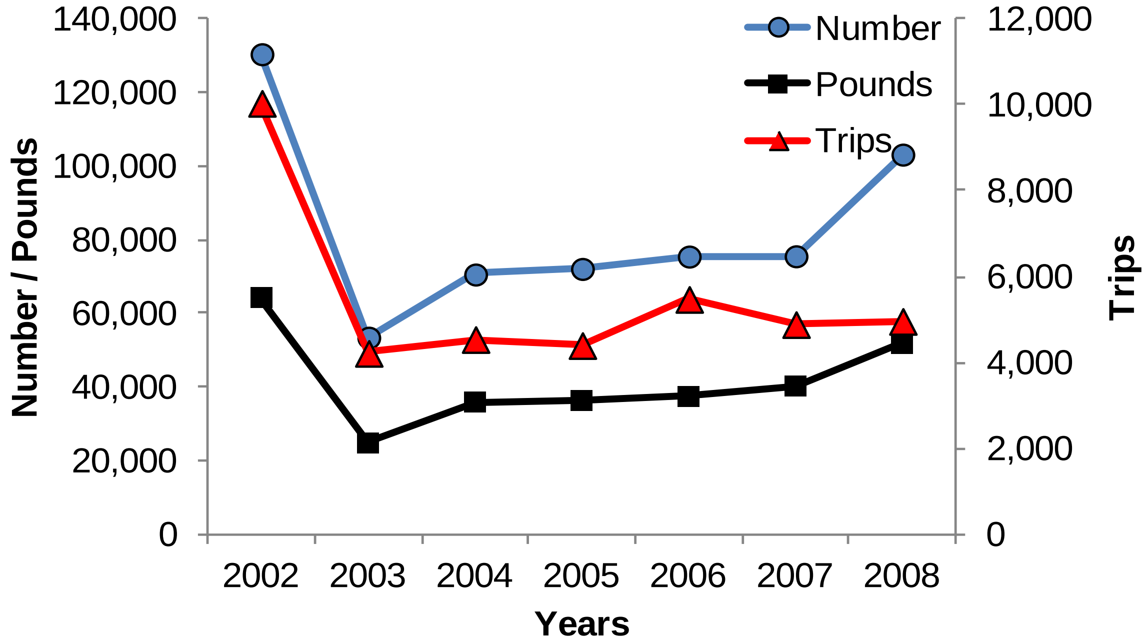

Figure 6.39. RCGL mullet (striped and white) trips and harvest by year: 2002–2008.

Approximately 38,555 trips using four different gear types were responsible for landing 290,586 lb of mullet during the period from 2002 to 2008. Small mesh gill nets accounted for 99.8% by lb of all mullet harvested by RCGL holders followed by large meshed gill nets (0.2%), crab pots (<0.1), and seine (<0.1, Table 6.11).

Table 6.11. Estimated catch statistics for striped mullet in RCGL for all gears used: 2002–2008.

		Trips		Harvest Number		Harvest Pounds (lb)		Discard Number	
Year	Gear	Number	Percent	Number	Percent	Number	Percent	Number	Percent
2002	Small Mesh Gill Nets	10,043	100.0	66,305	100.0	64,213	100.0	6,549	100.0
	All	10,043	100.0	66,305	100.0	64,213	100.0	6,549	100.0
2003	Large Mesh Gill Nets	84	2.0	485	1.7	415	1.7	0	0.0
	Small Mesh Gill Nets	4,139	98.0	28,271	98.3	24,359	98.3	3,514	100.0
	All	4,223	100.0	28,757	100.0	24,774	100.0	3,514	100.0
2004	Large Mesh Gill Nets	141	3.1	74	0.2	102	0.3	1,267	44.1
	Small Mesh Gill Nets	4,404	96.9	34,662	99.8	35,845	99.7	1,609	55.9
	All	4,545	100.0	34,736	100.0	35,947	100.0	2,875	100.0
2005	Large Mesh Gill Nets	7	0.2	0	0.0	0	0.0	72	2.1
	Small Mesh Gill Nets	4,398	99.8	35,888	100.0	36,314	100.0	3,420	97.9
	All	4,405	100.0	35,888	100.0	36,314	100.0	3,492	100.0
2006	Large Mesh Gill Nets	176	3.2	8	0.0	24	0.1	244	4.6
	Small Mesh Gill Nets	5,289	96.5	38,123	99.9	37,317	99.8	5,108	95.4
	Seine	15	0.3	45	0.1	44	0.1	0	0.0
	All	5,479	100.0	38,175	100.0	37,385	100.0	5,352	100.0
2007	Large Mesh Gill Nets	94	1.9	7	0.0	8	0.0	14	0.2
	Small Mesh Gill Nets	4,798	98.1	35,465	100.0	40,161	100.0	7,435	99.8
	All	4,893	100.0	35,472	100.0	40,168	100.0	7,449	100.0
2008	Crab Pot	58	1.2	14	0.0	11	0.0	0	0.0
	Large Mesh Gill Nets	32	0.6	19	0.0	97	0.2	0	0.0
	Small Mesh Gill Nets	4,877	98.2	51,431	99.9	51,677	99.8	9,207	100.0
	All	4,967	100.0	51,465	100.0	51,785	100.0	9,207	100.0
All Years	Crab Pot	58	0.1	14	0.0	11	0.0	0	0.0
(2002–08)	Large Mesh Gill Nets	534	1.4	594	0.2	644	0.2	1,597	4.2
	Small Mesh Gill Nets	37,949	98.4	290,144	99.8	289,887	99.8	36,842	95.8
	Seine	15	0.0	45	0.0	44	0.0	0	0.0
	All	38,555	100.0	290,797	100.0	290,586	100.0	38,439	100.0

6.2.3.2 RCGL Discard Estimates

From 2002 to 2008, RCGL reported a total of 38,439 discarded mullet. During this time, 95.8% of all discarded mullet by RCGL holders were initially captured in small mesh gill nets and 4.2% were initially captured by large mesh gill nets. From 2002 to 2004 a decline in discarded mullet is observed from 6,549 mullet in 2002 to 2,875 in 2004. After 2004, the number of mullet discards begins to trend back up surpassing the 2002 numbers with a total of 9,207 discards in 2008 (Table 6.11 and Figure 6.40).

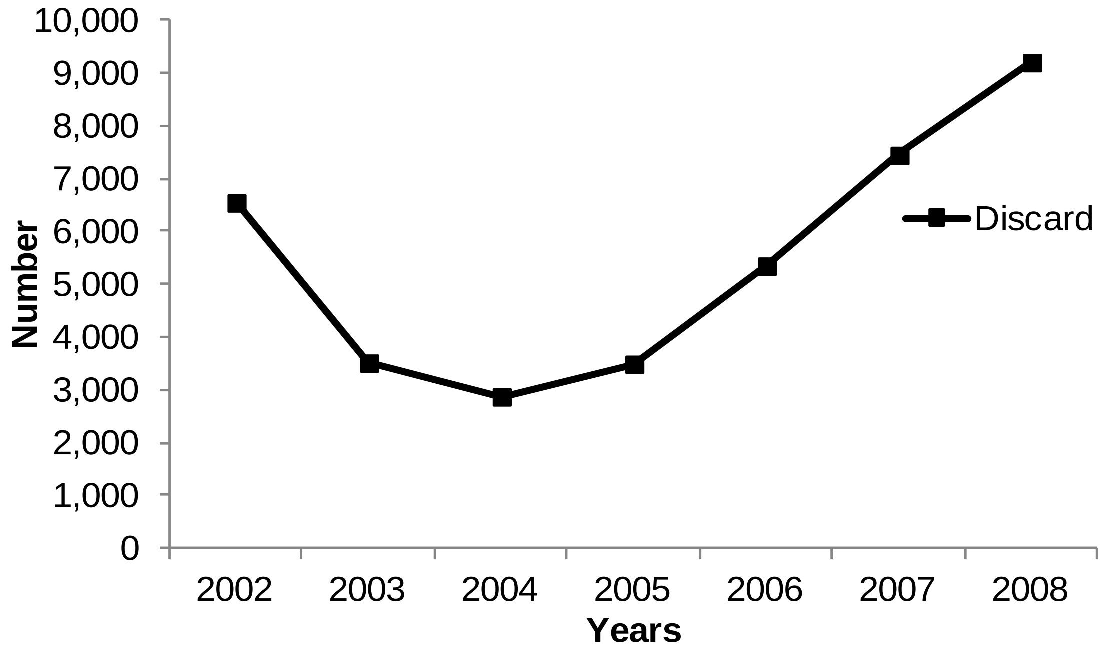

Figure 6.40. RCGL mullet (striped and white) discards by year: 2002–2008.

6.2.3.3 RCGL Seasonality of Harvest and Discard

From 2002 to 2008, the highest numbers of trips, accounting for 23.1% of all trips, were taken in October (8,889). During this same time series, 65.8% of the total harvest of mullet occurred during the months of July (16.1%), August (18.6%), September (12.3%) and October (18.8%). Mullet discards by RCGL holders from 2002 to 2008 with 76.9% of all discards occurring during the months of June (13.9%), July (12.6%), August (15.3%), September (16.9%) and October (18.2%; Table 6.11 and Figure 6.41).

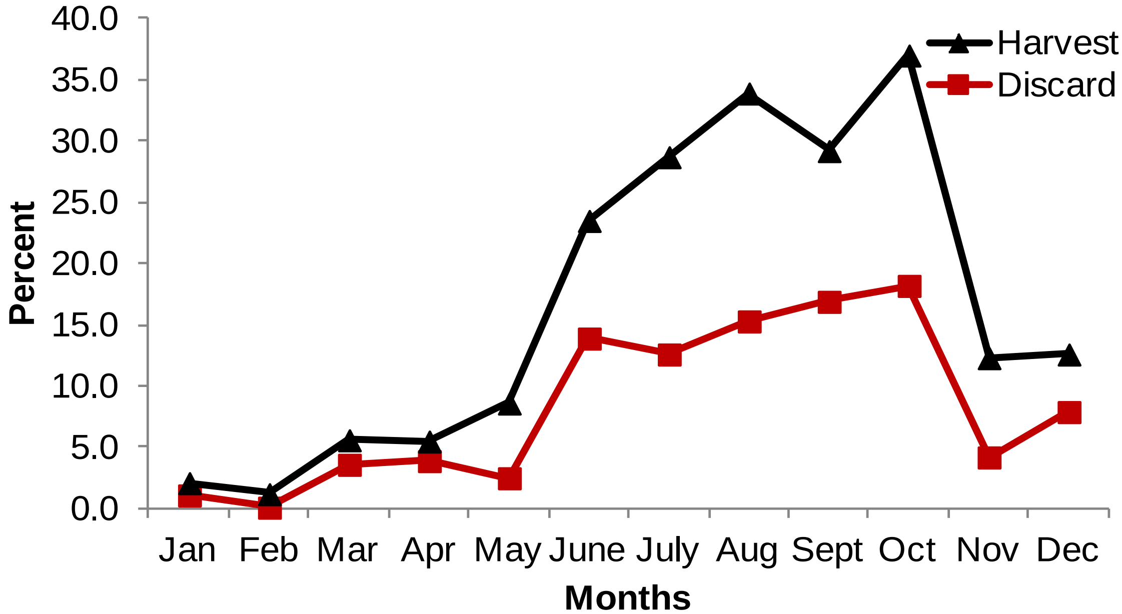

Figure 6.41. Monthly mullet (striped and white) percent harvest and discard by RCGL holders: 2002–2008.

6.2.3.4 RCGL Catch by Area

To more easily describe the spatial distribution of RCGL mullet harvest, the coast was divided into four regions: Northern, Pamlico, Central, and Southern (Figure 6.42). From 2002 to 2008, the contributions from each region to the total poundage of mullet harvested by weight were 41.1%, 19.6%, 18.9%, and 17.7% respectively for the Central, Northern, Pamlico, and Southern regions (Figure 6.43). Throughout this time span, the contributions from each region to the total percentage of trips taken were 29.7%, 29.4%, 24.2%, and 14.5% respectively for the Southern, Pamlico, Central, and Northern regions (Table 6.12 and Figure 6.44).

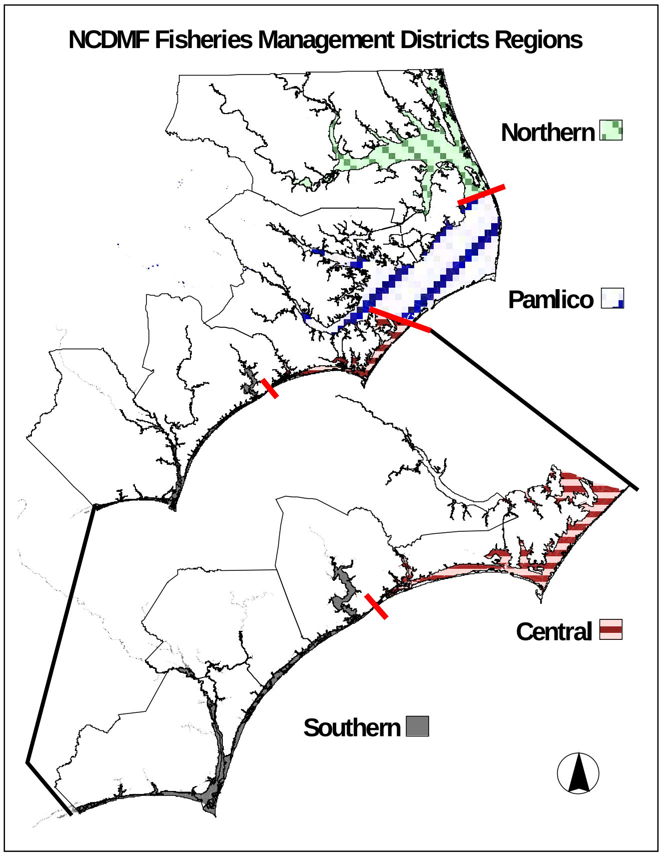

Figure 6.42. Regions used to describe the spatial distribution of mullet (striped and white) harvest from RCGL gears.

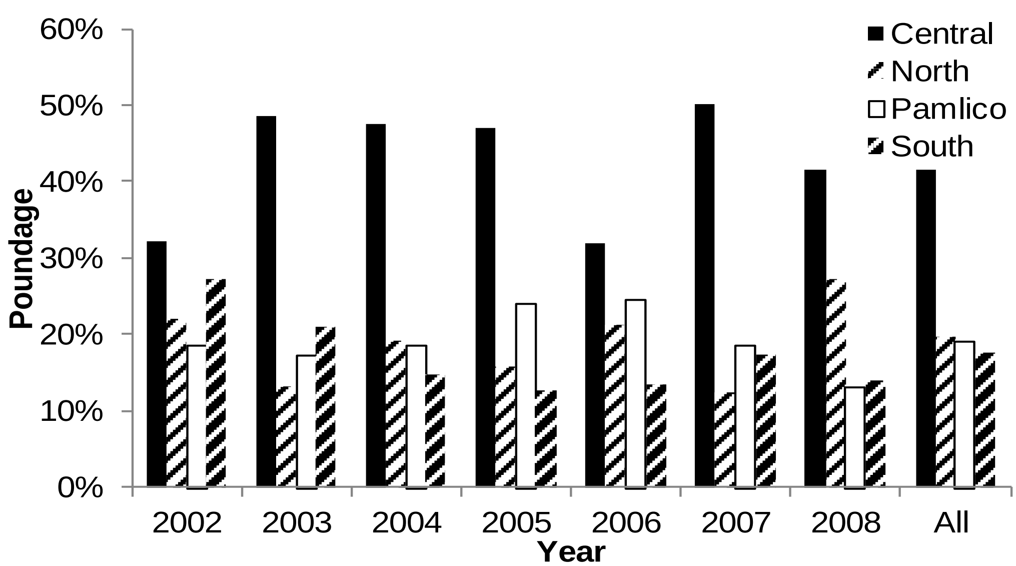

Figure 6.43. Yearly percent poundage by region for RCGL mullet (striped and white): 2002–2008.

Table 6.12. RCGL striped mullet catch and effort by year and region: 2002–2008.

		Trips		Harvest Number		Harvest Pounds (lb)		Discard Number	
Year	Region	Number	Percent	Number	Percent	Number	Percent	Number	Percent
2002	Central	2,410	24.0	22,059	33.3	20,609	32.1	1,499	22.9
	North	1,502	15.0	10,806	16.3	14,147	22.0	819	12.5
	Pamlico	3,248	32.3	13,865	20.9	11,968	18.6	3,032	46.3
	South	2,883	28.7	19,575	29.5	17,490	27.2	1,198	18.3
	All	10,043	100.0	66,305	100.0	64,213	100.0	6,549	100.0
2003	Central	1,014	24.0	13,582	47.2	12,004	48.5	563	16.0
	North	476	11.3	3,831	13.3	3,248	13.1	468	13.3
	Pamlico	1,147	27.2	4,968	17.3	4,295	17.3	2,251	64.1
	South	1,568	37.1	6,332	22.0	5,186	20.9	232	6.6
	Unknown	18	0.4	44	0.2	40	0.2	0	0.0
	All	4,223	100.0	28,757	100.0	24,774	100.0	3,514	100.0
2004	Central	1,250	27.5	15,551	44.8	17,078	47.5	386	13.4
	North	527	11.6	6,640	19.1	6,870	19.1	62	2.1
	Pamlico	1,318	29.0	5,965	17.2	6,645	18.5	1,735	60.4
	South	1,408	31.0	6,401	18.4	5,231	14.6	692	24.1
	Unknown	42	0.9	178	0.5	123	0.3	0	0.0
	All	4,545	100.0	34,736	100.0	35,947	100.0	2,875	100.0
2005	Central	942	21.7	15,897	44.6	16,953	46.9	113	3.3
	North	456	10.5	5,386	15.1	5,659	15.7	119	3.5
	Pamlico	1,399	32.2	8,014	22.5	8,643	23.9	1,316	38.6
	South	1,507	34.7	5,970	16.7	4,506	12.5	1,817	53.3
	Unknown	38	0.9	412	1.2	393	1.1	46	1.3
	All	4,341	100.0	35,679	100.0	36,154	100.0	3,411	100.0
2006	Central	1,230	22.4	11,952	31.3	11,912	31.9	373	7.0
	North	784	14.3	7,591	19.9	7,916	21.2	886	16.6
	Pamlico	1,863	34.0	10,092	26.4	9,205	24.6	3,112	58.2
	South	1,351	24.7	6,363	16.7	4,980	13.3	537	10.0
	Unknown	251	4.6	2,177	5.7	3,372	9.0	444	8.3
	All	5,479	100.0	38,175	100.0	37,385	100.0	5,352	100.0
2007	Central	1,239	25.3	14,798	41.7	20,093	50.0	382	5.1
	North	783	16.0	4,634	13.1	4,990	12.4	618	8.3
	Pamlico	1,284	26.2	8,125	22.9	7,435	18.5	6,239	83.8
	South	1,427	29.2	7,102	20.0	6,914	17.2	210	2.8
	Unknown	160	3.3	812	2.3	736	1.8	0	0.0
	All	4,893	100.0	35,472	100.0	40,168	100.0	7,449	100.0
2008	Central	1,234	24.8	21,487	41.8	21,568	41.6	496	5.4
	North	1,041	21.0	12,782	24.8	14,019	27.1	4,692	51.0
	Pamlico	1,059	21.3	7,043	13.7	6,726	13.0	2,937	31.9
	South	1,288	25.9	7,992	15.5	7,169	13.8	977	10.6
	Unknown	345	6.9	2,160	4.2	2,303	4.4	106	1.1
	All	4,967	100.0	51,465	100.0	51,785	100.0	9,207	100.0
All (2002–2008)	Central	9,318	24.2	115,326	39.7	120,216	41.4	3,812	9.9
	North	5,570	14.5	51,670	17.8	56,850	19.6	7,664	20.0
	Pamlico	11,317	29.4	58,073	20.0	54,916	18.9	20,623	53.8
	South	11,432	29.7	59,736	20.6	51,476	17.7	5,662	14.8
	Unknown	854	2.2	5,783	2.0	6,968	2.4	596	1.6
	All	38,491	100.0	290,588	100.0	290,426	100.0	38,357	100.0

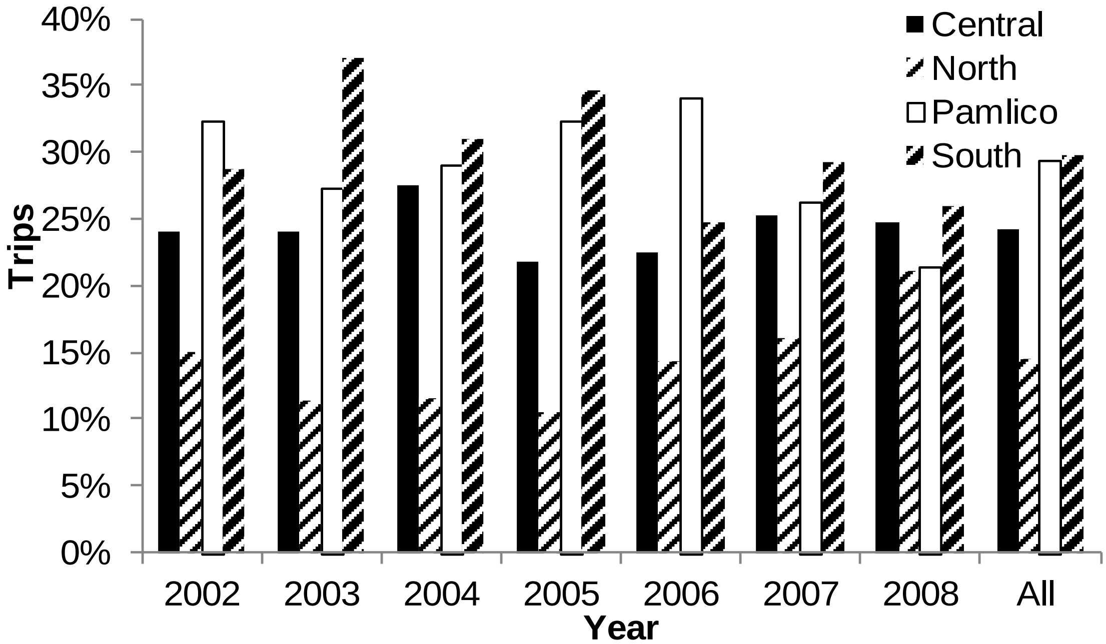

Figure 6.44. Yearly percent trips by region for RCGL mullet (striped and white): 2002–2008.

6.2.4 Bait Mullet Cast Net Fishery

The 2006 Striped Mullet FMP included the issue of examining and managing the bait mullet cast net fishery. This issue arose when the discarding of large numbers of bait mullet caught in cast nets at the end of fishing trips, and reports of fishermen harvesting large amounts of bait mullet from North Carolina and selling them in other states was brought to the attention of the division. The recommendation from NCDMF was to implement a possession limit of 200 mullets (white and striped in aggregate) per person in the recreational fishery. The intent was to eliminate anglers from taking large amounts of bait mullets from North Carolina and selling them in other states without impinging on normal fishing practices. A possession limit in the recreational fishery allows Marine Patrol to distinguish between a commercial and a recreational fishing operation and enforce accordingly. The advisory committee endorsed this recommendation and Marine Fisheries Commission Rule 15A NCAC 03M .0502 was amended to included section (b) “it is unlawful to possess more than 200 mullet per person per day for recreational purposes”, and went into effect July 1, 2006.

7.0 PROTECTED SPECIES

7.1 BACKGROUND

Protected species is a broad term that encompasses a host of species identified by federal or state protective statutes. The federal protective authorities are paramount and the dominant ones are the Endangered Species Act (ESA), Marine Mammal Protection Act (MMPA), and Migratory Bird Treaty Act (MBTA). Protected species in FMPs are generally discussed in relation to fisheries being prosecuted for the FMP species and specifically whether these fisheries have an incidental take of protected species. The protected species discussion herein intends to identify the principal fisheries, describe the various federal and state laws that deal with protected species, and discuss the ongoing management programs and implications of protected species incidental takes in the striped mullet fisheries.

7.2 PROTECTED SPECIES LEGISLATION

7.2.1 Federal Endangered Species Act

The ESA was enacted 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 with eighteen sections that cover many aspects of endangered species protection and management (STAC 2006).

The ESA defines a species as threatened when it is likely to become an endangered species within the foreseeable future. An endangered species is defined as any species which is in danger of extinction throughout all or a significant part of its range. A take is to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct (STAC 2006). Candidate species are species that appear to warrant consideration for addition to the federal ESA list. They are sometimes referred to as "species of special concern". These species receive no substantive or procedural protection under the ESA.

Section 10 of the ESA provides for exceptions to the take prohibitions in the form of permits. These permits can be for either an intentional or an incidental take. Intentional take permits are intended for scientific purposes or to enhance the propagation or survival of the affected species. Incidental take permits (ITP) are for activities that are otherwise lawful but are expected to incidentally take a listed species. Permit holders must develop and implement conservation plans that reduce and minimize the impacts of the take. When a Section 10 permit application is reviewed and deemed appropriate, a permit is granted to authorize a specified level of takes. Along with the specified take that is authorized, the permit includes reporting requirements, and often includes other conditions that must be met (tagging, handling guidelines, data analyses, conservation plans, etc.).

Section 7 of the ESA relates to interagency cooperation amongst federal agencies. There are two primary provisions to this section: 1) all federal agencies shall utilize their authorities towards the furtherance of the goals of the ESA; and 2) and each federal agency must consult with the Secretary [in practice NMFS or U.S. Fish and Wildlife Service (USFWS)] to insure that any action funded, authorized, or carried out by the agency is not likely to jeopardize the continued existence of a listed species or result in the destruction or adverse modification of its critical habitat. Although this section relates to federal agency cooperation, it can impact state projects through a federal nexus. If a project has federal authorization, funding, or other participation, it is subject to Section 7 consultation between the federal agency and NMFS. NCDMF has received biological opinions and incidental take statements in regards to Section 7 consultations on several federally funded division research projects.

7.2.2 Marine Mammal Protection Act

The Marine Mammal Protection Act of 1972 was enacted in response to increasing concerns by scientists and the public that significant declines in some species of marine mammals were caused by human activities. It established a national policy to prevent marine mammal species and population stocks from declining to a point where they ceased to be significant functioning elements of the ecosystem.

The Department of Commerce through the NMFS is charged with protecting whales, dolphins, porpoises, seals, and sea lions. Walruses, manatees, otters, and polar bears are protected by the Department of the Interior through the USFWS. The MMPA established a moratorium on the taking of marine mammals in U.S. waters. It defines “take” to mean “to hunt, harass, capture, or kill” any marine mammal or attempt to do so. Exceptions to the moratorium can be made through permitting actions for take incidental to commercial fishing and other non-fishing activities, for scientific research, and for public display at licensed institutions such as aquaria and science centers.

The MMPA requires NMFS to categorize each commercial fishery into one of three categories based upon the level of serious injury and mortality to marine mammals that occurs incidental to each fishery. Category I fisheries pose the greatest threat and Category III fisheries the least threat. The category in which a fishery is placed determines whether fishermen are subject to certain provisions of the MMPA, such as registration, observer coverage and take reduction plan requirements. According to the 2014 List of Fisheries created by NOAA, several North Carolina fisheries are listed as Category II (occasional mortality or serious injury) including the: North Carolina inshore gill net fishery, North Carolina long haul seine fishery, Mid-Atlantic haul/beach seine fishery, North Carolina roe mullet stop net fishery, and the Atlantic blue crab trap/pot fishery (Federal Register 2014).

7.2.3 Migratory Bird Treaty Act

The original 1918 statute implemented by the 1916 Convention between the U.S. and Great Britain (for Canada) for the protection of migratory birds. Later amendments implemented treaties between the U.S. and Mexico, the U.S. and Japan, and the U.S. and the Soviet Union (now Russia). The statute makes it unlawful, unless permitted by regulations, to pursue, hunt, take, capture, kill or sell any migratory bird. The statute does not discriminate between live or dead birds and grants full protection to any bird parts including feathers, eggs and nests. Over 800 species are currently on the list; migratory birds are managed federally by the USFWS.

7.2.4 North Carolina Endangered Species Act

Listing of protected species from a state perspective lies with the NCWRC (NC General Statutes - Chapter 113 Article 25). The NCWRC compiled state lists of animals deserving protection over 20 years ago based on guidance from Scientific Councils on mammals, birds, reptiles, amphibians, freshwater fishes, mollusks, and crustaceans. Endangered, Threatened, and Special Concern species of mammals, birds, reptiles, amphibians, freshwater fishes, freshwater and terrestrial mollusks, and crustaceans are protected by state law. Protection for crustaceans and certain venomous snakes was enacted in 2002. However, state law does not allow for protection of invertebrate groups other than mollusks and crustaceans.

Under the state Endangered Species Act the NCWRC has the following powers and duties:

1) To adopt and publish an endangered species list, a threatened species list, and a list of species of special concern, as provided for in G.S. 113-334, identifying each entry by its scientific and common name.
2) To reconsider and revise the lists from time to time in response to public proposals or as the Commission deems necessary.
3) To coordinate development and implementation of conservation programs and plans for endangered and threatened species of wild animals and for species of special concern.
4) To adopt and implement conservation programs for endangered, threatened, and special concern species and to limit, regulate, or prevent the taking, collection, or sale of protected animals.
5) To conduct investigations to determine whether a wild animal should be on a protected animal list and to determine the requirements for conservation of protected wild animal species.
6) To adopt and implement rules to limit, regulate, or prohibit the taking, possession, collection, transportation, purchase or sale of those species of wild animals in the classes Amphibia and Reptilia that do not meet the criteria for listing pursuant to G.S. 113-334 if the Commission determines that the species requires conservation measures in order to prevent the addition of the species to the protected animal lists pursuant to G.S. 113-334. This subdivision does not authorize the Commission to prohibit the taking of any species of the classes Amphibia and Reptilia solely to protect persons, property, or habitat; to prohibit possession by any person of four or fewer individual reptiles; or to prohibit possession by any person of 24 or fewer individual amphibians.

The NCWRC develops conservation plans for the recovery of protected wild animal species, using the procedures set out in Article 2A of Chapter 150B of the General Statutes. The North Carolina Natural Heritage Program inventories, catalogues, and supports conservation of the rarest and the most outstanding elements of the natural diversity of our state. These elements of natural diversity include those plants and animals which are so rare or the natural communities which are so significant that they merit special consideration as land-use decisions are made.

Species that appear on the 2012 Natural Heritage Program List of the Rare Animal Species of North Carolina that may interact with gill nets are listed as endangered (E), threatened (T),special concern (SC) or significantly rare (SR) and are the loggerhead sea turtle (T), leatherback sea turtle (E), hawksbill sea turtle (E), Kemp’s Ridley sea turtle (E), Green sea turtle (T), and diamondback terrapin (SC), shortnose sturgeon (E), Atlantic sturgeon (SC), brown pelican (SR), and double-crested cormorant (SR).

7.3 SPECIES

The following protected species may be found in the same waters used by the North Carolina striped mullet fisheries. Many are listed under the ESA as endangered or threatened, while others are protected under the MMPA or MBTA. Although these species may be found in the general geographic area where the striped mullet fishery occurs, they may not be affected by the fishery. Some species may inhabit areas other than those in which the fishery is prosecuted or may migrate through the area at times when effort is reduced in the fishery.

Most of the species listed as endangered or threatened fall under federal jurisdiction either with the NMFS or the USFWS. The following is a list of some of the endangered (E), threatened (T), or federal species of concern (FSC) species that may occur in estuarine and ocean waters of North Carolina:

Fish

- Smalltooth sawfish (*Pristis pectinata*) E
- Shortnose sturgeon (*Acipenser brevirostrum*) E
- Atlantic sturgeon (*Acipenser oxyrinchus*) E

Reptiles

- Green sea turtle (*Chelonia mydas*) T
- Kemp's ridley sea turtle (*Lepidochelys kempii*) E
- Hawksbill sea turtle (*Eretmochelys imbricate*) E
- Leatherback sea turtle (*Dermochelys coriacea*) E
- Loggerhead sea turtle (*Caretta caretta*) T/E
- Northern diamondback terrapin (*Malaclemys terrapin terrapin*) FSC in Dare, Pamlico, and Carteret counties in North Carolina

Mammals

- West Indian manatee (*Trichechus manatus)* E
- Fin whale (*Balaenoptera physalus*) E
- Humpback whale (*Megaptera novaeangliae*) E
- North Atlantic right whale (*Eubalaena glacialis*) E
- Sperm whale (*Physeter catodon*) E
- Sei whale (*Balaenoptera borealis*) E

Birds

- Double-crested cormorant (*Phalacrocorax auritus*)
- Common loon (*Gavia imner*)
- Ruddy duck (*Oxyura jamaicensis*)
- Red breasted merganser (*Mergus serrator*)
- Brown pelican (*Pelecanus occidentalis*)
- Lesser scaup duck (*Aythya affinis*)
- Hooded merganser (*Lophodytes cucullatus*)
- Scup (*Stenotomus chrysops*)
- Great black-backed gull (*Larus marinus*)
- Bufflehead (*Bucephala albeola*)
- Surf scoter (*Melanitta perspicillata*)
- Herring gull (*Larus argentatus*)
- American black duck (*Anas rubripes*)
- Red throated loon (*Gavia stellata*)
- Pied-billed grebe (*Podilymbus podiceps*)

7.3.1 Protected Species Interactions in the Striped Mullet Fishery

Of the federal and state protected species listed above, bottlenose dolphins, sea turtles, diamondback terrapins, Atlantic sturgeon, and several migratory bird species may interact with the striped mullet fishery. The dominant gears for the harvest of striped mullet in North Carolina waters are runaround gill nets and set gill nets (Figure 6.17). An in depth description of these fisheries may be found in the Section 6, Status of the Fisheries. Most research and documentation of protected species interactions for gears landing striped mullet have focused on the set gill net fishery.

7.3.2 Bottlenose Dolphin

The bottlenose dolphin (*Tursiops truncatus*) inhabits temperate and tropical waters throughout the world. According to the 2009 U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessment (Waring et al. 2009) nine bottlenose dolphin stocks have been identified in the nearshore waters of the Western North Atlantic. Two of these stocks are found in North Carolina estuaries and are identified as the Northern North Carolina Estuarine System Stock (NNCESS) and the Southern North Carolina Estuarine System Stock (SNCESS). Bottlenose dolphins have been observed throughout the year in North Carolina estuarine waters but will migrate offshore when water temperatures fall below 10º C.

From 2003 to 2007, sixty-four dolphins of the NNCESS were found stranded or entangled in fishing gear within the area from Beaufort to the North Carolina/ Virginia border. This stock interacts with three fisheries (blue crab trap/pot fishery, long haul seine fishery, and inshore gill net fishery). It is unknown how many of these were due to interactions with these fisheries (Waring et. al. 2009).

7.3.3 Shortnose Sturgeon

Documented reports of shortnose sturgeon in North Carolina are limited to two areas: western Albemarle Sound (1881 and 1998) and the Cape Fear River [1987 (Ross et al. 1988)]. Although these two areas likely harbor distinct population segments, the Cape Fear population may number less than 50 fish, and there has been only one adult male captured from the Albemarle region. Historical reports from the 19th century indicate that shortnose sturgeon inhabited the Pamlico and Neuse rivers, but obstructions and poor water quality may have eliminated shortnose sturgeon from these rivers since then (SSSRT 2010). Occasional identification of shortnose sturgeon may actually be mis-identified juvenile Atlantic sturgeon. No shortnose sturgeon has been documented from Albemarle Sound since 1998 (SSSRT 2010).

7.3.4 Atlantic Sturgeon

The Atlantic sturgeon is an anadromous species found in Atlantic coastal waters of the United States, and major river basins from Labrador (Churchill River, George River, and Ungava Bay), to Port Canaveral and Hutchinson Island, Florida (Van den Avyle 1984). Atlantic sturgeon is a mobile, long lived species that uses a wide variety of habitats. Atlantic sturgeon require freshwater habitats to reproduce and for development of early life stages, in addition to hard bottom substrate for spawning (Vladykov and Greeley 1963; Huff 1975; Smith 1985b). Coastal migrations and frequent movements between the estuarine and upstream riverine habitats are characteristic of this species (ASMFC 1998). Juvenile and adult Atlantic sturgeon frequently congregate in upper estuarine habitats around the saltwater interface, and may travel upstream and downstream throughout the summer and fall, and during late winter and spring spawning periods. Historically, Atlantic sturgeon was abundant in most North Carolina coastal rivers and estuaries; with most occurring in the Roanoke River/Albemarle Sound system and in the Cape Fear River (Kahnle et al. 1998; see Greene et al. 2009 for more information on Atlantic sturgeon).

Several studies have documented interactions with Atlantic sturgeon in set gill nets in North Carolina waters. Some of these studies focused on sturgeon specifically while others focused on comparing traditional and alternative methods of fishing or constructing gill nets and their effect on bycatch. White and Armstrong (2000) studied the survival of Atlantic sturgeon in flounder gill nets in Albemarle Sound, Williams (2000) documented bycatch of Atlantic sturgeon in the fall shallow water striped mullet gill net fishery in Albemarle Sound, Rose (2000; 2001; 2004) documented the bycatch of Atlantic sturgeon in the shad gill net fishery in Albemarle Sound, Thorpe et al. (2001) and Thorpe and Beresoff (2005) documented bycatch of Atlantic sturgeon in southern area of the state in the flounder gill net fishery, and Hassell (2007) documented bycatch of Atlantic sturgeon in the flounder gill net fishery in the Pamlico River (see NCDMF 2013b for more information on Atlantic sturgeon interactions in North Carolina fisheries).

7.3.5 Sea Turtles

Sea turtles are air-breathing reptiles with streamlined bodies and large flippers that inhabit tropical and subtropical ocean waters throughout the world. Of the seven species of sea turtle worldwide, five occur in North Carolina. They include the Kemp's ridley sea turtle, hawksbill sea turtle, leatherback sea turtle, green sea turtle, and the loggerhead sea turtle. Although sea turtles live most of their lives in the ocean, adult females must return to land to lay their eggs on sandy beaches. They often migrate long distances between foraging grounds and nesting beaches. Kemp's ridley, green, and loggerhead sea turtles are known to move into North Carolina coastal waters as large juveniles to forage on crustaceans, mollusks, or grasses (STAC 2006). The loggerhead and green sea turtles are federally listed as threatened, while the others are listed as endangered.

The geographic distribution of loggerhead sea turtles includes the subtropical and tropical waters and continental shelves and estuaries along the margins of the Atlantic, Pacific, and Indian oceans. Loggerhead sea turtles are rare or absent far from mainland shores. In the Western Hemisphere, their range extends as far north as Newfoundland and as far south as Argentina. Green sea turtles have a global distribution in tropical and subtropical waters. In U.S. Atlantic waters, green sea turtles occur around the Virgin Islands and Puerto Rico and from Texas to Massachusetts. Leatherback sea turtles occupy the open seas, although they are occasionally seen in coastal waters. Leatherbacks prefer warmer waters; however, they frequently appear in New England waters north to Newfoundland during the summer months. Hawksbill sea turtles are typically a tropical species found throughout the Caribbean. They are commonly observed in the Florida Keys, Bahamas, and southwestern Gulf of Mexico. Hawksbill stragglers have been reported as far north as Massachusetts and as far south as northern Argentina. This species is infrequently found in shallow coastal estuarine systems. Kemp's ridley sea turtles occur most frequently in the Gulf of Mexico, but they also occur along the Atlantic coast as far north as Long Island, NY and Martha's Vineyard, MA.

As water temperatures begin to rise during the spring months, sea turtles migrate northward along the coast and into estuarine waters (Shoop and Kenney 1992; Thompson and Huang 1993; Musick et al. 1994; Witzell and Azarovitz 1996; Braun-McNeill and Epperly 2004; Mansfield et al. 2009). When waters begin cooling during the fall, many sea turtles migrate southward out of the temperate latitudes to warmer waters. Others move offshore to warm waters in or near the Gulf Stream (McClellan and Read 2007; Mansfield et al. 2009). In 1988, researchers with the NMFS Laboratory in Beaufort, NC began monitoring the distribution of sea turtles in North Carolina estuarine and near-shore waters, employing three complementary methods to assess turtle distributions: aerial surveys, public sightings, and mark-recapture studies (Epperly et al. 1995a; 1995b). This research identified a distinct seasonal pattern of sea turtle distribution in the estuarine and near-shore ocean waters of North Carolina. In April, as coastal waters begin to warm, sea turtles enter North Carolina's estuaries. During summer months, sea turtles may be found from the Croatan and Roanoke sounds to the Cape Fear River and as far west as the lower reaches of the Neuse River estuary. The greatest densities of sea turtles occur in Core Sound and along the eastern shore of Pamlico Sound. In the fall, sea turtles leave the estuaries as water temperatures cool and are rarely seen inside the barrier islands from January to March. Sea turtles are observed in offshore ocean waters throughout the year.

Females of all five species of sea turtles lay clutches of eggs in nests on coastal beaches. The adults aggregate off the nesting beaches during the spring to mate. After mating, females move onshore to lay eggs. Up to seven clutches may be laid during a single nesting season. After an incubation period of two months, the hatchlings dig to the surface and move toward the ocean. The young swim offshore and spend their early life in offshore waters. After several years at sea, most species enter the coastal waters and move into bays, river mouths, and estuaries where they spend their juvenile life.

Hawksbill turtles have been reported off the coast of North Carolina during the months of June, July, October and November. This species of turtle prefers shallow coastal water with depths not greater than 66 feet. Preferred habitat includes coral reefs, rocky bottoms, reefs, and coastal lagoons. Adult hawksbills primary food source is sponges, but they also eat urchins, algae, barnacles, mollusks, jellyfish, and fish. Hawksbills exhibit a wide tolerance for nesting substrate type and nests are typically placed under vegetation. Nesting occurs principally in Puerto Rico and the U.S. Virgin Islands but does occur in the southeast coast of Florida and the Florida Keys. The largest threat to the hawksbill is the loss of coral reef habitat. The extent to which hawksbills are killed or debilitated after becoming entangled in marine debris has not been quantified, but it is believed to be a serious and growing problem. Hawksbills (predominantly juveniles) have been reported entangled in monofilament gill nets, fishing line, and synthetic rope. Hawksbills are incidentally taken by several commercial and recreational fisheries. Fisheries known or suspected to incidentally capture hawksbills include those using trawls, gill nets, traps, driftnets, hooks, beach seines, spear guns, and nooses (NMFS 1993b). There were no strandings reported of hawksbill sea turtles in North Carolina between 1991 and 1999, but there were nine between 2001 and 2010 (NCWRC/NMFS Sea Turtle Stranding and Salvage Network (STSSN)).

The leatherback sea turtle is the largest turtle in the world and has a worldwide distribution in tropical and temperate waters. This species is found off the coast of North Carolina from April to October with occasional sightings into the winter. The main prey species of leatherbacks are jellyfish and tunicates and occur almost exclusively in ocean waters (STAC 2006). There is one record of a NC nesting site at Cape Lookout in 1966 (Lee and Socci 1989), and an additional nesting site was reported near Cape Hatteras in 2000. Leatherbacks become entangled fairly often in long lines, fish trap, buoy anchor lines, and other ropes and cables (NMFS 1992). Between 1990 and 2000, there were 12 reported leatherback strandings in North Carolina, between 2001 and 2005 there were 75, and since 2006 there have been 17 reported strandings (NCWRC/NMFS STSSN).

The Kemp's ridley sea turtle occurs primarily in the Gulf of Mexico, but they also occur along the Atlantic coast as far north as New England. Juveniles occur year-round within the sounds, bays, and coastal waters of North Carolina. Adult Kemp's ridley turtles are primarily a bottom feeder, feeding on crabs, shrimp, urchins, starfish, jellyfish, clams, snails, and squid. Incidental take by shrimp trawls has been identified as the largest source of mortality with between 500 and 5,000 killed annually (NMFS 1993a). In North Carolina 17% of the sea turtle strandings between 1990 and 2000 were Kemp's ridley (WRC/NMFS STSSN; 1990–2000). Since 2001, there have been 651 strandings, which represents 13.5 percent of the total sea turtle strandings during this time period (NCWRC/NMFS STSSN).

The green sea turtle has a global distribution in tropical and subtropical waters. In U.S. Atlantic waters, it occurs around the Virgin Islands and Puerto Rico and from Texas to Massachusetts. Green turtles are sighted in oceanic waters and within the sounds of North Carolina during the period from May through October. Due to their food preference for submerged aquatic vegetation, adult green turtles are normally found in lagoons, bays, and tidal inlets. No major nesting sites are located along the U.S. coastline however, limited annual nesting occurs in Florida from April to July. From 1979–1989, there were two reported (1987, Baldwin Island and 1989, Cape Hatteras) and one confirmed (1979, Camp Lejeune) nesting sites in North Carolina. In 2009, there were three nests in North Carolina; and in 2010, there were 18 green turtle nests (NCWRC Sea Turtle Nest Monitoring System data). In 1992, NMFS finalized regulations to require the use of Turtle Excluder Devices (TEDs) in shrimp trawl fisheries. A significant threat to the green turtle continues to be fishing gear, primarily gill nets, but also trawls, traps and pots, and dredges. Green sea turtles have been recovered entangled in trap lines with the trap in tow (NMFS 1991a). Strandings have drastically increased since 2008. From 1991–2000, green turtles accounted for 18% of the sea turtle strandings in North Carolina and between 2001–2010 they make up 32% of total strandings (NCWRC/NMFS STSSN).

The loggerhead sea turtle has a subtropical (and occasionally tropical) distribution, including continental shelves and estuaries along the margins of the Atlantic, Pacific, and Indian oceans. It is rare or absent far from mainland shores. The loggerhead turtle is the most common sea turtle in North Carolina (STAC 2006) and is present throughout the year, with peak densities occurring from June to September. The loggerhead turtle diet includes algae, seaweeds, horseshoe crabs, barnacles, various shellfish, sponges, jellyfish, squid, urchins, and fish. Nesting occurs along the U.S. Atlantic coast from New Jersey to Florida, however, the majority of nesting activity occurs from South Carolina to Florida. In North Carolina, nesting activity has been reported from April to September. The highest nesting densities are reported south of Cape Lookout. In 2010, there were 847 loggerhead turtle nests in North Carolina (NCWRC STNNS data). The primary threat to loggerhead turtle populations worldwide is incidental capture in fishing gear, primarily in long lines and gill nets, but also in trawls, traps and pots, and dredges. While the impact of the crab pot fishery on loggerhead populations has not been quantified, this species may be particularly vulnerable since they feed on species caught in traps and on organisms growing on the traps, trap lines, and floats (NMFS 1991b). Loggerhead turtles account for over half of the sea turtle strandings in North Carolina (NCWRC/NMFS STSSN).

All sea turtle species are listed as either threatened or endangered under the ESA. NCDMF has taken numerous steps to reduce the potential of sea turtle interactions and especially mortalities in the fisheries of the state. These restrictions include areas closed to commercial fishing at times when sea turtles are likely to be present, gear restrictions (i.e. limiting the amount or size of nets used and reduced tow times for trawls), and requiring net attendance by fishermen during certain times of the year.

Several studies have documented interactions with sea turtles in set gill nets in North Carolina waters. Some of these studies focused on sea turtles specifically while others focused on comparing traditional and alternative methods of fishing or constructing gill nets and their effect on bycatch. Thorpe et al. (2001), Thorpe and Beresoff (2005), and Kimel et al. (2008) documented bycatch of green, Kemp's ridley, and loggerhead sea turtles in the southern area of the state in several gill net fisheries and Montgomery (2001 and 2002) documented the bycatch of green and loggerhead sea turtles in the Core Sound area (see NCDMF 2013a for more information on sea turtle interactions in North Carolina fisheries).

7.3.6 Diamondback Terrapins

Diamondback terrapins are found throughout North Carolina's high salinity coastal marshes. This species is listed federally as a species of concern (FSC) in Dare, Pamlico, and Carteret counties in North Carolina, although it affords them no legal protection. The diamondback terrapin it is listed as a "Special Concern" species by the NCWRC, making it protected under state regulations. The NCWRC Scientific Council on Amphibians and Reptiles (SCAR) is currently evaluating changing the listing of the diamond back terrapin to "Threatened" (SCAR 2011).

In a South Carolina study, terrapins were captured in salinities ranging from 4.3 to 22 ppt, with most captures in 10.1 to 15 ppt (Bishop 1983). Preferred habitats are the waters immediately adjacent to the marsh, small creeks, and mosquito control ditches. Terrapins are a long-lived species, probably surviving in excess of forty years. Females mature in seven to nine years, and fecundity is relatively low (Hildebrand 1932).

Populations of diamondback terrapins have declined throughout their range from Cape Cod, Massachusetts to southern Texas (Palmer and Cordes 1988; Seigel and Gibbons 1995). Possible reasons for this decline (Grant 1997) are: (1) degradation and loss of habitat, (2) mortality on roads (Wood 1995), (3) raccoon predation (Seigel 1980), and (4) incidental drowning in trawls, nets, and crab pots (Bishop 1983; Wood 1995).

Several studies have documented interactions with diamondback terrapins in set gill nets in North Carolina waters. These studies focused on comparing traditional and alternative methods of fishing or constructing gill nets and their effect on bycatch. Thorpe et al. (2001) and Thorpe and Beresoff (2005) documented the bycatch of diamondback terrapins in the southern area of the state in several gill net fisheries, Montgomery (2001; 2002) documented the bycatch of diamondback terrapins in the Core Sound area, and Evans (2001) documented the bycatch of diamondback terrapins in the Ocracoke area of Pamlico Sound.

7.3.7 Birds

There are several species of diving ducks and seabirds that are unintentionally caught in gill nets with some leading to mortalities. The USFWS completed a study to assess bird mortality in nearshore anchored gill nets in the ocean from New Jersey to Virginia and found that an estimated 2,387 birds were killed in the mid-Atlantic gill net fishery from February through April 1998 (Forsell 1999). A few studies have been conducted on seabird bycatch in the American shad gill net fishery (Rose 2000; 2001; 2004). These nets primarily caught diving birds such as loons, cormorants and grebes. These studies took place over an entire fishing season, generally lasting more than 100 days. These nets had a mesh size of 5.5 inches stretch mesh, and are larger than that used to catch striped mullet. Floating nets caught more birds than sinking nets overall (111 versus 61) and the most common bird caught in these nets was the red-throated loon (42% of the overall total).

Other studies have documented interactions with migratory birds in gill nets in North Carolina waters. These studies focused on comparing traditional and alternative methods of fishing or constructing gill nets and their effect on bycatch. Thorpe et al. (2001) and Thorpe and Beresoff (2005) documented bycatch of birds in the southern area of the state in several gill net fisheries, Montgomery (2001) documented the bycatch of cormorants and loons in the Core Sound area, Evans (2001) documented the bycatch of a loon in the Ocracoke area, and Darna (2000; 2002) documented the bycatch of cormorants, loons, and merganser's in the Neuse River area of Pamlico Sound.

7.4 NORTH CAROLINA DIVISION OF MARINE FISHERIES PROGRAMS

An agreement was established in 1979 with the NCWRC to exercise regulatory jurisdiction over any species of sea turtle, and their eggs and nests, consistent with designation of such species as endangered or threatened by the USFWS. In 1980, the MFC established a Sea Turtle Sanctuary off the coast of North Carolina to protect nesting beaches (MFC Rule – 15A NCAC 03R.0101). In 1983, proclamation authority was given to the director of NCDMF by MFC to close areas to protect endangered/threatened species (MFC Rule-15A NCAC 03I.0107). In 1989, an addition was made to the MRFSS program (now MRIP) to include a sea turtle sightings query on the survey form. The NCDMF observer program began in 1999 in the Fisheries Management section when the sea turtle stranding network noted significant increases in sea turtle strandings in the southeastern portion of Pamlico Sound. The purpose of these observations was to begin the process of characterizing effort, catch, and bycatch by area and season in various fisheries. In addition, this program was established to monitor fisheries for the potential of protected species bycatch. The data collected is used for fisheries management decisions, stock assessments, and conservation efforts for protected species. Currently, the observer program primarily focuses on large mesh gill nets but data are also being collected in small mesh gill nets and recreational hook and line. Data collected from observer trips include: date, location, unit, time, season, gill net description (net length, number of net shots, mesh size, presence/absence of tie downs, vertical mesh height, and hanging ratio), soak time, and water depth. Additionally, environmental parameters (wind, tide stage and water quality data) are collected when feasible. Total catches of target species are estimated and final disposition (kept or discarded) is recorded. Sea turtle and sturgeon interaction information includes species, condition, tag numbers, and final disposition. All interactions involving protected species are documented. All observers are required to adhere to these data collection parameters.

To maintain the gill net flounder fishery, NCDMF applied for and received an Incidental Take Permit (ITP #1259) under Section 10 of the ESA in 2000 (Gearhart 2001). The ITP authorized protected species interactions, allowing the fishery to operate under certain restrictions. The ITP contained a comprehensive conservation plan designed to reduce sea turtle interactions by establishing an authorized threshold of sea turtle takes, and intensive monitoring by fisheries observers, while allowing traditional gill net fisheries to be prosecuted. Observations in 2000 identified the deep water region of Pamlico Sound as the primary source for sea turtle interactions and subsequent mortality leading NMFS to establish a permanent rule for the 2001 fishing season that closed all potential fishing grounds utilized by the deep water large mesh gill net fisheries. In 2001, NCDMF applied for and received another ITP (# 1348) that implemented further restrictions by establishing prohibited fishing corridors and restricted areas throughout Pamlico Sound, known as the Pamlico Sound Gill Net Restricted Area (PSGNRA). NMFS then closed the rest of Pamlico Sound to gill nets with mesh sizes larger than 4.25 inch stretched mesh on September 27, 2001.

In 2003, NCDMF applied for and received a three-year ITP (#1398). This ITP contained a Habitat Conservation Plan (HCP) which implemented an intensive sea turtle observer and characterization program throughout the PSGNRA from September through December. These restricted areas remained unchanged and were monitored annually from September 1 through December 15 of each year. Observed levels of sea turtle interactions in the flounder gill net fishery remained below thresholds that were established by the ITP from 2002 through 2004 (Gearhart 2003; Price 2004; Price 2005).

The Sea Turtle Advisory Committee (STAC) was formed in 2003 by the MFC in response to continuing problems with protected species interactions in fisheries throughout the North Carolina coast. Their objective was to develop solutions for the reduction of sea turtle interactions in commercial and recreational (hook and line) fishing gear, while maintaining economically viable fisheries throughout the estuarine waters of North Carolina. The STAC was comprised of stakeholders concerned with the bycatch of protected species in commercial and recreational fisheries. Stakeholders included recreational and commercial fishermen and the scientific community representing state and federal agencies, academia, and an environmental organization. The committee summarized its findings in a report which included a background summary about federal and state management, sea turtle natural history, sea turtle strandings, and characterization of North Carolina estuarine fisheries. The document concluded with identification of problems, development of solutions, and recommendations for the reduction of commercial and recreational fishery interactions with sea turtles, while maintaining North Carolina fisheries (STAC 2006).

Over a three year effort, the STAC identified four inshore gears of primary concern with relation to sea turtle incidental catch throughout North Carolina. These gears were gill nets, pound nets, shrimp trawls, and recreational hook and line. Other gears were identified as gears of other concern, and many gears were identified as no concern (STAC 2006).

Recommendations were provided to the MFC following completion of this report, and many of the recommended actions are currently in place. Throughout the STAC process, the recommendation to implement observer coverage for multiple fisheries of either primary or other concern was made in order to gather information where it is limited. The STAC also supported continued efforts for gear modification and testing with the objective of reducing sea turtle interactions.

STAC Recommendations for Gill Nets (>5 in stretch; STAC 2006):

1) Establish mandatory observer coverage of all large mesh (≥ 5 in. stretch) gill nets throughout all estuarine waters. The level of coverage should have a minimum goal of 2% of the total effort by area. Coverage should increase (~10%) in areas when/where sea turtle interactions are occurring.
2) Provide education on sea turtle resuscitation to fishermen. Support outreach programs that encourage reporting sea turtles and compliance with regulations.
3) Implement state seasonal/area closures in identified problem areas.
4) Support continued efforts for gear modification and testing with the objective of reducing sea turtle interactions.

In 2005, NCDMF applied for and received a six-year permit (ITP # 1528) with a few changes to the PSGNRA management area including the establishment of a state closure on top of the federal closure, redirection of observer coverage and the elimination of the permit requirements along the mainland side of Pamlico Sound (ITP # 1528; Price 2006). Management of the PSGNRA under this ITP was consistent and has provided continued protection of sea turtles while allowing a shallow water gill net fishery to operate along the Outer Banks and mainland side of Pamlico Sound.

In the fall of 2010, the MFC reestablished the STAC to address sea turtle bycatch. The duties of the reestablished STAC include but are not limited to: reviewing observer reports, devising means for fishermen to report sea turtle interactions, assisting with fishermen education, determining measures to reduce the incidental take of sea turtles, monitor observer program issues, and review all future ITP provisions and take calculations prior to formal application to NMFS. The STAC provided recommendations and guidance to the MFC and NCDMF in addressing the protection of sea turtles in North Carolina.

In August 2010, NCDMF applied for a ten year ITP under Section 10 of the ESA for the incidental take of sea turtles. In September 2013, NCDMF received ITP # 16230 for the incidental take of sea turtles in inshore estuarine waters for the large and small mesh set gill net fisheries (NMFS 2013). The conservation plan prepared by NCDMF describes measures designed to monitor, minimize, and mitigate the incidental take of ESA-listed sea turtles. The conservation plan includes managing inshore gill net fisheries by dividing estuarine waters into six management units (Figure 7.1). Each of the management units is monitored seasonally and by fishery. This permit applies only to the areas defined as follows:

Management Unit A: encompasses all estuarine waters north of 35° 46.30'N to the North Carolina/Virginia state line. This includes all of Albemarle, Currituck, Croatan, and Roanoke sounds as well as the contributing river systems in this area. Most of this area is currently defined as the Albemarle Sound Management Area (ASMA).

Management Unit B: encompasses all estuarine waters south of 35° 46.30'N, east of 76° 30.00'W, and north of 34° 48.27'N. This Management Unit includes all of Pamlico Sound and the northern portion of Core Sound.

1) Shallow Water Gill Net Restricted Area (SGNRA) 1
   The area from Wainwright Island to Ocracoke Inlet bound by the following points: Beginning at a point on Core Banks at 34° 58.7963'N - 76° 10.0013'W, running northwesterly to Marker # 2CS at the mouth of Wainwright Channel at 35° 00.2780'N - 76° 12.1682'W, then running northeasterly to Marker "HL" at 35° 01.5665'N - 76° 11.4277'W, then running northeasterly to Marker #1 at 35°09.7058'N - 76° 04.7528'W, then running southeasterly to a point at Beacon Island at 35°05.9352'N - 76° 02.7408'W, then running south to a point on the northeast corner of Portsmouth Island at 35° 03.7014'N - 76° 02.2595'W, then running southwesterly along the shore of Core Banks to the point of beginning.

2) SGNRA 2
   The area from Ocracoke Inlet to Hatteras Inlet bound by the following points: Beginning at a point near Marker #7 at the mouth of Silver Lake at 35° 06.9091'N - 75° 59.3882'W, running north to Marker # 11 near Big Foot Slough Entrance at 35° 08.7890'N - 76° 00.3606'W, then running northeasterly to a point at 35° 13.4489'N'N - 75° 47.5531'W, then running south to a point northwest of the Ocracoke/Hatteras Ferry terminal on the Ocracoke side at 35° 11.5985'N - 75°47.0768'W, then southwesterly along the shore to a point of beginning.

3) SGNRA 3
   The area from Hatteras to Avon Channel bound by the following points: The area from Hatteras to Avon Channel bound by the following points: Beginning at a point

near Marker “HR” at 35° 13.3152’N – 75° 41.6694’W, running northwest near Marker “42 RC” at Hatteras Channel at 35° 16.7617’N – 75° 44.2341’W, then running easterly to a point off Marker #2 at Cape Channel at 35° 19.0380’N – 75° 36.2993’W, then running northeasterly near Marker #1 at the Avon Channel Entrance at 35° 22.8212’N – 75° 33.5984’W, then running southeasterly near Marker #6 on Avon Channel at 35° 20.8224’N - 75° 31.5708’W, then running easterly near Marker #8 at 35° 20.9412’N – 75° 30.9058’W, then running to a point on shore at 35° 20.9562’N - 75° 30.8472’W, then following the shoreline in a southerly and westerly direction to the point of beginning.

4) SGNRA 4

The area from Avon Channel to Rodanthe bound by the following points: Beginning at a point near Marker #1 at the Avon Channel Entrance at 35° 22.8212’N - 75° 33.5984’W, then running northerly to a Point on Gull Island at 35° 28.4495’N - 75° 31.3247’W, then running north near Marker “ICC” at 35° 35.9891’N – 75° 31.2419’W, then running northwesterly to a point at 35° 41.0000’N – 75° 33.8397’N – 75° 29.3271’W, then following the shoreline in a southerly direction to a point on shore near Avon Harbor at 35° 20.9562’N - 75° 30.8472’W, then running westerly near Marker #8 at 35° 20.9412’N - 75° 30.9058’W, then running westerly near Marker #6 on Avon Channel at 35° 20.8224’N - 75° 31.5708’W, then running northwesterly to the point of beginning.

5) Mainland Gill Net Restricted Area (MGNRA)

The area on the mainland side of Pamlico Sound, from the shoreline of Dare, Hyde, Pamlico and Carteret counties out to 200 yards between 76° 30’W and 75° 42’W.

6) Core Sound Gill Net Restricted Area (CGNRA)

All Internal Coastal waters south of latitude 35° 00.00’N and north of latitude 34° 48.27’N which runs approximately from the Club House on Core Banks westerly to a point on the shore at Davis near Marker “1”.

Management Unit C: includes the Pamlico, Pungo, and Neuse river drainages west of 76° 30.00’W.

Management Unit D: divided into two areas, D-1 and D-2, to allow the NCDMF to effectively address areas of high sea turtle abundance or “hot spots”.

Management Unit D-1: encompasses all estuarine waters south of 34° 48.27’N and east of a line running from 34° 40.6750’N – 76° 37.00’W to 34° 42.48’N – 76° 37.00”W then to the head of Turner Creek, and northerly up the western shoreline of the North River. Management Unit D-1 includes Southern Core Sound, Back Sound, and North River.

Management Unit D-2: encompasses all estuarine waters west of a line running from 34° 40.6750’N – 76° 37.00’W to 34° 42.48’N – 76° 37.00”W, then to the head of Turner Creek, and northerly up the western shoreline of the North River; and east of the NC Hwy 58 Bridge. Management Unit D-2 includes Newport River (including the Atlantic Intracoastal Waterway and Harlowe Creek up to the NC Hwy 101 Bridge) and Bogue Sound.

Management Unit E: encompasses all estuarine waters south and west of the Hwy 58 Bridge to the North Carolina/South Carolina state line. This includes the Atlantic Intracoastal Waterway (ICW) and adjacent sounds and the New, Cape Fear, Lockwood Folly, White Oak, and Shallotte rivers. See NMFS 2013 for additional information on conditions and gill net restrictions included in ITP #16230.

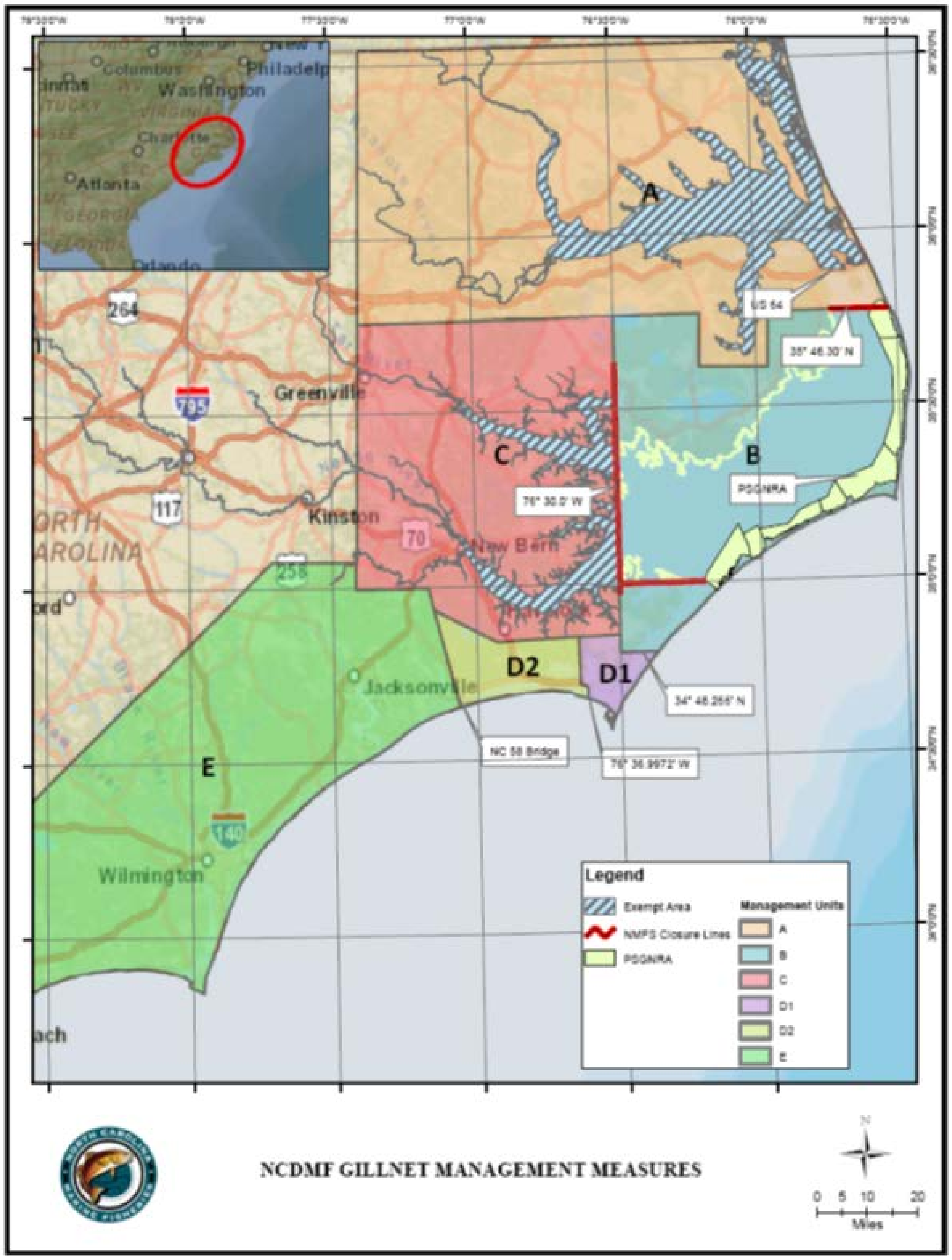

Figure 7.1. Map of Sea Turtle Management Units for North Carolina's estuarine waters in Incidental Take Permit #16230.

In the latter part of 2010, NCDMF reallocated funds to establish the Protected Resources Section within the division and obtained funding to support a statewide at-sea observer program for the estuarine gill net fishery. The new Protected Resources Section is the lead for division actions involving protected species such as at-sea observer programs, marine mammal stranding responses and marine mammal take reduction teams, and other protected species issues that may arise (NCDMF Strategic Plan 2010).

Marine mammal stranding response along the central North Carolina coast, transitioned from North Carolina State University Center for Marine and Science Technology to the NCDMF in October of 2010. This project is funded year to year from the John H. Prescott Marine Mammal Rescue Assistance Foundation, pending successful proposal review and acceptance. A full-time stranding coordinator was hired and stranding personnel have responded to numerous marine mammal strandings. North Carolina stranding response is divided into four areas: University of North Carolina-Wilmington personnel respond to all strandings in the southern part of the state up to and including Camp LeJeune; NCDMF stranding personnel respond to strandings from Hammocks Beach State Park to Cape Lookout National Seashore and in Albemarle and Pamlico sounds; Cape Hatteras (CAHA) National Seashore stranding personnel respond to strandings in CAHA National Seashore, and DENR personnel respond to strandings from CAHA north to the VA border. Stranding personnel conduct outreach by giving public seminars at marine mammal meetings, local museums, Universities, and classrooms. Stranding personnel disseminate results and tissue samples from stranded animals to collaborating researchers and agencies.

On April 6, 2012, the ESA rule listing Atlantic sturgeon as an endangered species became effective. In June 2012, NCDMF applied for a ten year ITP under Section 10 of the ESA for the incidental take of Atlantic sturgeon in inshore estuarine waters for the large and small mesh set gill net fisheries. In July 2014, NCDMF received ITP # 18102 for the incidental take of Atlantic sturgeon in inshore estuarine waters for the large and small mesh set gill net fisheries (NMFS 2014). The conservation plan prepared by NCDMF describes measures designed to monitor, minimize, and mitigate the incidental take of ESA-listed Atlantic sturgeon. The conservation plan includes managing inshore gill net fisheries by dividing estuarine waters into seven management units (Figure 7.2). Each of the management units is monitored seasonally and by fishery. This permit only applies to the areas defined as follows:

Management Unit A is divided into three subunits—A-1, A-2, and A-3—to allow NCDMF to effectively address subunits where proactive management actions may be taken at a finer scale.

> Management Subunit A-1 will encompass Albemarle Sound as well as contributing river systems in the unit not crossing a line 36° 4.30'N -75° 47.64'W east to a point 36° 2.50'N -75° 44.27'W in Currituck Sound or 35° 57.22'N -75° 48.26'W east to a point 35° 56.11'N -75°43.60'W in Croatan Sound and 36° 58.36'N -75° 40.07'W west to a point 35° 56.11'N -75°43.60'W in Roanoke Sound.
>
> Management Subunit A-2 will encompass Currituck Sound north of a line beginning at 36° 4.30'N -75° 47.64' east to a point at 36° 2.50'N -75° 44.27'W as well as the contributing river systems in this unit.
>
> Management Subunit A-3 will encompass Croatan Sound waters south from a point at 35° 57.22'N -75° 48.26'W east to a point 35° 56.11'N -75°43.60'W and Roanoke Sound waters south from a point 36° 58.36'N -75° 40.07'W west to a point 35° 56.11'N -75°43.60'W south to 35° 46.30'N.

Management Unit B will encompass all estuarine waters South of 35° 46.30'N, east of 76° 30.00'W and north of 34° 48.27'N. This management unit will include all of Pamlico Sound and the northern portion of Core Sound.

Management Unit C will include the Pamlico, Pungo, Bay, and Neuse river drainages west of 76° 30.00’W.

Management Unit D will encompass all estuarine waters south of 34° 48.27’N and west of a line running from 34° 40.6750’N – 76° 37.00’W to 34° 42.48’N – 76° 37.00”W to the NC Hwy 58 bridge. Management unit D includes southern Core Sound, Back and Bogue sounds, and North, and Newport rivers (including the Atlantic Intracoastal Waterway and Harlowe Creek up to the NC Hwy 101 Bridge).

Management Unit E will encompass all estuarine waters south and west of the NC Hwy 58 Bridge to the North Carolina/South Carolina state line. This includes the Atlantic Intracoastal Waterway (IWW) and adjacent sounds, and the White Oak, New, Cape Fear, Lockwood Folly, and Shallotte rivers.

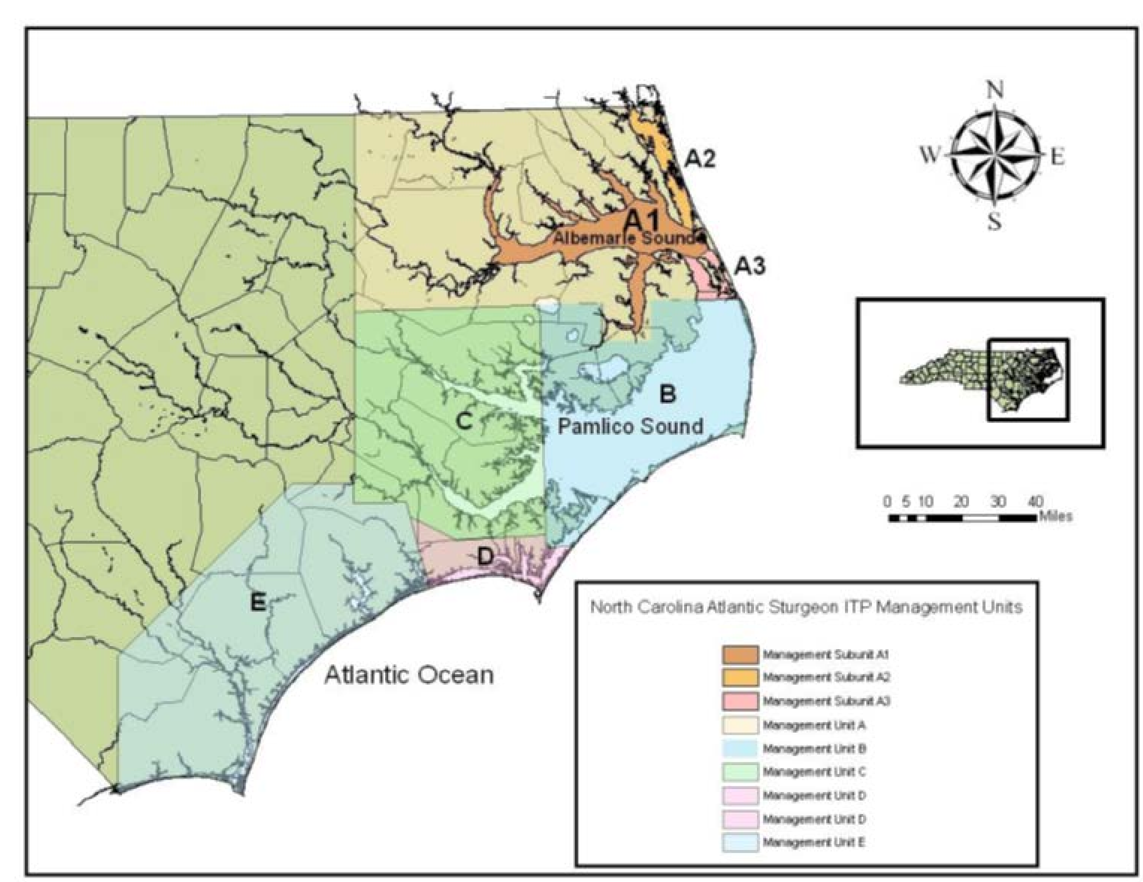

Figure 7.2. Atlantic Sturgeon Management Units for North Carolina’s estuarine waters in Incidental Take Permit #18102.

In addition to the gill net fishery observations in the PSGNRA since 2000, the NCDMF has also obtained commercial gill net fishery observations outside of the PSGNRA since 2004 in order to characterize effort, catch, finfish bycatch, and protected species interactions (Brown and Price 2005; Price 2007; Price 2009). The NCDMF has conducted both inshore and nearshore shrimp trawl observations (Brown 2009a; 2009b), and has obtained a limited number of pound net observations (Price 2007).

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 NMFS and other state and federal agencies to develop regulations that minimize impacts to protected species while trying to allow the prosecution of many economically important fisheries. In addition to the ITPs issued for the PSGNRA, the NCDMF has been issued ITPs for the shrimp trawl fishery off the North Carolina coast between Browns Inlet and Rich's Inlet allowing limited tow times in lieu of the use of TEDs because of high concentrations of algae which clog both shrimp trawl nets and TEDs.

The NCDMF has tested modified gill net designs for the purpose of reducing sea turtle interactions and still maintain acceptable levels of target species (Gearhart and Price 2003; Brown and Price 2005; Price and Van Salisbury 2007). These studies have identified low-profile gill net gear that can be used in the deep water portion of Pamlico Sound to mitigate the bycatch of sea turtles. In addition, the 2007 study indicated the potential transference of this technology to other gill net fisheries where similar conditions and sea turtle bycatch issues exist (Price and Van Salisbury 2007; Gilman et al. 2010). The NCDMF will continue to be proactive in developing ways to minimize impacts to protected species within North Carolina waters.

8.0 DESCRIPTION OF THE SOCIOECONOMIC CHARACTERISTICS OF THE STRIPED MULLET FISHERY

8.1 DEFINITIONS

Commercial fishing – Fishing in which fish harvested, either in whole or in part, are intended to enter commerce through sale, barter, or trade. Since 1994, a commercial fisherman in North Carolina is required to have a license issued by the NCDMF and is allowed only to sell to a licensed dealer.

Fishing trip – A period of time over which fishing occurs. The time spent fishing includes configuring, deploying, and retrieving gear, clearing animals from the gear, and storing, releasing or discarding catch. When fishing vessels are used, a fishing trip also includes the time spent traveling to and from fishing areas or locales and ends when the vessel offloads product at sea or returns to the shore. When fishing from shore or man-made structures, a fishing trip may include travel between different fishing sites within a 24-hour period.

Inflation-adjusted values – Inflation is a general upward movement in the price of goods and services in an economy. In this document, inflation is measured by changes in the U.S. Consumer Price Index (CPI). Ex-vessel prices and values can be adjusted according to the CPI to remove the effects of inflation so the value of a dollar remains consistent across years. Inflation adjusted values allow for a more clear understanding and analysis of changes in values over time.

Nominal ex-vessel price and value – Total landed dollar amount of a given species (or species landing condition and market category). Example: 100 lb of striped mullet at a PRICE of $0.80 per pound will have a VALUE of $80. These values represent the average amount paid to a fisherman by a seafood dealer.

Recreational fishing – A recreational fishing trip is any trip for the purpose of recreation from which none of the catch is sold or bartered. This includes trips with effort but no catch. Anglers who wish to use limited amounts of commercial fishing gear in joint and coastal waters under NCDMF jurisdiction are required to have a RCGL.

8.2 COMMERCIAL FISHING

8.2.1 Ex-vessel Value and Price

Landings data for striped mullet are included from 1972 to 2011. The North Carolina trip ticket program (NCTTP) began in 1994 when it was mandated that all commercial landings be reported to NCDMF. Prior to 1994, landings were voluntarily provided by fishermen and seafood dealers. Due to the relatively long timeline of the provided landings, it is useful to tie the value of annual landings back to an established baseline to control for the effects of inflation. Changes in landings values from year to year since 1972 can be more clearly understood after removing the influence of inflation and the changing value of the dollar over time. For this reason nominal and inflation adjusted ex-vessel values are provided (Table 8.1).

Table 8.1. Nominal and inflation adjusted ex-vessel and price per pound of striped mullet landings in North Carolina: 1972–2011.

Year	Nominal Value	Inflation Adjusted Value	Nominal Price Per Pound	Inflation Adjusted Price Per Pound
1972	$97,932	$97,932	$0.08	$0.08
1973	$91,951	$86,566	$0.08	$0.08
1974	$206,927	$175,447	$0.10	$0.08
1975	$204,083	$158,563	$0.10	$0.08
1976	$208,208	$152,954	$0.10	$0.07
1977	$193,291	$133,326	$0.11	$0.07
1978	$230,787	$147,959	$0.13	$0.08
1979	$343,427	$197,731	$0.19	$0.11
1980	$360,145	$182,695	$0.16	$0.08
1981	$259,094	$119,143	$0.20	$0.09
1982	$283,196	$122,669	$0.19	$0.08
1983	$206,253	$86,560	$0.19	$0.08
1984	$323,123	$129,996	$0.19	$0.08
1985	$310,804	$120,740	$0.21	$0.08
1986	$425,586	$162,313	$0.22	$0.08
1987	$654,536	$240,842	$0.25	$0.09
1988	$1,634,408	$577,500	$0.53	$0.19
1989	$1,637,650	$552,047	$0.79	$0.27
1990	$1,861,881	$595,460	$0.62	$0.20
1991	$823,424	$252,710	$0.56	$0.17
1992	$1,171,094	$348,908	$0.64	$0.19
1993	$1,942,472	$561,905	$0.63	$0.18
1994	$1,058,691	$298,605	$0.61	$0.17
1995	$1,944,319	$533,284	$0.85	$0.23
1996	$1,091,892	$290,893	$0.62	$0.17
1997	$1,777,617	$462,956	$0.73	$0.19
1998	$1,061,430	$272,195	$0.48	$0.12
1999	$838,924	$210,486	$0.57	$0.14
2000	$1,602,702	$389,041	$0.57	$0.14
2001	$1,181,912	$278,961	$0.51	$0.12
2002	$1,251,676	$290,828	$0.48	$0.11
2003	$779,570	$177,098	$0.48	$0.11
2004	$721,855	$159,733	$0.45	$0.10
2005	$801,181	$171,477	$0.49	$0.11
2006	$977,756	$202,729	$0.57	$0.12
2007	$721,171	$145,387	$0.43	$0.09
2008	$672,108	$130,486	$0.40	$0.08
2009	$715,265	$139,361	$0.42	$0.08
2010	$1,002,386	$192,151	$0.48	$0.09
2011	$1,014,981	$188,612	$0.62	$0.12

From 1972 to 1987, total statewide landings value remained relatively stable (Figure 8.1). There was an increase in demand in the mid-1980s due to new markets for striped mullet roe in Asia. This demand led to substantially higher ex-vessel prices per pound, which resulted in more directed effort and higher landings for striped mullet (Figure 8.2). Nominal values peaked in the mid-1990s, with the highest value observed in 1995 at $1,942,472. Beginning in 1991, ex-vessel prices began to drop due to a slowing of the Asian economy and fewer processors buying striped mullet and roe from North Carolina fishermen. Ex-vessel values followed this trend. 2010 and 2011 saw a rebound in both price and landings of striped mullet.

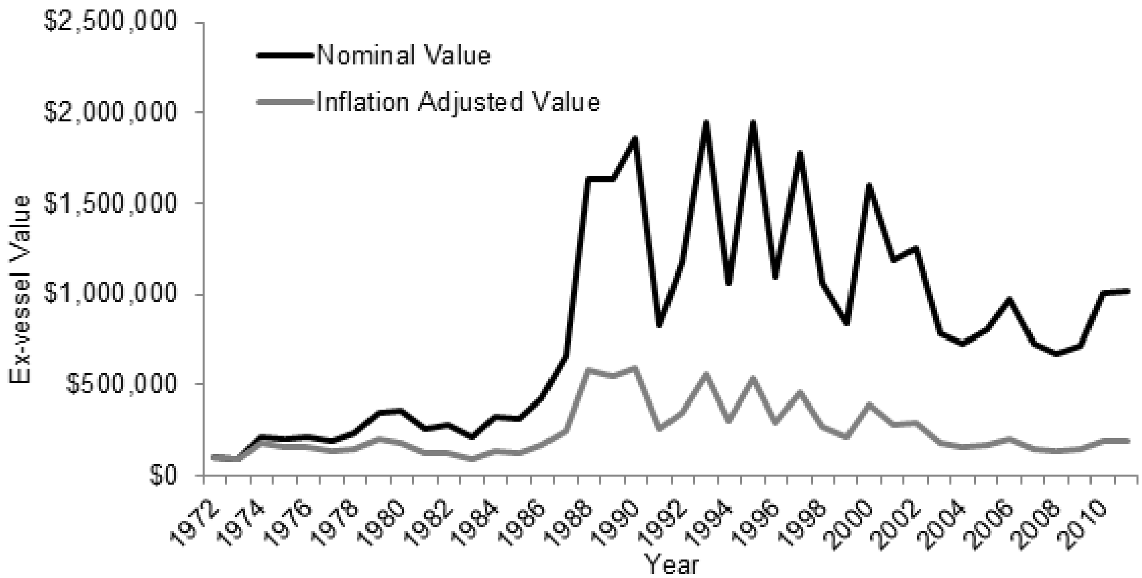

Figure 8.1. Value of commercial striped mullet landings in North Carolina: 1972–2011.

Inflation-adjusted figures (deflated to the value of a dollar in 1972) typically show less volatility. The 1990 high of $595,460 (inflation-adjusted) is over six times greater than the lows of approximately $87,000 in 1973 and 1983. The total value of striped mullet has varied greatly from year to year from the late 1980's though the early 2000s. A large portion of the volatility has been a direct result of the drastic variation in the pounds of striped mullet landed annually. The ex-vessel value of annual landings has been in an overall downward trend since 2000, but has exhibited some improvement in 2010 and 2011.

The average nominal price per pound paid to fisherman consistently rose from 1972 and 1987 (Figure 8.2). The price per pound more than doubled in 1988 with the opening of roe markets in Asia. Since 1990, the average nominal price per pound has seen some downward movement, but has remained relatively high. The inflation-adjusted price per pound reached a high of $0.27 in 1990. By 2008, it had dropped to approximately $0.08 per pound, equal to the price in 1972. There was a rebound in the nominal and inflation adjusted basis price in 2010 and 2011.

Price per pound tends to fluctuate in a single year depending on the month the fish are harvested. October and November traditionally have brought higher prices per pound primarily due to the increased availability of fish with roe in those months (Figure 8.3). Demand for roe in the fall was not as strong from 2007 through 2009, but rebounded in 2010 and 2011.

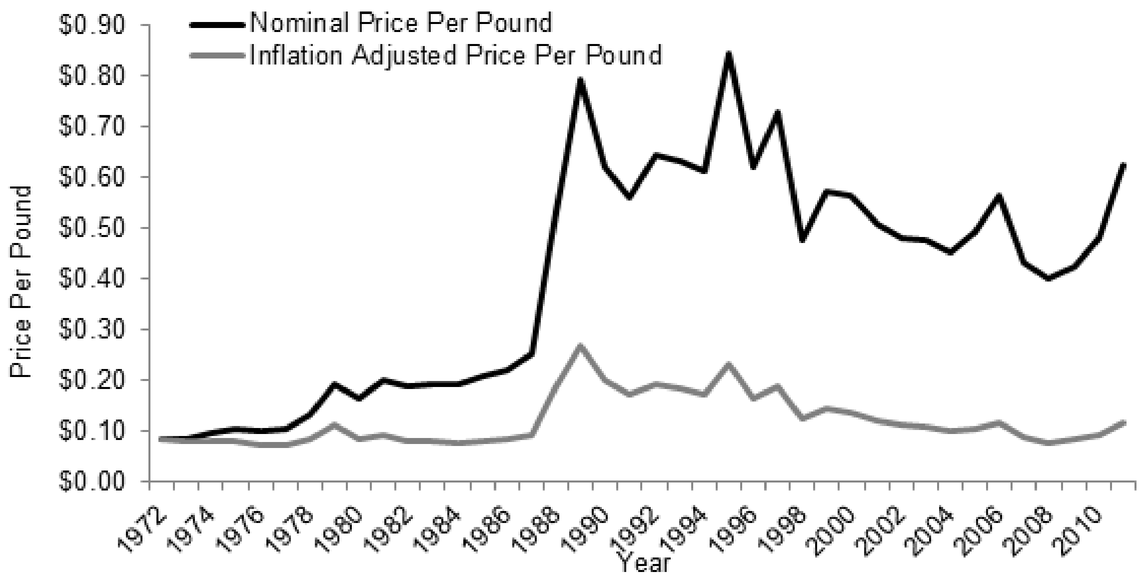

Figure 8.2. Average price per pound of striped mullet landings in North Carolina: 1972–2011.

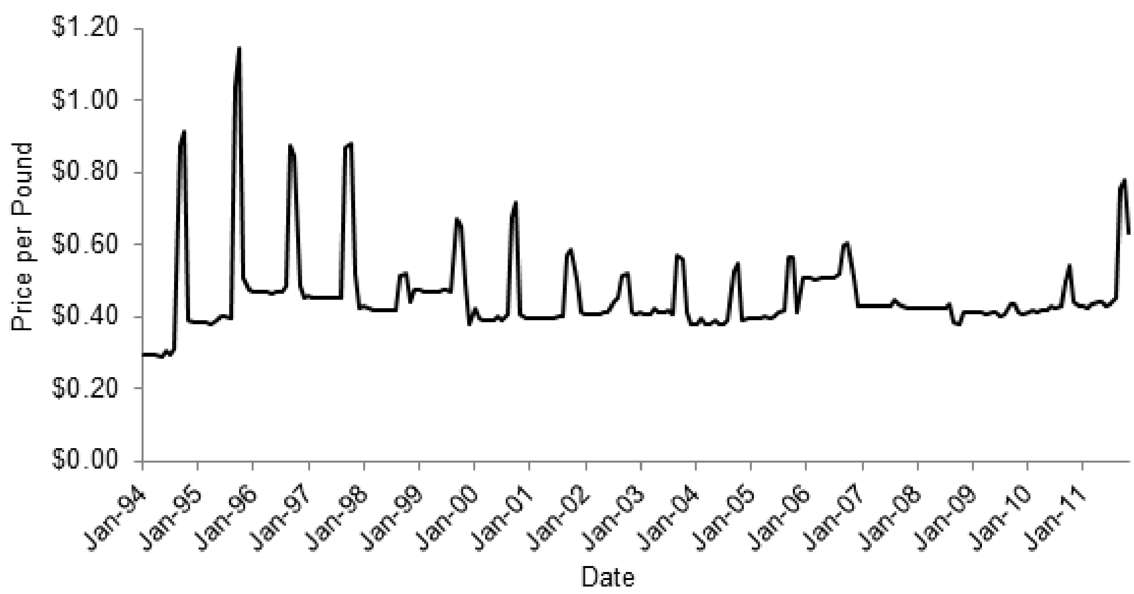

Figure 8.3. Average price per pound of striped mullet by month: 1994–2011.

8.2.2 Gear and Price

From 1994 to 2011, 91.9% of all striped mullet were caught using gill nets. An additional 5.3% were caught using beach seines and 1.6% in cast nets. The remaining 1.2% was caught using other gears such as pound nets or trawls (Figure 8.4).

Table 8.2 shows the number of pounds landed, the nominal ex-vessel value, and the nominal price per pound for each of the gears listed in Figure 8.4 by year from 1994 to 2011. Gill nets were the primary gear used in each of these years with runaround gill nets accounting for most landings since 2001.

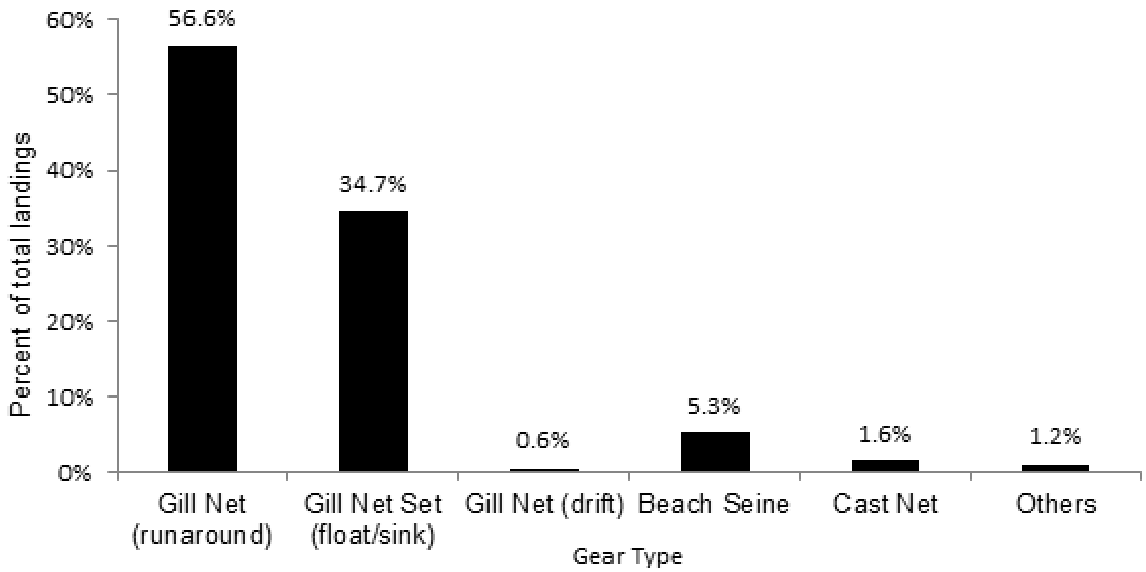

Figure 8.4. Percent of landings by gear used to harvest striped mullet in all North Carolina waters: 1994–2011.

Table 8.2. The average nominal price per pound for striped mullet using different commercial gears: 1994–2011.

Year	Gear	Pounds (lb)	Ex-Vessel Value	Price Per Pound
1994	Beach Seine	148,108	$128,876	$0.87
	Cast Net	11,719	$6,234	$0.53
	Gill Net (drift)	18,758	$13,860	$0.74
	Gill Net (runaround)	561,580	$411,869	$0.73
	Gill Net Set (float/sink)	888,086	$430,808	$0.49
	Others	97,990	$67,044	$0.68
	Total	1,726,242	$1,058,691	$0.61
1995	Beach Seine	101,643	$92,241	$0.91
	Cast Net	21,545	$13,277	$0.62
	Gill Net (drift)	42,793	$43,673	$1.02
	Gill Net (runaround)	1,141,011	$1,022,780	$0.90
	Gill Net Set (float/sink)	954,908	$746,580	$0.78
	Others	36,546	$25,768	$0.71
	Total	2,298,446	$1,944,319	$0.85
1996	Beach Seine	30,832	$22,689	$0.74
	Cast Net	18,613	$8,668	$0.47
	Gill Net (drift)	11,959	$8,621	$0.72
	Gill Net (runaround)	880,721	$570,063	$0.65
	Gill Net Set (float/sink)	790,659	$462,988	$0.59
	Others	24,080	$18,862	$0.78
	Total	1,756,863	$1,091,892	$0.62
1997	Beach Seine	185,037	$149,721	$0.81
	Cast Net	26,421	$11,891	$0.45
	Gill Net (drift)	22,147	$19,355	$0.87
	Gill Net (runaround)	1,156,393	$894,666	$0.77
	Gill Net Set (float/sink)	1,026,290	$682,102	$0.66
	Others	26,369	$19,882	$0.75
	Total	2,442,657	$1,777,617	$0.73
1998	Beach Seine	148,154	$72,920	$0.49
	Cast Net	29,657	$12,664	$0.43
	Gill Net (drift)	22,065	$11,729	$0.53
	Gill Net (runaround)	1,101,176	$542,182	$0.49
	Gill Net Set (float/sink)	906,972	$417,192	$0.46
	Others	10,084	$4,744	$0.47
	Total	2,218,108	$1,061,430	$0.48

Year	Gear	Pounds (lb)	Ex-Vessel Value	Price Per Pound
1999	Beach Seine	14,904	$9,690	$0.65
	Cast Net	15,890	$7,852	$0.49
	Gill Net (drift)	3,508	$2,297	$0.65
	Gill Net (runaround)	659,305	$398,893	$0.61
	Gill Net Set (float/sink)	758,227	$415,130	$0.55
	Others	9,017	$5,062	$0.56
	Total	1,460,850	$838,924	$0.57
2000	Beach Seine	204,810	$128,476	$0.63
	Cast Net	30,238	$22,961	$0.76
	Gill Net (drift)	3,069	$2,150	$0.70
	Gill Net (runaround)	1,228,574	$765,953	$0.62
	Gill Net Set (float/sink)	1,342,129	$671,762	$0.50
	Others	20,267	$11,400	$0.56
	Total	2,829,086	$1,602,702	$0.57
2001	Beach Seine	89,282	$48,832	$0.55
	Cast Net	25,976	$10,586	$0.41
	Gill Net (drift)	4,799	$2,625	$0.55
	Gill Net (runaround)	1,345,375	$706,956	$0.53
	Gill Net Set (float/sink)	838,490	$405,509	$0.48
	Others	13,734	$7,404	$0.54
	Total	2,317,655	$1,181,912	$0.51
2002	Beach Seine	247,242	$115,728	$0.47
	Cast Net	38,121	$15,900	$0.42
	Gill Net (drift)	6,239	$2,865	$0.46
	Gill Net (runaround)	1,350,455	$675,179	$0.50
	Gill Net Set (float/sink)	936,693	$433,790	$0.46
	Others	17,555	$8,213	$0.47
	Total	2,596,304	$1,251,676	$0.48
2003	Beach Seine	15,344	$7,669	$0.50
	Cast Net	18,036	$7,774	$0.43
	Gill Net (drift)	3,657	$1,901	$0.52
	Gill Net (runaround)	809,361	$414,397	$0.51
	Gill Net Set (float/sink)	763,014	$338,968	$0.44
	Others	19,903	$8,861	$0.45
	Total	1,629,314	$779,570	$0.48

Year	Gear	Pounds (lb)	Ex-Vessel Value	Price Per Pound
2004	Beach Seine	103,022	$57,716	$0.56
	Cast Net	18,454	$9,573	$0.52
	Gill Net (drift)	1,418	$585	$0.41
	Gill Net (runaround)	923,929	$434,910	$0.47
	Gill Net Set (float/sink)	527,947	$208,579	$0.40
	Others	23,846	$10,493	$0.44
	Total	1,598,617	$721,855	$0.45
2005	Beach Seine	80,498	$45,621	$0.57
	Cast Net	23,143	$12,766	$0.55
	Gill Net (drift)	17,058	$6,969	$0.41
	Gill Net (runaround)	1,023,186	$524,955	$0.51
	Gill Net Set (float/sink)	463,480	$205,013	$0.44
	Others	13,029	$5,858	$0.45
	Total	1,620,394	$801,181	$0.49
2006	Beach Seine	89,341	$48,176	$0.54
	Cast Net	34,158	$21,879	$0.64
	Gill Net (drift)	2,732	$1,445	$0.53
	Gill Net (runaround)	1,189,196	$681,802	$0.57
	Gill Net Set (float/sink)	406,991	$221,033	$0.54
	Others	6,189	$3,420	$0.55
	Total	1,728,607	$977,756	$0.57
2007	Beach Seine	102,722	$42,291	$0.41
	Cast Net	50,322	$30,829	$0.61
	Gill Net (drift)	666	$286	$0.43
	Gill Net (runaround)	1,056,796	$451,935	$0.43
	Gill Net Set (float/sink)	442,692	$189,075	$0.43
	Others	15,606	$6,755	$0.43
	Total	1,668,804	$721,171	$0.43
2008	Beach Seine	22,989	$8,361	$0.36
	Cast Net	56,206	$27,139	$0.48
	Gill Net (drift)	481	$202	$0.42
	Gill Net (runaround)	1,196,892	$471,895	$0.39
	Gill Net Set (float/sink)	386,708	$159,281	$0.41
	Others	12,582	$5,231	$0.42
	Total	1,675,859	$672,108	$0.40

Year	Gear	Pounds (lb)	Ex-Vessel Value	Price Per Pound
2009	Beach Seine	37,410	$16,492	$0.44
	Cast Net	76,524	$37,148	$0.49
	Gill Net (drift)	51	$21	$0.41
	Gill Net (runaround)	1,199,549	$504,872	$0.42
	Gill Net Set (float/sink)	358,356	$151,028	$0.42
	Others	13,724	$5,705	$0.42
	Total	1,685,615	$715,266	$0.42
2010	Beach Seine	15,847	$7,594	$0.48
	Cast Net	79,124	$36,236	$0.46
	Gill Net (drift)	1,329	$551	$0.41
	Gill Net (runaround)	1,467,229	$728,370	$0.50
	Gill Net Set (float/sink)	508,307	$225,016	$0.44
	Others	10,800	$4,619	$0.43
	Total	2,082,636	$1,002,386	$0.48
2011	Beach Seine	24,069	$17,324	$0.72
	Cast Net	42,616	$21,862	$0.51
	Gill Net (drift)	64	$22	$0.34
	Gill Net (runaround)	1,005,670	$666,899	$0.66
	Gill Net Set (float/sink)	536,783	$300,239	$0.56
	Others	16,973	$8,635	$0.51
	Total	1,626,175	$1,014,981	$0.62

Landings from all gill nets and seines were hampered by summer and fall hurricanes in 1996, 1999, and 2003 (beach seine only). In these years, landings were significantly lower than the preceding and succeeding years. Beach seine landings in these years were approximately one third to one tenth of what they normally had been.

When a gill net ban was enacted in Florida in 1995, some fishermen came to North Carolina waters to fish for striped mullet. Florida fishermen brought techniques, such as utilizing spotting towers, which were different from the traditional tactics that North Carolina fishermen were using, but were readily adopted. This likely led to an increase in runaround gill net landings in the fishery.

8.2.3 Marketing, Distribution, and Processing

From 1994 to 2004, more than 200 dealers purchased striped mullet from fishermen (Table 8.3). The number of dealers purchasing striped mullet ranged from 248 dealers in 1997 to 181 dealers in 2011. Throughout the time series, approximately half of the dealers recorded purchasing more than $500 of striped mullet. Three to eleven percent of dealers recorded more than $20,000 of striped mullet each year.

Table 8.3. Number of dealers and the nominal ex-vessel value of purchased striped mullet: 1994–2011.

Annual Ex-Vessel Value	1994	1995	1996	1997	1998	1999	2000	2001	2002
Less than $100	79	88	72	72	83	73	62	75	59
$100 to $500	41	41	47	50	51	41	44	41	40
$500.01 to $1,000	16	15	21	22	21	23	24	12	21
$1,000.01 to $2,000	18	18	30	23	27	17	17	24	22
$2,000.01 to $5,000	15	25	26	27	22	18	26	26	27
$5,000.01 to $10,000	18	22	16	14	13	11	11	14	13
$10,000.01 to $20,000	17	14	16	18	15	15	14	12	12
Greater than $20,000	14	23	16	22	14	12	24	15	14
Total	218	246	244	248	246	210	222	219	208

Annual Ex-Vessel Value	2003	2004	2005	2006	2007	2008	2009	2010	2011
Less than $100	72	74	70	57	68	67	70	65	62
$100 to $500	35	41	31	38	33	41	47	40	35
$500.01 to $1,000	25	19	16	16	13	14	12	15	16
$1,000.01 to $2,000	25	20	21	19	20	19	14	22	19
$2,000.01 to $5,000	19	22	20	19	25	16	18	12	15
$5,000.01 to $10,000	13	13	14	16	8	16	13	10	8
$10,000.01 to $20,000	11	11	5	8	9	8	7	11	12
Greater than $20,000	11	7	12	12	8	8	9	15	14
Total	211	207	189	185	184	189	190	190	181

Approximately 60% of all striped mullet are landed in the fall months during roe season. In past years, a few large processors bought large amounts of these roe striped mullet and took them as fresh whole fish to Florida for processing. Once at the processor, the roe is extracted from the fish where it is primarily destined for Asian markets to be sold for food and medicinal purposes. The remaining fish are filleted, frozen, and often shipped overseas, primarily to Egypt and other African countries for human consumption. Striped mullet roe is also a local delicacy in some parts of coastal North Carolina where it is dried to preserve it for later consumption. Seafood markets in areas where striped mullet is landed frequently sell the meat and roe to local customers. During the non-roe season, striped mullet is sold as bait or fresh for human consumption.

8.2.4 Economic Impact of Commercial Fishing

In 2011, striped mullet landings accounted for 1.4% of the total value of seafood landed in North Carolina and 3.2% of the total value of finfish landed in North Carolina. The number of participants in the fishery by year and the nominal value of their annual landings for 1994 through 2011 are shown in Table 8.4. Participation mostly decreased through the time series. It is likely that lower dockside prices paid to fishermen accounted for the decreasing number of annual participants in the fishery. While varying from year to year, approximately half of the participants were paid less than $100 for the striped mullet that they landed in each of the years from 1994 to 2011. Three to seven percent of the fishermen received more than $5,000 from the fishery in each of these years.

Table 8.4. Number of participants in the striped mullet fishery by year and nominal value (unadjusted for inflation) of annual striped mullet landings: 1994–2011.

Annual Ex-Vessel Value	1994	1995	1996	1997	1998	1999	2000	2001	2002
<$100	787	723	735	656	623	520	610	539	525
$100–$500	273	298	311	305	276	216	240	225	217
$500.01–$1,000	96	124	142	136	82	76	108	92	81
$1,000.01–$2,000	98	109	102	108	84	72	98	72	78
$2,000.01–$5,000	70	111	94	117	72	75	89	65	73
$5,000.01–$10,000	27	52	27	57	30	17	39	49	28
$10,000.01–$20,000	10	26	9	25	12	9	29	23	22
>$20,000	5	14	3	7	4	5	11	4	8
Total	1,366	1,457	1,423	1,411	1,183	990	1,224	1,069	1,032

Annual Ex-Vessel Value	2003	2004	2005	2006	2007	2008	2009	2010	2011
<$100	469	406	450	401	432	489	523	453	399
$100–$500	197	183	170	156	185	155	163	206	183
$500.01–$1,000	85	68	57	56	61	47	62	74	60
$1,000.01–$2,000	77	51	45	76	51	55	46	54	65
$2,000.01–$5,000	54	60	52	52	57	53	38	59	72
$5,000.01–$10,000	26	13	30	34	21	24	26	28	29
$10,000.01–$20,000	*	10	11	14	5	7	7	15	14
>$20,000	*	5	4	6	5	3	5	7	5
Total	920	796	819	795	817	833	870	896	827

*denotes confidential data

The expenditures and income within the commercial and recreational fishing industry in North Carolina produce ripple effects in the state's economy. Each dollar earned and spent within the industry generates a more vigorous economy by stimulating additional activity in other industries that fosters jobs, income, and economic output. These impacts are calculated using the NCDMF economic impact model for commercial and recreational fishing in North Carolina and IMPLAN economic modeling software. This software uses an input-output model to estimate economic impacts as dollars are spent and re-spent in the state economy.

In 2011, commercial fishing for striped mullet in North Carolina supported an estimated 49 full-time and part-time jobs, $696,000 in income, and approximately $1,602,000 in output impacts to the state's economy (Table 8.5). This estimate is limited and must be viewed as conservatively low, as it does not include wholesale (seafood dealers), retail, and foodservice sectors due to lack of economic data for those sectors. Efforts are currently under way to incorporate national level supply chain information with the state level data utilized by the NCDMF commercial fishing economic impact model to better estimate the full economic impact of the North Carolina commercial fishing industry.

Table 8.5. Economic impacts of commercial striped mullet fishing in North Carolina in 2011.

Participants[1]	Ex-Vessel Value[1]	Jobs[2,3]	Income Impacts (in thousands)[3]	Output Impacts (in thousands)[3]
827	$1,014,981	49	$696.10	$1,601.90

[1]As reported by the NCTTP.
[2]Represents both full-time and part-time jobs.
[3]Economic impacts calculated using the NCDMF commercial fishing economic impact model and IMPLAN economic impact modeling software.

The NCDMF has been conducting in-depth socioeconomic interviews with commercial fishermen throughout the North Carolina coast since 2001. More than 1,000 fishermen have been interviewed to date. Results to date show 94 fishermen who were interviewed identified themselves as striped mullet fishermen. Seventy one percent of these fishermen considered themselves full-time fishermen. On average, these fishermen earned 75% of their personal income from commercial fishing activities.

Like most of North Carolina's full and part time commercial fishermen, nearly all of the respondents also targeted other species at other times during the year. Most respondents indicated fishing a gill net (97%). Other commercial gears commonly fished during the year included crab pots (42%), peeler pots (13%), and shrimp trawls (14%). Other species commonly targeted by striped mullet fishermen included flounder (67%), blue crabs (45%), spot (40%), spotted sea trout (26%), white perch (24%), shrimp (22%), striped bass (22%), shad (19%), clams (16%), oysters (16%), catfish (13%), and croaker (12%). Thirteen percent stated they also have a valid North Carolina fish dealer's license.

Approximately 45% of the fishermen interviewed indicated that they fish all year long. Of those who did not fish all year, fishing activity was highest from April through November. The peak fishing participation months for these fishermen were June, September, and October.

The average striped mullet fishermen (including full and part time) reported that they earned just under $15,000 profit annually from all of their commercial fishing activities (all species). They averaged $122 for routine fishing trip costs (fuel, ice, groceries, etc.) and nearly $10,900 in annual business costs (new equipment, repairs, business loan payments, etc.). These fishermen were asked about the business issues that they were facing. The most commonly cited important issues were low prices for seafood, competition from imported seafood, fuel prices, losing working waterfronts, and coastal development. Issues commonly cited as not important or not greatly affecting their fishing business included overfishing, closed seasons, size limits, federal regulations, inability to predict the future of the industry, and weather.

8.3 RECREATIONAL FISHING

8.3.1 Recreational Fishing Activity

Recreational fishermen commonly target striped mullet for bait and personal consumption. Information on recreational fishing traditionally used for assessing the catch of several recreational species through the Marine Recreational Information Program (MRIP) is not utilized for striped mullet due to concerns over high error estimates associated with the data. The NCDMF recently began conducting a survey of recreational fishermen who use a cast net to catch white and striped mullet. The results of this survey are preliminary and not available at the time of this writing.

In 2002, the NCDMF began interviewing recreational fishermen who purchased a Recreational Commercial Gear License (RCGL) that allows them to use limited amounts of commercial gear. These fishermen are prohibited from selling their catch as it is intended solely for personal use. Specific monthly or bimonthly harvest data were collected from 2002 to 2008. Socioeconomic surveys of RCGL holders were conducted in 2001, 2004, and 2007.

Over the survey time period, the months from June through October accounted for over 75% of the total striped mullet harvest by RCGL holders. Gill nets made up the vast majority of landings from RCGL fishermen targeting striped mullet. The RCGL holder surveys did not specifically determine the final disposition of the striped mullet landed by these anglers. However, it is presumed they use the fish primarily as bait for other species or for harvesting consumption of their meat and roe. Drying striped mullet and their roe is a common practice of some coastal North Carolina residents.

8.3.2 Economic Impact of the Recreational Fishery

Table 8.6 provides expenditure information of the RCGL striped mullet fishery in 2007. Those who made overnight trips as opposed to those who made day trips separate the data. Expenditures by those who made overnight trips tended to be greater when compared to day trips. An average overnight trip lasted approximately four days and resulted in total expenditures of $234.63 while day trips incurred average expenditures of $30.30.

It is estimated that RCGL fishermen took 4,893 trips in 2007. Of these trip estimates, 3,022 were day trips and 1,871 were overnight trips. The total estimated expenditures of RCGL trips landing striped mullet was approximately $420,000. Lodging expenses were left out in this expenditure estimate as there was a very low positive response rate for lodging. On these trips, striped mullet made up approximately 33% of the landings. Applying this ratio to the overall expenses, it is estimated that $138,586 can be attributed to striped mullet. The total combined output impact of all RCGL trips that can be attributed to striped mullet in 2007 was approximately $206,500.

Table 8.6. Expenditures of RCGL fishing trips for striped mullet in 2007.

	Overnight trips	Day trips
# of trips taken	1,871	3,022
Avg. # of miles traveled	140.3	37.6
Avg. # of nights	3.73	N/A
Avg. # of people who fished on the trip	2.1	1.8
Avg. cost of lodging/night	$59.12	N/A
Avg. cost of ice	$10.56	$2.06
Avg. cost of food/trip	$95.59	$8.60
Avg. cost of fuel & oil/trip	$69.36	$19.64

8.4 DEMOGRAPHIC CHARACTERISTICS

8.4.1 Commercial Fishermen

Demographic data were collected from 93 of the 94 commercial fishermen who reported targeting striped mullet. Table 8.7 shows a summary of the demographic characteristics of the striped mullet fishermen included in this analysis. Nearly all of the striped mullet fishermen were white males. The average age was 49 years old and fishermen had an average of 28 years of fishing experience. The typical striped mullet fisherman was married and had a high school education. The majority of fishermen had household incomes of more than $30,000.

Respondents had lived in their communities for an average of 32 years and had commercial fishermen in their family for an average of four generations. Most felt that commercial fishing was historically and economically important in their communities. The majority felt that they had to work harder to land the same amount of fish as compared to previous years. Fifty-eight percent of respondents expected to still be commercial fishing in 10 years.

Table 8.7. Demographic characteristics of striped mullet fishermen who participated in the NCDMF commercial fisherman socioeconomic survey.

Demographic	Category Values	Sample Size	Average or percent
Years fishing		93	28
Age		93	49.2
Gender		93	
	Male		98%
	Female		2%
Ethnic Group		93	
	White		96%
	Hispanic		2%
	Black		2%
Education		93	
	Less than High School		32%
	High School graduate		43%
	Some College		17%
	College graduate		8%
Marital Status		93	
	Married		80%
	Divorced		7%
	Separated		5%
	Never married		5%
	Widowed		3%
Total Household Income		93	
	Less than $15,000		11%
	$15,001–$30,000		33%
	$30,001–$50,000		19%
	$50,001–$75,000		16%
	$75,001–$100,000		8%
	Refused to answer		13%

8.4.2 Recreational Fishermen

Data were collected from 204 individuals who said they had targeted striped mullet on at least one RCGL fishing trip in 2007. The average RCGL holder who targeted striped mullet was approximately 56 years old and had lived in North Carolina for over 49 years (Table 8.8). The vast majority were males. Most of these fishermen had some college education and had total household incomes of greater than $30,000 per year.

Table 8.8. Demographic data of RCGL holders who targeted striped mullet in 2007.

Demographic	Category Values	Sample Size	Average or Percent
Born in NC		204	87%
Years Lived in NC		156	49.2
Age		204	55.9
	<16 years		2%
	17 to 25		3%
	26 to 40		9%
	41 to 60		56%
	>60 years		40%
Marital Status		203	
	Married		75%
	Divorced		9%
	Widowed		6%
	Separated		2%
	Never Married		7%
Ethnic Group		204	
	Hispanic/Latino		0%
	Caucasian/White		97.5%
	African-American/Black		0.5%
	Native American		2%
Gender		203	
	Male		95%
	Female		5%
Education		199	
	Less than High School		11%
	High School Graduate		32%
	Some College		33%
	College Graduate		24%
Total Household Income		184	
	Less than $5,000		2%
	$5,000–$15,000		7%
	$15,001–$30,000		11%
	$30,001–$50,000		27%
	$50,001–$75,000		23%
	$75,001–$100,000		15%
	More than $100,000		14%

9.0 ENVIRONMENTAL FACTORS

9.1 HABITAT

As described in the life history section (5.1), striped mullet utilize a variety of habitats with variations in habitat preference due to location, season, and ontogenetic stage (Cardona 2000; Pattillo et al. 1999; Able and Fahay 1998). Although primarily estuarine, striped mullet use habitats throughout the estuaries and the coastal ocean. Striped mullet are found in most habitats identified by the North Carolina Coastal Habitat Protection Plan (CHPP) including: water column, wetlands, submerged aquatic vegetation (SAV), soft bottom, and shell bottom (Deaton et al. 2010). Each of these habitats is part of a larger habitat mosaic, which plays a vital role in the overall productivity and health of the coastal ecosystem. The CHPP focuses on the overall fish habitat and threats to the habitat while this FMP describes striped mullet habitat and its threats or needs for the various life stages of striped mullet. Although striped mullet are found in all of these habitats, the usage varies by habitat. Additionally, these habitats provide the appropriate physiochemical and biological conditions necessary to maintain and enhance the striped mullet population.

Striped mullet habitat use varies greatly based on life history stages, seasons, and location (Cardona 2000; Pattillo et al. 1999; Able and Fahay 1998). Salinity seems to play a major role in habitat use and distribution of both adult and juvenile mullet (Cardona 2000). They are a highly euryhaline fish and live in a wide range of salinities, based on size and maturity (Cardona 2000; Pattillo et al.1999). The availability of suitable food may also influence habitat use by striped mullet (Moore 1974). They are found in almost all shallow marine and estuarine habitats including beaches, tidal flats, lagoons, bays, rivers, channels, marshes, and grass beds (Nordlie 2000; Pattillo et al.1999; Moore 1974). 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. Once in inshore waters, they prefer depths of 3 meters or less.

Suitable and adequate habitat is a critical element in the ecology and productivity of estuarine systems. Degradation or improvement in one aspect of the habitat may have a corresponding impact on the water quality. Maintenance and improvement of suitable estuarine habitat and water quality are probably the most important factors in providing sustainable striped mullet stocks. Information on the ecological value of each of these habitats to striped mullet and their threats are provided below. For additional information on the environmental factors discussed in this section, please refer to the North Carolina Coastal Habitat Protection Plan (CHPP; Deaton et al. 2010).

9.1.1 Water Column

Water column habitat is defined as "the water covering a submerged surface and its physical, chemical, and biological characteristics" (Deaton et al. 2010). Striped mullet spawn in warm saline waters offshore then move to cooler, less saline coastal waters (McDonough et al. 2003; McDonough and Wenner 2003; Powles 1981). Indirect evidence suggests that striped mullet spawn offshore in the continental shelf waters of the South Atlantic Bight from the 36 m line into the Gulf Stream. Spawning begins when water temperatures begin to drop in the fall (Able and Fahay 1998). Larvae and small juveniles have been collected over the outer half of the shelf during the winter months. Fahay (1975) captured juveniles near the Gulf Stream off the North Carolina coast in January. However, these juveniles were probably subject to advection currents, moving them north into Middle Atlantic Bight waters. Powles (1981) found an inverse relationship of larval length to distance from shore. Pelagic juveniles begin shoreward movement via Ekman currents once they are between 20–25 mm in length. Inlets are a critical component of the water column habitat for striped mullet, once nearshore, larvae must pass through inlets to reach estuarine nursery areas. Peters et al. (1995) documented striped mullet larvae in Beaufort Inlet between October and April, but in relatively low numbers compared to other species. NOAA has performed a yearly plankton bridge net survey at Beaufort Inlet. Although this survey is not dominated by striped mullet, they are ranked tenth highest in cumulative number of larvae (1987–2004; Taylor et al. 2009). Terminal groins can potentially threaten successful recruitment since they can obstruct inlet passage (Blanton et al. 1999; Churchill et al. 1997; Kapolnai et al. 1996). Threats to water quality are further defined in the water quality degradation section.

9.1.2 Soft Bottom

Soft bottom habitat is defined as “unconsolidated, unvegetated sediment that occurs in freshwater, estuarine, and marine systems” (Deaton et al. 2010). The soft bottom habitat is separated into freshwater, estuarine, and marine habitats due to differing geomorphology, sediment type, water depth, hydrography, and/or salinity regimes (Deaton et al. 2010). Underlying geology, basin morphology, and physical processes influence the physical and chemical makeup of the soft bottom habitat, which may influence striped mullet distribution. In general, coarse sands are concentrated along high-energy and eroding shorelines, while fine muds are concentrated along low-energy shorelines and deep water basins (Riggs 1996; Wells 1989). Soft bottom habitat is used by striped mullet as foraging grounds and is necessary as a corridor (Deaton et al. 2010).

Soft bottom plays an important role in the functionality of estuarine systems, acting as both a source and sink for nutrients, chemicals, and microbes. Natural and human-induced nutrients and toxins are trapped and reprocessed in soft bottom areas through intense biogeochemical processes. The fate of these materials depends strongly on freshwater discharge, density stratification, and salt wedge formation (Paerl et al. 1998; Matson and Brinson 1990; Matson and Brinson 1985). In North Carolina, an abundance of nutrients and organic matter are stored in soft bottoms. These materials are processed both within the sediments and from the sediments into the overlying water column through microbial processes. The estuarine soft bottom provides striped mullet nursery area habitat, food, and refuge from large predators. Structure found in soft bottom may also play a role as habitat for striped mullet. NCDMF field staff that sample for striped mullet in rivers and creeks find schools around structure such as fallen trees.

Soft bottom also plays an important role in the life cycle of striped mullet. Soft bottom habitat is a key source of food for striped mullet throughout its life cycle. During the larval stage, striped mullet are planktonic, macrophagous carnivores feeding on zooplankton like diatoms, copepods, and mosquito larvae until they reach sizes between 20 to 30 mm. At this point their feeding ecology changes to benthic, microphagous omnivores, eating organic detritus, filamentous algae, plant tissue, diatoms, and benthic microorganisms (Pattillo et al. 1999; Collins 1985; Blaber and Whitfield 1977). Soft bottom sediments produce benthic microalgae, microscopic photosynthetic algae, on their surfaces, which striped mullet forage on. These benthic microalgae, primarily composed of benthic diatoms and blue green algae, are the base of the food chain (Miller et al. 1986; Peterson and Peterson 1979). Benthic microalgae support small benthic invertebrates that live in the sediment. Detrital matter from other habitats such as tidal marsh and SAV drifts away and settles on intertidal flats, shorelines, and shallow soft bottoms, where it can be broken down and consumed by striped mullet (Peterson and Peterson 1979). The organic matter produced or imported onto soft bottom sediments can also be re-suspended under certain environmental conditions, where it becomes available to larval striped mullet and other organisms in the water column. Fishermen have stated that they search for mullet schools around piers and docks and often capture fish adjacent to these structures over soft bottom.

Juvenile striped mullet use ocean waters adjacent to sandy beaches and in the surf zone in the Gulf States and along North Carolina's coast (Ross and Lancaster 2002). Perry and Carter (1979) sampled three sand and broken shell beach stations located on the southwest coast of Louisiana over a period of six and a half years using a bag seine. During this study, juvenile and adult striped mullet were the third most abundant species taken, with the majority taken in January. Striped mullet are also found in beach habitats as well as estuarine habitats in Texas (Moore 1974). In Japan, the surf zone of sandy beaches is considered a transient habitat for striped mullet, orienting fish larvae to the estuaries (Kinoshita et al. 1988; Fujita et al. 2002). Threats to ocean beaches and surf zone include beach nourishment and storm water outfalls.

9.1.3 Submerged Aquatic Vegetation

Submerged aquatic vegetation (SAV) is a fish habitat dominated by one or more species of underwater vascular plants. The MFC defines SAV habitat as submerged lands that:

"(i) are vegetated with one or more species of submerged aquatic vegetation including bushy pondweed or southern naiad (*Najas guadalupensis*), coontail (*Ceratophyllum demersum*), eelgrass (*Zostera marina*), horned pondweed (*Zannichellia palustris*), naiads (*Najas* spp.), redhead grass (*Potamogeton perfoliatus*), sago pondweed (*Stuckenia pectinata*, formerly *Potamogeton pectinatus*), shoal grass (*Halodule wrightii*), slender pondweed (*Potamogeton pusillus*), water star grass (*Heteranthera dubia*), water starwort (*Callitriche heterophylla*), waterweeds (*Elodea* spp.), widgeon grass (*Ruppia maritima*) and wild celery (*Vallisneria americana*). These areas may be identified by the presence of above-ground leaves, below-ground rhizomes, or reproductive structures associated with one or more SAV species and include the sediment within these areas; or

(ii) have been vegetated by one or more of the species identified in Sub-item (4)(i)(i) of this Rule within the past 10 annual growing seasons and that meet the average physical requirements of water depth (six feet or less), average light availability (secchi depth of one foot or more), and limited wave exposure that characterize the environment suitable for growth of SAV. The past presence of SAV may be demonstrated by aerial photography, SAV survey, map, or other documentation. An extension of the past 10 annual growing season's criteria may be considered when average environmental conditions are altered by drought, rainfall, or storm force winds.

This habitat occurs in both subtidal and intertidal zones and may occur in isolated patches or cover extensive areas. In defining SAV habitat, the Marine Fisheries Commission recognizes the Aquatic Weed Control Act of 1991 (G.S. 113A-220 et. seq.) and does not intend the submerged aquatic vegetation definition, or rules 15A NCAC 03K .0304, .0404 and 03I .0101, to apply to or conflict with the non-development control activities authorized by that Act. [2014 MFC rule 15A NCAC 03I .0101 (4)(i)]."

The spatial structure of SAV habitat can be quite variable, ranging from small isolated patches of plants less than a meter in diameter to continuous meadows covering several acres (Deaton et al. 2010). By nature, the extent of SAV coverage tends to fluctuate on the scale of days to decades, depending on species and physical conditions (Fonseca et al. 1998). In addition, SAV abundance, biomass, and species composition in North Carolina waters varies seasonally with changes in temperature and light conditions (SAFMC 1998; Dawes et al. 1995). Due to these changes, the MFC and the North Carolina Coastal Resources Commission (CRC) refined the definition of SAV to encompass both the seasonal and spatial complexity of this habitat as defined above. Under current MFC rule, SAV habitat is designated as a Fish Habitat Area [MFC rule 15A NCAC 03I .0101 (4) (i)].

In addition to their importance to ecosystem function, SAV also provides crucial structural habitat for fishes and invertebrates. The three dimensional structure of SAV affords a surface for epiphytic algae and animals to attach to, as well as a safe area for refuge and foraging for a number of species of fishes and invertebrates (SAFMC 1998). Additionally, SAV coverage provides a safe corridor for movement of fishes and invertebrates between adjacent foraging habitats (Micheli and Peterson 1999; Irlandi and Crawford 1997). SAV has also been shown to harbor higher or equivalent densities, growth, and survival of nekton to adjacent salt marshes, and higher densities, growth, and survival of nekton as compared to macroalgae, oyster reefs, or soft bottom habitats (Minello et al. 2003; Minello 1999).

SAV provides ecological services that maintain and enhance the overall functionality of estuaries and coastal rivers. The above- and below-ground structures of SAV modify wave energy regimes, stabilize sediments and adjacent shorelines, and cycle nutrients within the system (SAFMC 1998; Thayer et al. 1984). These processes generally increase water clarity, decrease the frequency of nuisance algal blooms, and promote conditions favorable for growth and expansion of SAV (Thayer et al. 1984). Furthermore, because of their high rate of primary production, SAV provides an important source of organic matter. The large quantities of organic material produced by SAV support the base of a complex food web necessary for the maintenance of fish and invertebrate populations (Thayer et al. 1984).

Striped mullet likely use SAV as nursery, forage, and refuge habitats (Deaton et al. 2010). Work in Florida Bay indicates that striped mullet move on and off seagrass-covered mud banks at dawn and dusk with greatest capture at low tide. At high tide, the fish would occupy the top of the bank and move toward the edge as the tide receded, leaving the bank only at the lowest water levels (<10cm) then returning as water level begins to rise (Sogard et al. 1989). Mullet will also feed on epiphytes and epifauna from seagrasses and other structures (Odum 1968; Collins 1985). There is very little information about the use of SAV by striped mullet in North Carolina. However, anecdotal observations from independent sampling by NCDMF staff might indicate habitat preference for seagrass. Grass beds are threatened by physical destruction from bottom disturbing fishing gear, dredging, and damage from boat use, as well as degradation of water quality.

9.1.4 Shell Bottom

Shell bottom is defined in the CHPP as "estuarine intertidal or subtidal bottom composed of surface shell concentrations of living or dead oysters (*Crassostrea virginica*), hard clams (*Merceneria merceneria*), and other shellfish" (Deaton et al. 2010). Common terms to describe shell bottom in North Carolina include "oyster beds", "oyster rocks", "oyster reefs", "oyster bars", and "shell hash"." Shell hash can be described as a mixture of sediments with unconsolidated broken shell (oyster, clam and/or other shellfish). In North Carolina, shell bottom can be either intertidal or subtidal, and can consist of fringing or patch reefs (ASMFC 2007). Several reports have documented striped mullet foraging around oyster reefs (Bliss et al. 2010; Deaton et al. 2010).

9.1.5 Hard Bottom

Hard bottom habitat is defined in the CHPP as "exposed areas of rock or consolidated sediments, usually colonized by a thin veneer of live or dead biota, and generally located in the ocean rather than in the estuarine system" (Deaton et al. 2010). At this time, the use of hard bottom by striped mullet is not documented in scientific literature.

9.1.6 Wetlands

Wetlands are defined as "areas that are inundated or saturated by an accumulation of surface or groundwater at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions" (federal regulations [40 CFR 230.3(t)]; EMC rules [15A NCAC 2B .0202(71)]; Deaton et al. 2010). Wetlands are considered one of the most biologically productive ecosystems on Earth (Teal 1962). The primary productivity associated with wetlands is converted into secondary production of fishes and invertebrates through detrital and microalgal pathways (Peterson and Howarth 1987). In coastal regions, wetlands typically are found in both estuarine and freshwater areas. Estuarine wetlands are tidal in nature and generally occur in low energy environments of bays, sounds, and rivers in polyhaline and mesohaline waters. Freshwater wetlands, including freshwater marshes, bottomland hardwood forests, and swamp forests, generally occur in low-salinity to freshwater areas of creeks, streams, and rivers. Striped mullet use wetlands for foraging, refuge, and as a nursery habitat (Deaton et al. 2010).

The high primary productivity that occurs in wetlands and the transfer of detritus into the estuary from wetlands provides the base of the food chain supporting many marine organisms including the striped mullet. Overall, North Carolina has approximately 212,800 acres of marsh habitat and is second to South Carolina in total acreage in the South Atlantic. The North Carolina Division of Water Quality (now North Carolina Division of Water Resources) estimated wetland losses but concluded that approximately 66% of North Carolina's original wetland extent remains and 83% of its original salt marsh, bottomland hardwood, and swamp forests still remain (NCDWQ 2000a). In North Carolina, these salt marsh habitats are important nursery areas for striped mullet, as well as many other fish and invertebrate species (Weinstein 1979).

The striped mullet is considered a transient estuarine fish because they spend a portion of their life cycle (juvenile stage) in estuarine rivers and marshes (Peterson and Turner 1994; Kneib and Wagner 1994). Work in Texas by Rozas and Zimmerman (2000) found that striped mullet preferred low elevation marsh edges to high elevation marsh. Kneib and Wagner (1994) found that striped mullet abundance was highest in the low marsh during incoming and slack high tide. Allen et al. (2007) showed similar results and suggested striped mullet were either attracted to slower flows or actively avoided faster flows. Peterson and Turner (1994) showed that striped mullet used the marsh edge surface (<3 m from creek) even though juvenile mullet were observed in the interior of marshes during deep flood tides. While the majority of research shows striped mullet prefer marsh edge, other studies have indicated that striped mullet also use interior marsh habitat (Peterson and Turner 1994). Striped mullet have been observed foraging on these flooded marshes (Allen et al. 2007) YOY striped mullet at their highest abundance in May and the lowest abundance in September in tidal creeks (Bretsch and Allen 2006). Within these creeks and wetlands Kneib and Wagner (1994) found that striped mullet preferred *Scirpus alterniflora* over *Scirpus spp.* marsh found in similar elevations.

Wetlands are threatened by many human activities, including dredging for marinas and channels, filling for development, ditching and draining for agriculture, silviculture, channelization, and shoreline stabilization.

9.1.7 Spawning Habitat

The spawning location of striped mullet is largely based in theory and indirect evidence. The concentrated abundance of eggs and larvae in offshore collections support offshore waters as spawning grounds (Broadhead 1953; Anderson 1958; Arnold and Thompson 1958; Finucane et al. 1978; Martin and Drewry 1978; Powles 1981; Ditty and Shaw 1996; Able and Fahay 1998). Anecdotal offshore observations of spawning behaviors and large, seaward migrations of spawning adults also indicate offshore spawning (Jacot 1920; Arnold and Thompson 1958). Anderson (1958) observed striped mullet larvae from lower Florida to North Carolina (from the 20 fathom line extending into the Gulf Stream). This supports other suggestions that striped mullet spawn offshore in and around the edge of the South Atlantic Bight (SAB; Collins and Stender 1989). However, in addition to offshore waters, spawning likely also occurs in nearshore coastal waters, lower estuarine areas and sounds (albeit less frequently), and perhaps in freshwater in extremely rare circumstances (Jacot 1920; Breder 1940; Johnson and McClendon 1969; Shireman 1975; Martin and Drewry 1978; Collins and Stender 1989; Bettaso and Young 1999). It is believed that the spawning migration for striped mullet is cued by environmental conditions. These cues include northeasterly winds, and cold strong fronts with dropping barometric pressure. These factors may vary due to unseasonably warm temperatures and hurricanes (Thompson et al. 1991; Mahmoudi 1993).

9.1.8 Water Quality

Parameters which are important for defining the quality of habitats used by striped mullet include dissolved oxygen, temperature, and salinity. These parameters are discussed in more detail in the life history physio-chemical tolerances and preferences section (5.1.2) of this FMP.

<u>9.1.8.1 Salinity</u>

The striped mullet is a euryhaline species (Hotos and Vlahos 1998; Collins 1985a). Striped mullet live in salinities ranging from 0.0 ppt to 75.0 ppt, but prefer a median range of 20.0 ppt to 26.0 ppt (Pattillo et al. 1999; Leard et al. 1995; Collins 1985). Size plays a role in the osmoregulation capabilities of the mullet. Young-of-the-year striped mullet can fully osmoregulate by the time they reach a standard length of 40–69 mm (1.6–2.7-in), at an age of approximately 7 to 8 months old, and can tolerate freshwater to full seawater salinities (Pattillo et al.1999; Collins 1985).

<u>9.1.8.2 Temperature</u>

As with salinities, striped mullet are able to live in a wide range of temperatures from 2.0°C to 41.0°C. In the laboratory, smaller striped mullet (< 50 mm) generally preferred higher water temperatures, 30.0 to 32.4°C, than larger fish, 19.5 to 29.0°C (Major 1977; Collins 1985a). Peak growth of juveniles of mixed *Mugil* spp. (striped mullet and white mullet) occurred at greater than 25.0°C in laboratory experiments (Peterson et al. 2000).

9.1.8.3 Dissolved Oxygen

Striped mullet have the ability to tolerate low levels of dissolved oxygen (DO). They have enhanced hemoglobin concentrations that allow them to meet seasonally heavy oxygen demands during warm summer months and the autumn spawning period. They also have the ability to capture air in the upper posterior portion of the pharynx by jumping, rolling, or holding the head above water and moving it into the upper pharyngeal chamber to supplement their oxygen supply for respiration (Pattillo 1999).

9.2 THREATS

9.2.1 Water Quality Degradation

9.2.1.1 Human Population Growth

Good water quality in North Carolina's estuaries is essential to the striped mullet population because of its estuarine dependent lifestyle. Striped mullet spend the majority of their lifetime in estuarine waters with the exception of a brief larval stage in offshore waters as well as yearly fall migrations to the ocean to spawn. There have been significant human population increases over the past 20 years in several watershed basins that drain into our estuaries such as in the White Oak River Basin (NCDWQ 2001), Lumber River Basin (NCDWQ 1999), and Neuse River Basin (NCDWQ 2002). This increase in population, especially in the coastal regions of these basins causes generation of increased storm water runoff, addition of new septic tanks, need for more wastewater treatment capacity, need for new and expanded water supply sources, and the location of new marinas (NCDWQ 2001). These population impacts on water quality can vary dependent on development locations, land use, and topography of the river basin (Deaton et al. 2010).

9.2.1.2 Discharges

There are two primary sources of pollution, nonpoint and point source. Point source pollution is defined as pollution from a defined point such as a pipe while nonpoint source pollution is pollution from a non-defined point of entry such as storm water runoff. Both source types contribute to oxygen consuming wastes, nutrients, sediment, as well as toxins, pesticides, and heavy metals. Point source dischargers (municipal and industrial wastewater treatment plants, small domestic wastewater treatment systems for schools, commercial offices, residential subdivisions, and individual homes) in North Carolina must apply for and obtain a National Pollutant Discharge Elimination System (NPDES) permit from the North Carolina Division of Water Resources (NCDWR; NCDWQ 2000b).

Sediment and nutrients are the major pollution substances associated with nonpoint source pollution but fecal coliform bacteria, heavy metals, oil, and grease as well as any substance that may be washed from the ground or removed from the atmosphere also results from nonpoint sources. There are several activities that are associated with nonpoint source pollution. These include land clearing, plowing, drainage ditch construction, pesticide, and fertilizer use, as well as concentrated livestock operations (NCDWQ 2000b).

9.2.1.3 Nutrients

Nitrogen and phosphorus (components of fertilizers) and animal and human wastes are referred to as nutrients. These elements, in small quantities, are beneficial to aquatic life but can be detrimental in large quantities. In excessive amounts, nutrient loading leads to habitat degradation, toxicity, hypoxia, anoxia, algal blooms, fish kills, and loss of biodiversity (Paerl 2002). These are all signs of cultural eutrophication and water quality degradation (Paerl 2002; NCDWQ 2000a). Cultural eutrophication is the rapid process of the accumulation of nutrients and sediments caused by man (NCDWQ 2000a). Urban runoff, crop agriculture, animal operations, erosion, and industrial expansion in the coastal regions have led to the rise of nitrogen loading in our estuaries.

Atmospheric depositions of nitrogen (AD-N) used to be considered a minor source of nitrogen input. However, recent research has shown this nitrogen input to be a highly significant source of externally supplied nitrogen entering the estuaries (Paerl 2002). There also may be a link between acidic deposition (acid rain) and eutrophication of estuaries (Driscoll et al. 2003). Sources of both AD-N and acid rain are mostly from burning fossil fuels and by agricultural activities (Driscoll et al. 2003; Pearl 2002).

Dinoflagellate algal blooms have been known to occur from nutrient over enrichment and can be detrimental to marine life since some may be toxic. Fish sampling by NCDWQ (now NCDWR), NCDMF, and North Carolina State University (NCSU) was initiated in 1998 in the Neuse, Tar/Pamlico, and New rivers to determine the occurrence of and species impacted by these toxic dinoflagellates including *Pfisteria piscicida*. The predominant fish affected with lesions was the Atlantic menhaden (*Brevoortia tyrannus*). Less than 0.1% of striped mullet sampled showed any sign of lesions.

The first record of the toxic dinoflagellate *Gymnodinium breve* bloomed in North Carolina in 1987. Larval recruitment of striped mullet was low during the bloom but increased significantly later in the season, suggesting that there were immediate effects (Warlen et al. 1998). Another dinoflagellate *Gymnodinium pulchellum* was responsible for fish kills in the Indian River, Florida in October 1996 and also had an effect on striped mullet (Steidinger et al. 1998).

Anthropogenic alterations have been shown to cause declines in striped mullet populations in some regions. For example, in a lake in Egypt, salinities have declined and nutrient load has increased from agricultural drain water inflows, reduced evaporation due to reduction of lake areas, and increased sewage outfall from Cairo. These impacts of degrading water quality caused a declined in the mullet fishery from 65% of the total catch during the 1920s to only 2.2% during the early 1980s (Khalil 1997).

9.2.1.4 Oxygen Depletion

Oxygen depletion, or anoxia (no oxygen) and hypoxia (low oxygen), can occur naturally from stratification of the water column caused by wind, temperature, and salinity conditions. However, nutrient over enrichment also leads to anoxia and/or hypoxia. Increased runoff and organic loading from heavy rainfall will cause hypoxic and anoxic events. Algal blooms mentioned above remove DO from the water at night (no photosynthesis). When these blooms die, bacteria decomposing the dead plant material remove oxygen. Although algal blooms occur naturally under undisturbed conditions, additional nutrient inputs caused by man increase their frequency and intensity.

Several hurricanes occurring in September and October of 1999 significantly impacted water quality in North Carolina. Because of the heavy rainfall in short time periods during these storms, record flooding caused an input of at least half of the typical nitrogen load, as well as twice the amount of carbon input into Pamlico Sound through the Neuse River. This heavy pulse of nutrients and freshwater runoff caused bottom water hypoxia, an increase in algal biomass for a long period of time, and the displacement of many marine organisms as well as an increase in the occurrence of fish disease (Paerl et al. 2001).

Fish can move from hypoxic areas and seek more oxygenated waters. Any consequences suffered by fish because of low DO depend on their ability to detect and avoid low DO areas. Wannamaker and Rice (2000) found that white mullet could detect and respond to hypoxic events and avoid areas of 2.0 mg O_2/liter or less. Mullet appeared to be more sensitive to moderate hypoxia than both spot and pinfish. Mullet also showed higher ventilation rates. These high ventilation rates demonstrate that hypoxia may cause greater respiratory distress and may explain why they avoid hypoxic zones.

One commonly observed effect of anoxia and hypoxia are fish kills. Low oxygen is considered the leading cause of fish kill events in 22 coastal states (Lowe et al. 1991). There were 16 fish kill events in 2012, reported to NCDWQ, of which 9 were estuarine (NCDWQ 2012). Two of these events recorded the presence of mullet. Poor dissolved oxygen and algal blooms were cited as the suspect cause by NCDWQ. Fish kills affecting striped mullet are not unique to North Carolina. In Texas, approximately 16% of the 383 million fish found dead during fish kills (from 1951 to 2006) were striped mullet (Thronson and Quigg 2008).

9.2.1.5 Turbidity and Sedimentation

Other natural processes that occur in our estuaries are erosion and sedimentation. Both processes occur when waves and currents erode shorelines and transport sediment into the waters, causing short- and long-term changes along the coast. However, this process, like eutrophication, has been accelerated because of man's activities. Sediment loading usually results from nonpoint sources such as building and road construction. Storm water runoff from urban areas, agriculture, silviculture, animal operations, as well as mining and removal of vegetated buffers accelerates sediment loading as well as increases turbidity in the water column (NCDWQ 2000b). Water activities such as dredging, boating, and fishing with bottom disturbing gears also add to an increase in turbidity. Of all of these sources, agriculture is one of the largest contributors of sedimentation in the southeastern US (SAFMC 1998).

Sediment impacts on fish depend on the concentration of sediment, type of sediment, and the duration of the sedimentation. These impacts can plug gills and reduce respiratory abilities. This can lead to a reduced tolerance to disease, toxins, and turbidity. Other effects include the alteration of habitats that can affect spawning, and rearing habitat (NCDWQ 2000b).

9.2.1.6 Toxic Chemicals

Toxic chemicals that are found in the water column include heavy metals, polycyclic aromatic hydrocarbons (PAHs), petroleum hydrocarbons, polychlorinated biphenyls (PCBs), dioxins, antifoulants, chlorine, ammonia, and pesticides. Most of these chemicals come from localized point and nonpoint sources while activities contributing to heavy metal contamination include urban sprawl, dock and marina development, boating activity, dredge spoil disposal, automotive transportation, industrial shipping, and industrial emissions (Wilbur and Pentony 1999). Studies have shown that fine-grained sediments act as a reservoir for heavy metals and are readily adsorbed on tiny sediment particles, particularly organic rich muds (Riggs et al. 1991). Chemicals such as DDT, Diedrin, and TBT continue to contaminate sediments, even though they have been banned since 1977. Resuspension of sediments with heavy metal contamination can be a problem in fine-grained areas such as sheltered creeks. Because low concentrations of heavy metals in the water column can be easily incorporated into fine-grained sediment, such as organic rich mud, toxicant levels can accumulate in the sediment and be resuspended into the water column (Riggs et al. 1991). This is of particular concern as the majority of NC's primary nursery areas are composed of fine-grained sediments located in headwaters of various waterbodies.

Hackney et al. (1998) surveyed 165 sites within NC's sounds and rivers during 1994–1997 to evaluate environmental conditions as part of the United States Environmental Protection Agency (EPA) Environmental Assessment Program. Highest contamination levels occurred in low salinity areas with low flushing and high river discharge. Benthic populations were dominated by tolerant opportunistic species and had low species richness. It was estimated that 13.4% of the estuarine bottoms were incapable of supporting benthic production. Contaminants surveyed included nickel, arsenic, DDT, PCBs, and mercury. The investigation found that 37.5% to 75.8% of the randomly selected stations had contaminated surface sediment, and 19% to 36% of the sites were highly contaminated. Fish sores and lesions were more prevalent at sites with high sediment contamination (up to 50% of examined fish), but sores were also found at less contaminated sites. Laboratory bioassays showed that sediments from many sites were toxic to biological organisms. Riggs et al. (1991) and Riggs et al. (1989) assessed concentrations of heavy metals in the Neuse and Pamlico estuaries. In the Neuse River, surface sediments were found to be elevated with several heavy metals, including zinc, copper, lead, and arsenic and 17 areas between New Bern and the mouth of the river were identified as "contaminated areas of concern". The contaminated sites were primarily attributed to permitted municipal and industrial treatment plant discharges. Marinas were also found to contribute substantial amounts of copper and variable amounts of zinc and lead. Nonpoint sources were more difficult to evaluate. In the Pamlico River, heavy metal contamination was less severe, although arsenic, cobalt, and titanium exceeded the levels found in the Neuse River. These studies suggest that sediment contamination in some estuarine areas, especially those where both organic rich mud and wastewater discharges are present, may be significant and could affect fish populations and the base of their food chain.

Fish can uptake metals in different ways, through the skin and gills and the wall of the digestive tract. Mzimela et al. (2003) found that the groovy mullet (*Liza dumerelii)* accumulated elevated levels of iron, aluminum, zinc, manganese, chromium, copper, and lead (in that order) from discharges into Richards Bay, South Africa. This bay has a large array of different industries that discharge including fertilizer, paper pulp, and aluminum smelting industries (Mzimela et al. 2003).

Suitable water quality is a critical element in the ecology and productivity of estuarine systems. Degradation or improvement in one aspect of water quality may have a corresponding impact on habitat. Maintenance and improvement of suitable estuarine water quality and habitat are probably the most important factors in providing a sustainable striped mullet stock.

9.2.1.7 Dredge and Fill

Dredging, draining, and filling activities have altered or destroyed habitat used by striped mullet during various life stages. Due to regulations most of these activities affect wetlands and soft bottom. Dredging can affect SAV, but these impacts are generally not permitted.

Dredge and fill activities are most often associated with agriculture, residential development, and commercial forestry (Stanley 1992). Dredging activities do affect physical and biological features of soft bottom communities. New dredging for navigational channels or marina construction can alter topographic and hydrologic features that attract fish for feeding, refuge, or spawning, and modify sediment grain characteristics (SAFMC 1998). Dredging removes all benthic infauna from the affected areas immediately, reducing food availability temporarily to bottom feeding fish and invertebrates (Peterson and Wells 2000; Hackney et al. 1998). A variety of studies have estimated losses to wetlands. Although these estimates include losses of wetland areas that are isolated and not accessible, they do indicate the overall magnitude of habitat loss, which is thought to be significant in some areas. Hefner et al. (1994) reported that in North Carolina, the net loss of wetlands from the mid-1970s to the mid-1980s was 1.2 million acres (485,640 ha), the highest net loss among states in the southeastern United States. A majority of these losses were swamps and bottom land hardwood forests. In the North Carolina portion of the Chowan River basin, Craig and Kuenzler (1983) documented a 30% reduction in oak-gum-cypress forested wetlands from 1964 to 1974. Over that same period, it was also noted that 31% of the total land within the North Carolina portion of the basin had been artificially drained for agriculture (Craig and Kuenzler 1983).

Currently, only small areas of wetland (mostly non-riparian) can be filled without a permit and required mitigation. Land developers must also leave a fifty foot buffer (including some natural vegetation) in the Tar/Pamlico and Neuse rivers (with numerous exemptions). Even forestry operations cannot alter riparian wetlands without a 404 permit from the United States Army Corps of Engineers (USACE) or 401 water quality certification from the NCDWR. This buffer not only filters storm water and provides fish habitat, it stabilizes the shoreline. However, the conversion of non-riparian wetland to residential communities in many areas undoubtedly has an impact on the hydrology and water quality of adjacent riparian wetlands.

9.2.1.8 Terminal Groin

In 2011, Senate bill SB110 allowed up to four terminal groins to be constructed. Before these terminal groins could be constructed the applicants had to prepare an Environmental Impact Statement (EIS) that would consider alternatives, funding, and monitoring to significant adverse impacts and mitigation, if necessary. Terminal groins can potentially interfere with the passage of larvae and early juveniles from offshore spawning grounds into estuarine nursery areas. Successful transport of larvae through the inlet occurs within a narrow zone parallel to the shoreline and is highly dependent on along-shore transport processes (Blanton et al. 1999; Churchill et al. 1999; Hare et al. 1999). Obstacles such as jetties adjacent to inlets block the natural passage for larvae into inlets and reduce recruitment success (Kapolnai et al. 1996; Churchill et al. 1997; Blanton et al. 1999). As of April 2013, Figure Eight Island, Baldhead Island, Holden Beach, and Ocean Isle are in the preparation stages. The resource agencies have been working with these applicants to avoid and minimize impacts to fisheries resources.

9.2.2 Sea Level Rise and Climate Change

Rising sea level is a major threat to coastal and riparian wetlands in North Carolina. Analyses of data from tide gauge stations in Hampton, Virginia, and Charleston, South Carolina, from 1921 to 2000 (Riggs 2001), show sea level rising along the Atlantic coast by about 3.35 mm per year (1.1 ft per 100 years). Gauge data specific to North Carolina are available only for 20 years, but suggest a slightly greater rate of approximately 4.57 mm per year (1.5 ft per 100 years). The number and size of inlets will likely increase through time with sea level rise, causing potentially major changes in salinity distribution (Riggs and Ames 2003). Coastal marshes may keep pace with sea level rise according to their rate of accretion, which is largely determined by depth of mean high water inundation, vegetation density, atmospheric CO_2, and total suspended solids in flood water (Langley et al. 2009). Marsh areas are lost if their accretion rate falls behind sea level rise or if the shoreline is stabilized preventing landward migration. As the proportion of marsh declines relative to open water, tidal exchange increases such that sand deposition in tidal deltas and erosion of adjacent barrier islands are elevated (Fitzgerald et al. 2008). If the wetlands are not able to migrate landward as sea level rises, striped mullet may lose spawning habitat.

Weather patterns such as storm events and droughts, which may be exacerbated by climate change, can alter water column conditions in a manner that stresses aquatic organisms. With these changing conditions, it is possible that there will be shortages of freshwater for fish use and human consumption. Saltwater will move further upstream during droughts potentially moving striped mullet nursery habitat further upstream of its current location. During a drought in 2007, the Apalachicola National Estuarine Research Reserve (ANERR) in Florida observed a decrease in striped mullet (ANERR unpublished data; Petes et al. 2012). During the drought, Petes et al. (2012) observed a shift from some of the low salinity species (i.e. striped mullet) to higher salinity species.

9.3 HABITAT AND WATER QUALITY PROTECTION

9.3.1 Marine Fisheries Commission Authority

Presently, the MFC has authority for the following actions with regard to marine and estuarine resources: manage, restore, develop, cultivate, conserve, protect, and regulate. Marine and estuarine resources are "all fish [including marine mammals, shellfish, and crustaceans], except inland game fish, found in the Atlantic Ocean and in coastal fishing waters; all fisheries based upon such fish; all uncultivated or undomesticated plant and animal life, other than wildlife resources, inhabiting or dependent upon coastal fishing waters; and the entire ecology supporting such fish, fisheries, and plant and animal life." (G.S. 113-129)

The MFC has the power and duty to: authorize, license, regulate, prohibit, prescribe, and restrict:

- (A) All forms of marine and estuarine resources in coastal fishing waters with respect to:
  - (1) Time, place, character or dimensions of any method or equipment that may be employed in taking fish,
  - (2) Season for taking fish, and
  - (3) Size limits on and maximum quantities of fish that may be taken.
- (B) Possession, cultivation, transportation, importation, exportation and sale of all marine and estuarine resources and all related equipment and vessels.

The MFC also has authority to comment on State permit applications that may have an effect on marine and estuarine resources, regulate placement of fishing gear, develop and improve mariculture, regulate location and utilization of artificial reefs, and regulate the disposition of the young of edible fish. MFC authority is found in G.S. 143B-289.51 and 289.52.

9.3.2 Authority of Other Agencies

The North Carolina Division of Coastal Management (NCDCM) is responsible for development permits along the estuarine shoreline in 20 coastal counties. Wetland development activity throughout North Carolina is permitted through the USACE and the NCDWR (401-certification program). Various federal and state environmental and resource agencies, including NCDMF, evaluate projects proposed for permitting and provide comments and recommendations to the NCDCM, NCDWR, and USACE on potential habitat and resource impacts. Habitat protection relies on enforcement, the efforts of commenting agencies to evaluate impacts, and the incorporation of recommendations into permitting decisions.

Federal and state laws mandate water quality protection activities through government commissions and agencies. The NCDWQ is responsible for the regulation and protection of the state's surface waters. The division's responsibilities include monitoring, permitting, planning, modeling, and compliance oversight. North Carolina has also established a water quality classification and standards program for "best usage." These classifications are High Quality Waters (HQW), Outstanding Resource Waters (ORW), Nutrient Sensitive Waters (NSW) and Water Supply (WS) waters and outline protective management strategies aimed at controlling point and nonpoint source pollution. In conjunction with a NSW designation, a Nutrient Sensitive Waters Strategy (NSWS) is developed and includes a 30% reduction in nitrogen loading from agriculture, no net increase in phosphorous, protection for riparian areas, storm water runoff control, and wastewater discharge standards.

Permit issuance to individuals and/or entities requesting permission to impact surface waters and wetlands is granted by state and federal regulatory agencies (NCDWR, NCDCM, and USACE). Resource agencies (NCWRC, NCDMF, USFWS, and NMFS) are given the authority to request modification or denial of projects when the design is perceived as having adverse impacts to fisheries and aquatic resources. Basin wide water quality management plans prepared by the NCDWR also identify specific water quality concerns within an individual watershed. The NCDMF and NCWRC can request in water work moratoriums to minimize impacts to recruiting juveniles and anadromous fish spawning migrations. These moratoriums vary depending on the area, but generally range from February through September, but may extend into October. The NCWRC has the authority to designate waters as Inland Primary Nursery Areas. Currently, portions of the Roanoke, Tar, Neuse, and Cape Fear rivers are so designated. However, the NCWRC has no additional regulatory authority and can only regulate fishing activities in these areas.

The CRC regulations do not allow authorization of projects that can violate water quality standards or adversely affect the life cycle of estuarine resources. The CRC regulates development activities in Areas of Environmental Concern, which include coastal wetlands. Generally, no development is allowed in coastal wetlands except water dependent activities such as docks. The North Carolina Environmental Management Commission (EMC) manages wetlands through the 401/404 Certification Program, under the federal Clean Water Act. This program focuses on avoiding and minimizing filling of wetlands and streams through review of all Environmental Assessments (EAs), Coastal Area Management Act (CAMA) major permit applications, and USACE permit applications to determine if the project will violate water quality standards.

9.3.3 Coastal Habitat Protection Plans

Protection of the quantity and quality of striped mullet habitat, particularly areas designated as critical (i.e. spawning and nursery areas) is essential to the goal of this plan. Increasing human activity across North Carolina continues to have a significant influence on habitat quantity and quality as well as associated wildlife and fisheries resources. The 1997 FRA mandates that the DENR shall coordinate the preparation of CHPP for critical fisheries habitats (CHPP – G. S. 143B-279.8). The legislative goal of the CHPP shall be the long-term enhancement of coastal fisheries associated with coastal habitat. The NCDMF, NCDWR, and NCDCM shall prepare the CHPP, with assistance from other federal and state agencies. The plans shall:

1) Describe and classify biological systems in the habitats,
2) Evaluate the function, value to coastal fisheries, status, and trends of the habitats,
3) Identify existing and potential threats to the habitats and the impact on coastal fishing, and
4) Recommend actions to protect and restore the habitats.

In 2005, the MFC, the EMC, and the CRC jointly approved these plans and developed CHPP implementation plans. The CHPP is updated every 5 years, with the last update approved in 2010, and the most recent update currently underway and set to be approved in late 2015. Actions taken by all four commissions pertaining to the coastal area, including rule making, are to comply, “too the maximum extent practicable” with the plans. The CHPP helps to ensure consistent actions among these four commissions as well as their supporting DENR agencies.

The CHPP describes and documents the use of habitats by species supporting coastal fisheries, status of these habitats, and the impacts of human activities and natural events on those habitats. Fish habitat is defined in the CHPP as “freshwater, estuarine, and marine areas that support juvenile and adult populations of economically important fish, shellfish, and crustacean species (commercial and recreational), as well as forage species important in the food chain” (Deaton et al. 2010). Fish habitat also includes land areas that are adjacent to, and periodically flooded by riverine and coastal waters. Six fish habitats were discussed and designated based on distinctive physical properties, ecological functions, and habitat requirements for living components of the habitat: wetlands, SAV, soft bottom, shell bottom, ocean hard bottom, and water column.

The CHPP recommends that some areas of fish habitat be designated as “Strategic Habitat Areas” (SHAs), specific locations of individual fish habitat or systems of habitat that have been identified to provide critical habitat functions or that are particularly at risk due to imminent threats, vulnerability, or rarity. While all fish habitats are necessary for sustaining viable fish populations, some areas may be especially important to fish viability and productivity. Protection of these areas would therefore be a high priority (Deaton et al. 2010). In 2009, the MFC nominated and approved SHAs for the sounds and tributaries of Albemarle, Currituck, Roanoke, and Croatan sounds and the nearshore Atlantic Ocean. The SHA covering Pamlico Sound, the Tar/Pamlico Rivers, and Neuse River have been identified. The SHAs covering the remaining areas of the state are expected to be identified by early of 2014.

The CHPP focuses on the fish habitat and threats to the habitat. This FMP describes habitat conditions or needs for the various life stages of the striped mullet. The FRA gives precedent to the CHPP and stipulates habitat and water quality considerations in the FMP be consistent with the CHPP. Any recommendations will be considered and acted upon through the CHPP implementation process.

9.4 HABITAT AND WATER QUALITY RECOMMNEDED MANAGEMENT STRATEGY

In reviewing the 2006 Striped Mullet FMP habitat and water quality management recommendations, many have been implemented or are substantially underway. Many of these were also components of the CHPP implementation plan. They include:

Habitat

- CRC has revised dock rules to require review by resource agencies for GP dock applications located over SAV, shell bottom, or PNAs, and where water depth is less than 2 ft mean water level to avoid boating related impacts.
- Although North Carolina legislation has been passed to allow terminal groins to be built in coastal North Carolina, the NCDMF has been in talks with applicants to minimize the adverse impacts to fisheries. In addition, the NCDCM has created standards for beach nourishment projects. These standards include sediment size and moratorium periods to minimize impacts.
- Coast-wide imagery of SAV was taken in 2007/2008 and has been mapped.
- Additional bottom disturbing gear restrictions have been implemented through the bay scallop and oyster fishery management plans to avoid damage to SAV and oysters.
- DENR staff has been cooperating to develop permit conditions for marsh sills to minimize the impacts of vertical shoreline stabilization methods.

Water Quality

- Neuse and Tar-Pamlico NSW nutrient reduction measures have successfully reduced nutrient loading by more than their 30% reduction goals for point source dischargers and agriculture.
- NCDWR revised coastal storm water rules that limit impervious surface and run-off in coastal areas.
- Wetland buffers along coastal streams and rivers have been used to enhance wetlands and improve water quality.

9.4.1 Coastal Habitat Protection Plan Actions

There are many actions that natural resource managers can take to sustain and enhance habitat and water quality conditions for striped mullet. High priority needs include:

- Preserving existing coastal wetlands and restoring wetlands
- Protecting PNAs from dredging and water quality degradation
- Protecting and enhancing SAV habitat
- Assessing sediment contamination in NC estuaries and effects on mullet
- Reducing pollutant loading from point and non-point sources

These management needs are currently being addressed through several existing CHPP recommendations (Deaton et al. 2010) and implementation of actions that were approved by the CHPP Steering Committee. Listed below are those CHPP recommendations and implementation actions that could be beneficial for protecting and improving habitat and water quality issues affecting striped mullet. Numbering refers to the CHPP recommendations. Implementation actions are denoted by (I) following the recommendation number.

2.1 Support Strategic Habitat Area assessments by:

a) Coordinating, completing, and maintaining baseline habitat mapping (including seagrass, shell bottom, shoreline, and other bottom types) using the most appropriate technology
b) Selective monitoring of the status of those habitats

Of specific importance for striped mullet are:

- remapping and monitoring SAV in North Carolina to assess change in distribution
- assessing the distribution, concentration, and threat of heavy metals and other toxic contaminants in freshwater and estuarine sediments and identify the areas of greatest concern to focus water quality improvement efforts
- monitoring to determine if additional areas should be designated as Primary Nursery Areas due to their nursery importance to mullet

2.2 Identify, designate, and protect Strategic Habitat Areas.

3.1 Expand habitat restoration in accordance with restoration plan goals, including:

a) Creation of subtidal oyster reef no-take sanctuaries
b) Re-establishment of riparian wetlands and stream hydrology
c) Restoration of SAV habitat and shallow soft bottom nurseries

Of specific importance for striped mullet is protection and restoration of coastal wetlands and SAV.

3.3 Protect habitat from fishing gear effects through improved enforcement establishment of protective buffers around habitats, modified rules, and further restriction of fishing gear where necessary.

Of specific importance for striped mullet is periodic re-examination of areas where trawling, oyster dredging or mechanical harvest is currently allowed to determine if conflicts with habitat protection exist.

3.4 Protect estuarine and public trust shorelines and shallow water habitats by revising shoreline stabilization rules to include consideration of erosion rates and prefer alternatives to vertical shoreline stabilization measures that maintain shallow nursery habitat.

3.7 (I) Develop an interagency policy for marina siting to minimize impacts to ecologically important shallow habitats such as Primary Nursery Areas (PNA), Anadromous Fish Spawning Areas (AFSA), and SAV.

4.1 Reduce point source pollution discharges by:

a) Increasing inspections of wastewater treatment facilities, collection infrastructure, and disposal sites
b) Providing incentives for upgrading all types of discharge treatment systems
c) Developing standards and treatment methods that minimize the threat of endocrine disrupting chemicals on aquatic life.

4.5 Improve strategies throughout the river basins to reduce non-point pollution and minimize cumulative losses of fish habitat through voluntary actions, assistance, and incentives, including:
   a) Improved methods to reduce pollution from construction sites, agriculture, and forestry
   b) Increased on-site infiltration of storm water
   c) Encouraging and providing incentives for low-impact development

4.6 Improve strategies throughout the river basins to reduce non-point pollution and minimize cumulative losses of fish habitat through rule making, including:
   a) Increased use of effective vegetated buffers
   b) Implementing and assessing coastal storm water rules and modify if justified
   c) Modified water quality standards that are adequate to support SAV habitat

4.8 Reduce non-point source pollution from large-scale animal operations

9.4.2 Research Recommendations

Along with the management recommendation actions from the 2006 Striped Mullet FMP listed above, there are certain research questions that should be answered to determine the impacts on striped mullet. The Striped Mullet PDT discussed these recommendations and assigned a priority ranking of High, Medium, or Low as a way to determine how critical these needs are.

All recommendations below are from the CHPP (2010):

Habitat

- Identify, research, and designate additional areas as primary nursery areas that may be important to striped mullet, as well as other fisheries (Low).
- Develop and maintain accurate maps and documentation of wetlands, soft bottom, SAVs, and water column (Medium).

Water Quality

- Support research on the causes of hypoxia and anoxia and impacts on striped mullet populations in North Carolina's estuarine waters (Medium).
- Support additional research to document and quantify the influences of significant weather events (including climate change) on water quality and assess impacts on the striped mullet population (Medium).

10.0 PRINCIPAL ISSUES AND MANAGEMENT OPTIONS

10.1 RESOLUTION OF NEWPORT RIVER GILL NET ATTENDANCE ISSUE PAPER[1]

I. ISSUE

As part of the 2006 Shrimp Fishery Management Plan (FMP), a portion of the Newport River upstream of the line from Hardesty Farm subdivision to Penn Point (Hardesty Farm line) was designated a trawl nets prohibited area (TNPA) under Marine Fisheries Commission (MFC) Rule 15A NCAC 03R .0106 (7). Whereas this designation served the desired purpose of prohibiting shrimp trawling upstream of that line, it was done without consideration of the existing special secondary nursery area (SSNA) designation which allows for seasonal opening of an area now inside a TNPA. In 2011, the Newport River TNPA was then added to the small mesh gill net attendance areas under MFC Rule 15A NCAC 03R .0112 (b) (1) and the implications to the striped mullet fishery were not considered. There are two issues that need to be resolved: 1) correct the existence of a SSNA which can be opened to trawling within a TNPA and 2) address an inconsistency between the current rule and the intended gill net attendance requirements for this area brought about by the designation of the Newport River TNPA as a small mesh gill net attendance area.

II. ORIGINATION

Shrimp FMP Plan Development Team (PDT) after examination of rules for an issue paper.

III. BACKGROUND

As part of the 2006 Shrimp FMP, a portion of the Newport River upstream of the line from Hardesty Farm subdivision to Penn Point (Hardesty Farm line) was designated a TNPA under MFC Rule 15A NCAC 03R .0106 (7). Whereas this designation served the desired purpose of prohibiting shrimp trawling upstream of that line, it was done without consideration of the existing SSNA designation (allows for seasonal opening) or implications to small mesh gill net attendance in the affected area (Figure 10.1).

[1] Presented to: PDT 2/13/14 and 7/10/14; RAT Subgroup 3/20/14; RAT 4/3/14 and 5/1/14; AC 6/10/14 and 7/15/14; MRT 7/21/14.

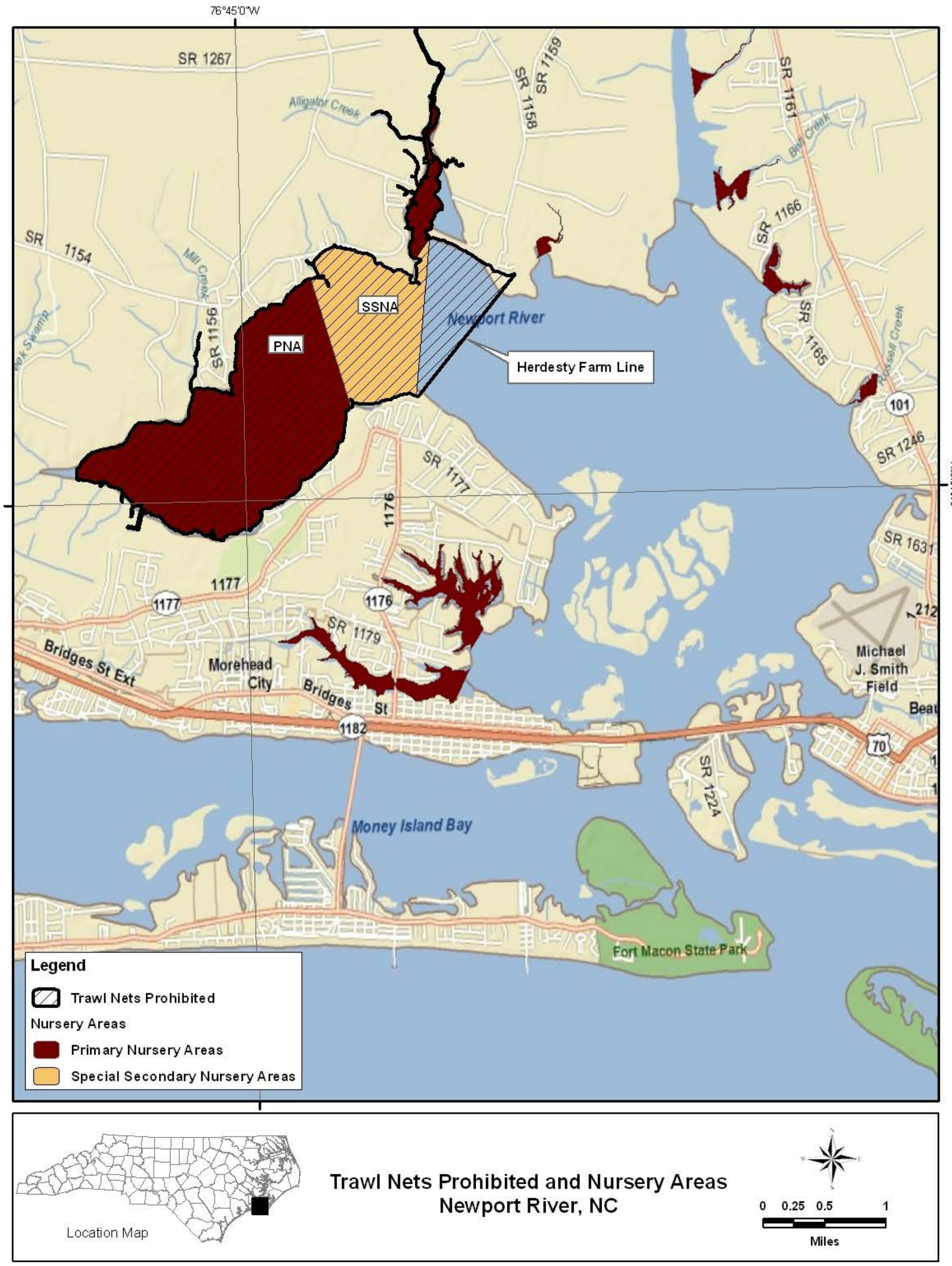

Figure 10.1. Existing nursery areas and trawl nets prohibited areas in the Newport River.

While examining a request to remove the TNPA designation to address the inconsistency with the SSNA designation as part of the 2011 Shrimp FMP, the PDT discussed the unintended consequences to gill net attendance caused by the TNPA designation from Rule 15A NCAC 03R. 0112. Rule 15A NCAC 03J .0103 (h) requires small mesh gill nets (less than five inches) to be attended from May 1 through November 30 in areas designated in Rule 15A NCAC 03R .0112 (b). In Rule 15A NCAC 03R .0112 (b), there are two provisions applicable to Newport River: item (5) describes the areas where attendance is required within 50 yards of any shoreline east of a line in Pamlico Sound **except** in the area from Core Sound to the South Carolina line from October 1 through November 30; and item (1) which requires attendance from May 1 through November 30 in primary and permanent secondary nursery areas and several TNPAs *including* the Newport River TNPA. Basically item (5) is a catchall category for any areas that were not specifically identified by items (1)-(4). Small mesh gill net attendance is required from May 1 through November 30 in Newport River upstream of the Hardesty Farm subdivision to Penn Point line according to Rule 15A NCAC 03R .0112 (b) (1). However, this eliminates a striped mullet gill net fishery that has been occurring there in the fall. Various staff and Marine Patrol officers did not feel gill net attendance was intended and have not enforced the Newport River TNPA portion of Rule 15A NCAC 03R .0112 (b) (1). Rather, Rule 15A NCAC 03R .0112 (b) (5) was interpreted to allow unattended small mesh gill net fishing to occur from October 1, and thus, allows the traditional striped mullet fishery to occur. The Shrimp FMP PDT recommended the shrimp trawl line remain as shown by the Newport River TNPA, but attempt to resolve the rule language in Rule 15A NCAC 03R .0112 (b) in the Striped Mullet FMP process so the small mesh gill net striped mullet fishery can continue from October 1 each year.

The Newport River SSNA was first listed in Rule 15A NCAC 03R .0005 in 1991 and is currently listed in Rule 15A NCAC 03R .0105 (6). The Newport River TNPA was first listed in Rule 15A NCAC 03R .0006 (17) in 1994 and the boundary line was the same as the SSNA line. This resulted in an area that could be opened to shrimp and crab trawling by proclamation under the SSNA rule but could not be opened to shrimp or crab trawling under the TNPA rule. In 2004, the Newport River TNPA was removed from rule and allowed for the opening of the SSNA to shrimp and crab trawling by proclamation.

In 1998, the first attended gill net areas appeared in Rule 15A NCAC 03J. 0103 (g) requiring attendance of gill nets less than five inches in Internal Coastal Waters and Joint Fishing Waters from May 1–October 31 in selected areas. In 2000, four TNPA's were added as gill net attendance areas in Rule 15A NCAC 03J. 0103 (h) (1) and did not include the Newport River. In 2004, the gill net attended areas were moved from Rule 15A NCAC 03J. 0103 (g) and (h) to Rule 15A NCAC 03R. 0112 (a) and (b). In 2006, the Newport River TNPA was relisted in Rule 15A NCAC 03R. 0106 (7) but was not included as an attended gill net area in Rule 15A NCAC 03R. 0112 (b) (1). In 2011, the Newport River TNPA, along with four other TNPA's, were added to the attended gill net area rule. The reasoning for this addition is unclear at this point as the staff involved has since retired. David Taylor (former Fisheries Management Section Chief) was contacted and he could not recall why the Newport River TNPA was added to the attended gill net areas rule. This addition resulted in the existing inconsistency between the gill net attendance time period in rule and when small mesh gill net attendance was intended and how it is currently enforced in the area in question.

IV. AUTHORITY

G. S. 113-134 RULES
G.S. 113-182 REGULATION OF FISHING AND FISHERIES

G.S. 143B-289.52 MARINE FISHERIES COMMISSION – POWERS AND DUTIES

N.C. Marine Fisheries Commission Rules (15A NCAC)
03J .0103 GILL NETS, SEINES, IDENTIFICATION, RESTRICTIONS
03R .0112 ATTENDED GILL NET AREAS

V. DISCUSSION

The management recommendation to have the "permanent shrimp line" in Newport River located at the Hardesty Farm subdivision to Penn Point line was unanimously supported during the 2006 Shrimp FMP and was implemented by adding it to the TNPA rule. This action accomplished the desired effect for the Shrimp FMP but did not take into consideration the SSNA upstream in Rule 15A NCAC .03J .0103. In 2011, the Newport River TNPA was added to the attended gill net areas in Rule 15A NCAC .03R .0112 (b) (1). Marine Patrol has been enforcing the attended gill net rule in a manner that only requires small mesh gill net attendance in the Newport River TNPA from May 1 through September 30, allowing the striped mullet fishery to occur. The Shrimp FMP PDT recommended a rule change be pursued to remove the Newport River TNPA from the attended gill net areas in Rule 15A NCAC 03R .0112 (b) (1) but leave it subject to 03R .0112 (b) (5), which requires small mesh gill net attendance from May 1 through September 30.

This issue has been dormant since November 2011 and has been raised as an issue for the Striped Mullet FMP Amendment 1. The proposed recommended rule change in Section VI shows a solution for the small mesh gill net attendance situation for the striped mullet fishery.

Upstream of the Newport River TNPA, there is a designated SSNA, which was unchanged during the 2006 Shrimp FMP. The proposed rule change still leaves an inconsistency by having a SSNA designation, which the director may open to trawling from August 16 to May 14, within a TNPA. Although the Shrimp FMP states the downstream line is to be the permanent one, it is illogical for this situation to exist. A possible fix would be to remove the SSNA designation for this area of the Newport River; however, this issue falls outside the purview of the Striped Mullet FMP. The issue should be explored by the Habitat and Water Quality Advisory Committee as part of the proposed Shrimp FMP management recommendation for addressing SSNAs.

VI. PROPOSED RULE(S)

15A NCAC 03R .0112 ATTENDED GILL NET AREAS

(a) The attended gill net areas referenced in 15A NCAC 03J .0103(g) are delineated in the following areas:

(1) Pamlico River, west of a line beginning at a point 35° 27.5768' N - 76° 54.3612' W on Ragged Point; running southwesterly to a point 35° 26.9176' N - 76° 55.5253' W on Mauls Point;

(2) Within 200 yards of any shoreline in Pamlico River and its tributaries east of a line beginning at a point 35° 27.5768' N - 76° 54.3612' W on Ragged Point; running southwesterly to a point 35° 26.9176' N - 76° 55.5253' W on Mauls Point; and west of a line beginning at a point 35° 22.3622' N - 76° 28.2032' W on Roos Point; running southerly to a point at 35° 18.5906' N - 76° 28.9530' W on Pamlico Point;

(3) Pungo River, east of the northern portion of the Pantego Creek breakwater and a line beginning at a point 35° 31.7198' N - 76° 36.9195' W on the northern side of the breakwater near Tooleys Point; running southeasterly to a point 35° 30.5312' N - 76° 35.1594' W on Durants Point;

(4) Within 200 yards of any shoreline in Pungo River and its tributaries west of the northern portion of the Pantego Creek breakwater and a line beginning at a point 35° 31.7198' N - 76° 36.9195' W on the northern side of the breakwater near Tooleys Point; running southeasterly to a point

35° 30.5312' N - 76° 35.1594' W on Durants Point; and west of a line beginning at a point 35° 22.3622' N - 76° 28.2032' W on Roos Point; running southerly to a point at 35° 18.5906' N - 76° 28.9530' W on Pamlico Point;

(5) Neuse River and its tributaries northwest of the Highway 17 highrise bridge;

(6) Trent River and its tributaries; and

(7) Within 200 yards of any shoreline in Neuse River and its tributaries east of the Highway 17 highrise bridge and south and west of a line beginning on Maw Point at a point 35° 09.0407' N - 76° 32.2348' W; running southeasterly near the Maw Point Shoal Marker "2" to a point 35° 08.1250' N - 76° 30.8532' W; running southeasterly near the Neuse River Entrance Marker "NR" to a point 35° 06.6212' N - 76° 28.5383' W; running southerly to a point 35° 04.4833' N - 76° 28.0000' W near Point of Marsh in Neuse River. In Core and Clubfoot creeks, the Highway 101 Bridge constitutes the attendance boundary.

(b) The attended gill net areas referenced in 15A NCAC 03J .0103(h) are delineated in the following ~~coastal and joint waters~~ Coastal and Joint Fishing Waters of the state south of a line beginning on Roanoke Marshes Point at a point 35° 48.3693' N - 75° 43.7232' W; running southeasterly to a point 35° 44.1710' N - 75° 31.0520' W on Eagles Nest Bay to the South Carolina State line:

(1) All primary nursery areas described in 15A NCAC 03R .0103, all permanent secondary nursery areas described in 15A NCAC 03R .0104, and no-trawl areas described in 15A NCAC 03R .0106(2), (4), (5), ~~(7),~~ (8), (10), (11), and (12);

(2) In the area along the Outer Banks, beginning at a point 35° 44.1710' N - 75° 31.0520' W on Eagles Nest Bay; running northwesterly to a point 35° 45.1833' N - 75° 34.1000' W west of Pea Island; running southerly to a point 35° 40.0000' N - 75° 32.8666' W west of Beach Slough; running southeasterly and passing near Beacon "2" in Chicamicomico Channel to a point 35° 35.0000' N - 75° 29.8833' W west of the Rodanthe Pier; running southwesterly to a point 35° 28.4500' N - 75° 31.3500' W on Gull Island; running southerly to a point 35° 22.3000' N - 75° 33.2000' W near Beacon "2" in Avon Channel ; running southwesterly to a point 35° 19.0333' N - 75° 36.3166' W near Beacon "2" in Cape Channel; running southwesterly to a point 35° 15.5000' N - 75° 43.4000' W near Beacon "36" in Rollinson Channel; running southeasterly to a point 35° 14.9386' N - 75° 42.9968' W near Beacon "35" in Rollinson Channel; running southwesterly to a point 35° 14.0377' N - 75° 45.9644' W near a "Danger" Beacon northwest of Austin Reef; running southwesterly to a point 35° 11.4833' N - 75° 51.0833' W on Legged Lump; running southeasterly to a point 35° 10.9666' N - 75° 49.7166' W south of Legged Lump; running southwesterly to a point 35° 09.3000' N - 75° 54.8166' W near the west end of Clarks Reef; running westerly to a point 35° 08.4333' N - 76° 02.5000' W near Nine Foot Shoal Channel; running southerly to a point 35° 06.4000' N - 76° 04.3333' W near North Rock; running southwesterly to a point 35° 01.5833' N - 76° 11.4500' W near Beacon "HL"; running southerly to a point 35° 00.2666' N - 76° 12.2000' W; running southerly to a point 34° 59.4664' N - 76° 12.4859' W on Wainwright Island; running easterly to a point 34° 58.7853' N - 76° 09.8922' W on Core Banks; running northerly along the shoreline and across the inlets following the Colregs Demarcation line to the point of beginning;

(3) In Core and Back sounds, beginning at a point 34° 58.7853' N - 76° 09.8922' W on Core Banks; running northwesterly to a point 34° 59.4664' N - 76° 12.4859' W on Wainwright Island; running southerly to a point 34° 58.8000' N - 76° 12.5166' W; running southeasterly to a point 34° 58.1833' N - 76° 12.3000' W; running southwesterly to a point 34° 56.4833' N - 76° 13.2833' W; running westerly to a point 34° 56.5500' N - 76° 13.6166' W; running southwesterly to a point 34° 53.5500' N - 76° 16.4166' W; running northwesterly to a point 34° 53.9166' N - 76° 17.1166' W; running southerly to a point 34° 53.4166' N - 76° 17.3500' W; running southwesterly to a point 34° 51.0617' N - 76° 21.0449' W; running southwesterly to a point 34° 48.3137' N - 76° 24.3717' W; running southwesterly to a point 34° 46.3739' N - 76° 26.1526' W; running southwesterly to a point 34° 44.5795' N - 76° 27.5136' W; running southwesterly to a point 34° 43.4895' N - 76° 28.9411' W near Beacon "37A"; running southwesterly to a point 34° 40.4500' N - 76° 30.6833' W; running westerly to a point 34° 40.7061' N - 76° 31.5893' W near Beacon "35" in Back Sound; running westerly to a point 34° 41.3178' N -76° 33.8092' W near Buoy "3"; running southwesterly to a point 34° 39.6601' N - 76° 34.4078' W

on Shackleford Banks; running easterly and northeasterly along the shoreline and across the inlets following the COLREGS Demarcation lines to the point of beginning;

(4) Within 200 yards of any shoreline in the area upstream of the 76° 28.0000' W longitude line beginning at a point 35° 22.3752' N - 76° 28.0000' W near Roos Point in Pamlico River; running southeasterly to a point 35° 04.4833' N - 76° 28.0000' W near Point of Marsh in Neuse River; and

(5) Within 50 yards of any shoreline east of the 76° 28.0000' W longitude line beginning at a point 35° 22.3752' N - 76° 28.0000' W near Roos Point in Pamlico River; running southeasterly to a point 35° 04.4833' N - 76° 28.0000' W near Point of Marsh in Neuse River, except from October 1 through November 30, south and east of Highway 12 in Carteret County and south of a line from a point 34° 59.7942' N - 76° 14.6514' W on Camp Point; running easterly to a point at 34° 58.7853' N - 76° 09.8922' W on Core Banks; to the South Carolina State Line.

History Note: *Authority G.S. 113-134; 113-173; 113-182; 113-221.1; 143B-289.52;*
Eff. August 1, 2004;
Amended Eff. April 1, 2016, April 1, 2011; April 1, 2009.

VII. Proposed Management Options

1) Status Quo

+ No new regulations are needed.
– Impact to commercial fishermen in the area once enforcement is brought in line with rule language
– Conflict between rule and intended enforcement is not resolved.

2) Remove the Newport River TNPA [Rule 15A NCAC 03R .0106 (7)] from Marine Fisheries Rule 03R .0112 (b) (1), but leave it subject to 03R .0112 (b) (5), which requires attendance from May 1 through September 30

+ Maintains consistency in the way it is currently enforced without changing intent
+ Commercial fishermen will not have to attend nets within 50 yards of shore from October 1 – November 30.
– The SSNA designation still exists within a TNPA.
– Less protection for bycatch species in the Newport River

VIII. Recommendation

NCDMF:

The NCDMF recommends option two to resolve the gill net attendance issue. This would bring current regulations in line with enforcement actions for this area and remove the unintended consequences of the TNPA designation on the striped mullet and other small mesh gill net fisheries. The removal of the SSNA designation for waters contained in the TNPA in the Newport River should be examined further as part of the Shrimp FMP Amendment 1 review of SSNAs by the Habitat and Water Quality Advisory Committee.

Finfish Advisory Committee (Striped Mullet FMP Advisory Committee):

Same as NCDMF recommendation.

MFC Selected Management Strategy:

Same as NCDMF recommendation.

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252-948-3874

February 19, 2013
March 31, 2014 Revised
April 25, 2014 Revised
May 13, 2014 Revised

10.2 MANAGEMENT MEASURES TO ADDRESS USER CONFLICT IN THE STRIPED MULLET RUNAROUND GILL NET FISHERY ISSUE PAPER[2]

I. ISSUE

Determine management measures to reduce conflicts occurring in confined creeks and in the vicinity of docks and marinas between recreational hook-and-line fishermen, striped mullet commercial fishermen using runaround gill nets, and shoreline residents.

II. ORIGINATION

North Carolina Division of Marine Fisheries (NCDMF) staff in response to recreational fishermen and shoreline residents' requests and complaints.

III. BACKGROUND

For the past several years, conflict has existed between commercial runaround gill net, recreational hook-and-line fishermen, and shoreline residents. Runaround gill nets are nets with floats on the topline and weights on the leadline which are deployed from a vessel around a school of fish (usually striped mullet) to encircle and capture them. The conflict primarily involves competition for limited space in creeks and a real or perceived reduction in the number of fish available to the recreational fishermen after runaround gill net operations have taken place. Other conflicts involve the use of gill nets in developed creeks at night where lights, noise and, in some instances, trespassing on private property and physical altercations have resulted.

The 2006 Striped Mullet Fishery Management Plan (FMP) had inshore mullet gill net fishing conflicts as one of its issues. The issue topic in the Striped Mullet FMP was the "setting of gill nets around private piers and in restricted navigation areas and disruptive practices associated with night fishing" and was characterized this way: "The change in inshore striped mullet fishing practices from traditional passive soak nets to active tower boats with runaround nets has created conflicts with marinas and shoreline residents. Setting of gill nets around private piers and in restricted navigation areas and disruptive fishing practices associated with night fishing have resulted in charges against the mullet fishermen of impeding navigation and disturbing the peace. The situation has resulted in petitions for rulemaking asking the Marine Fisheries Commission (MFC) for varying degrees of gill net

[2] Presented to: PDT 2/13/14 and 7/10/14; RAT Subgroup 3/20/14; RAT 4/3/14 and 5/1/14; AC 6/10/14 and 7/15/14; MRT 7/21/14.

exclusion from specific areas." The MFC chose to continue to deal with inshore gill net conflicts on a case-by-case basis. The recommendation in the Striped Mullet FMP was to move forward with the mediation process to resolve conflict between commercial and recreational striped mullet fishermen and shoreline residents. Mediation was attempted in a case involving commercial gill netters, flounder giggers and shoreline residents of Cape Carteret, North Carolina as recently as January 2013.

Competition and conflict in the striped mullet fishery typically occurs in the fall and winter in years when striped mullet are in high abundance. The NCDMF has received an increased number of complaints of conflicts between commercial gill net fishermen, recreational hook-and-line fishermen and residents mainly from creeks where runaround gill nets have encircled schools of striped mullet and displaced or blocked access to boaters, hook-and-line fishermen and resident's docks. Several requests have been made since the completion of the 2006 Striped Mullet FMP to close certain creeks to commercial gill netting, one involving stationary gill nets and two involving runaround gill nets. Three such incidents are described below, as reported to NCDMF, in some detail because they are representative of the numerous complaints that are received by NCDMF staff and describe the complexities involved.

The first example occurred in 2008 in the Newport and White Oak rivers in Carteret/Onslow counties between recreational fishing guides and commercial gill netters. The issue involved the setting and leaving of unattended large mesh gill nets for flounder and catching red drum as bycatch. The guides had documented with video and digital photos nets at low tide with red drum in them (by proclamation authority FF-59-2008, commercial fishermen were allowed four as bycatch at the time.) The gill netters claimed that some of the pictures were staged and that they were not violating any rules and that the recreational fishing mortality from the hook-and-line anglers exceeds what they kill as a by-product of flounder fishing. The situation became increasingly heated with threats of physical harm and property damage from both sides of the issue. Local police and sheriff departments were called several times. The videos and pictures were placed on fishing guide websites and other websites for wider distribution. The MFC met in Atlantic Beach in September, 2008 giving both sides an opportunity to publically tell their side of the story. There were approximately four guides and four gill netters. The MFC instructed the NCDMF to explore the possibility of mediation. The situation was summarized for the mediator and the parties were identified and mediation was set up. However, the groups could not agree to a meeting time and the effort was abandoned. The Director met with each side separately and the gill netters agreed to reduce the amount of net they set to 1,500 yards (they could fish 3,000 yards at the time). They also agreed to set at night as much as the tidal conditions allow (nets must be set at high tide), freeing up daytime hours for guides to fish. The large mesh gill net restrictions brought about by the sea turtle lawsuit settlement agreement and now the estuarine anchored gill net Incidental Take Permit (ITP) have restricted the construction and setting times of fixed gill nets such that the confrontations have been reduced, but not eliminated.

A second example is conflict occurring at night in Deer and Schoolhouse (Rocky Run) creeks in the Town of Cape Carteret. Residents reported fishermen shining halogen lights at all hours of the night, playing loud radios, and beating on docks to run fish into gill nets, as well as confrontations with fishermen over public trust rights. NCDMF staff met with residents in December 2008 after a petition for rulemaking was denied by the MFC. NCDMF staff heard their complaints and explained current fisheries rules as well as their enforcement. The jurisdiction of town police and Marine Patrol was outlined as well as what constituted a fisheries violation versus a disturbing the peace or trespassing violation and what officers could do in each case. Gill net fishing and flounder gigging were the primary sources of controversy. NCDMF staff held two meetings between fishermen, town officials and residents in March and May of 2012 in attempts to resolve the situation after the town residents again came to the MFC with a proposed proclamation prohibiting gill nets and seines in Deer Creek at night. Cooperation improved after the first of these meetings took place, but the town requested that the formal mediation process take place at the second meeting. The mediation occurred in January 2013, but did not result in any agreement when the town withdrew from the process. In February 2013, the MFC voted to implement measures prohibiting gill nets and seines in Deer Creek from 8:30 p.m. to sunrise from October through March, requiring reflectors on nets every 50 yards, restricting gill net and seine lengths to 200 yards and requiring that the nets be attended at all times (M-9-2013).

Finally, there is a recurring problem in the creeks in the vicinity of Oriental on the Neuse River that involves runaround gill net fishermen targeting striped mullet in close proximity to recreational hook-and-line fishermen fishing for spotted seatrout. Complaints from the recreational fishermen include gill nets blocking more than two-thirds of a creek, running nets all the way around a marina and docks blocking access to boats and fishermen within the creeks. The recreational fisherman who lodged that complaint was told about both the mediation and the petition for rulemaking processes and Marine Patrol contact was made with both sides to ensure that present restrictions were not being violated and that both sides were aware of the problem.

IV. AUTHORITY

G.S. 113-134 RULES.
G.S. 113-182 REGULATION OF FISHING AND FISHERIES.
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)
03J .0103 GILL NETS, SEINES, IDENTIFICATION, RESTRICTIONS
03J .0301(j) POTS (user conflict portion)
03R .0112 ATTENDED GILL NET AREAS

V. DISCUSSION

Clearly, there are documented conflicts between boaters, commercial fishermen, shoreline residents, and recreational fishermen. The broad issue of user group conflicts affects many of the fisheries in North Carolina and is too complicated to be addressed in a single issue paper. Therefore, under the purview of Amendment 1 to the Striped Mullet FMP, this paper will be restricted to the increasing conflict between shoreline residents, recreational hook-and-line fishermen and commercial runaround gill net fishermen in the more restricted waters of North Carolina, particularly those that have marinas, docks and piers on their shores. If the user groups cannot recognize and respect each other's right to the resource and cooperate, management measures that could be used to address this conflict include mediation, area closure, and gear restrictions. These options are not resource-related and should be considered only as conflict resolution measures.

Following is a brief discussion of possible management options to address conflict when the user groups are unable to cooperate. These may be used singularly or in combination:

Mediation

Mediation is a conflict resolution process that is designed to achieve a lasting resolution to the user groups involved in the conflict. Mediation can be used to settle disputes among fishermen when the conflicts involve gear, space, allocation, and perceptual issues. Solutions, mediated by a neutral party and agreed upon by both sides, can be implemented by proclamation, rule or statute, depending on the solution. The first and most important step is finding reasonable representative participants from both sides, whose opinions and solutions will be accepted by all involved. Mediation has been attempted three times in the history of the NCDMF and the MFC. The first attempt at mediation was to resolve a conflict on Bogue Banks between stationary stop net mullet fishermen on the beach and gill netters offshore in which gill netters were setting too close to the stop nets and blocking movement of mullet schools into the stop nets. The mediator met once with representatives of both groups, they discussed the matter and agreed upon a minimum distance gill nets were required to stay away from the stop nets and a marking system that was implemented by proclamation. In the second case between the Newport River gill netters and recreational guides, they could not even agree to meet and it failed. The mediation of the Cape Carteret creeks situation reached an impasse and demonstrated that it can be a long process and is certainly not a quick-fix solution. Even when mediation does not end in a compromise, it does provide a learning forum for all parties.

In the evaluation of possible actions, consideration needs to be given to administration and enforcement needs, as well as the likelihood that a proposed measure will successfully address the competition issue. There is limited or no benefit to putting in place a regulation that does not fully address the problem.

Gear Restriction/Rule Change

Gear restrictions may be able to resolve some conflict issues by reducing the amount of gear that is used or restrict how and where that gear is used, especially in small creeks with restricted access. Another alternative is to limit the continuous length of a net combined with minimum distance between nets or between nets and piers to allow better navigation and access by other user groups in the area. Rules exist that prohibit the setting of stationary gill nets in the channel of the Intracoastal Waterway or in any other location where it may constitute a hazard to navigation, so as to block more than two-thirds of any natural or manmade waterway, sound, bay, creek, inlet or any other body of water or in the middle third of any marked navigation channel (15A NCAC 03J .0101). Rules such as these that apply to runaround gill nets may alleviate conflicts. In creeks with no marked channels, interpretation and enforcement could be a problem.

Area Closures

The option to close a specific body of water to recreational and commercial fishing should only be used when the other methods of conflict resolution have been explored and exhausted and should be done as part of a comprehensive look at the problem since the NCDMF is charged by the N.C. General Assembly to be stewards of marine and estuarine resources and to manage those resources for the benefit of all the people of the state as a whole. During the development of the Fisheries Reform Act, the following was noted in regard to public trust: “Under the Public Trust Doctrine, all citizens have the right to use North Carolina's navigable waters for a variety of purposes, including fishing. As sovereign, the State is the owner and manager of the marine and estuarine resources that reside in

North Carolina, and is vested with all necessary authority to regulate fishing practices in order to conserve and perpetuate those fisheries."

Additional Discussion

Additional changes are proposed to 15A NCAC 03J .0103, specifically to the section providing the Fisheries Director's proclamation authority. Revisions include establishing a specified maximum gill net mesh size of six and one-half inches for Internal Coastal Waters and establishing a specified maximum net yardage of 2,000 yards. These changes will help clarify the location of the current regulations. Portions of rules have been suspended at each MFC meeting since 2007 and 2010 respectively and new proclamations have been issued following each meeting.

In 2010, the NCDMF began issuing proclamations (M-8-2010) to suspend section (i) (1) of rule 15A NCAC 03J .0103 and reduce the maximum gill net yardage. The intent of this proclamation was to implement gill net restrictions while the Division applied for a statewide ITP from the National Marine Fisheries Service under Section 10 of the Endangered Species Act. The suspension of the section (i) (1) of rule 15A NCAC 03J .0103 has continued as part of the ITP and the Southern Flounder FMP. The current proclamation (M-6-2014) makes it "unlawful to use or possess more than 2,000 yards of large mesh gill net (defined as four inches to six and one-half inches stretched mesh inclusive) per operation."

Also since 2007, a maximum gill net mesh size of six and one-half inches has been established for Internal Coastal Waters by proclamation (FF-15-2007). This was initially done for enforcement and to prevent "cheating" across area quota boundaries in the striped bass fishery. The most current proclamation (M-1-2014) makes it unlawful to use or possess gill nets with a mesh size of more than six and one-half inches (stretched mesh.) The stated intent of this proclamation is to allow harvest of flounder and shad while reducing the taking of red drum and brood stock striped bass.

To reduce confusion for the public, the proposed changes clearly identify these regulations would be contained in a proclamation, not in a rule that may or may not have been suspended. Additional minor changes are proposed for consistent capitalization, to spell out numbers, consistent use of terms, etc.

VI. PROPOSED RULE(S) (Option 3)

15A NCAC 03J .0103 GILL NETS, SEINES, IDENTIFICATION, RESTRICTIONS

(a) It is unlawful to use gill nets:

(1) ~~With~~ with a mesh length less than ~~2 ½~~ two and one-half inches.

(2) ~~In internal waters~~ in Internal Coastal Waters from April 15 through December 15, with a mesh length ~~5~~ five inches or greater and less than ~~5 ½~~ five and one-half inches.

(b) The Fisheries Director may, by proclamation, limit or prohibit the use of gill nets or seines in ~~coastal waters,~~ Coastal Fishing Waters, or any portion thereof, or impose any or all of the following restrictions on gill net or seine fishing operations:

~~(1) Specify area.~~

~~(2) Specify season.~~

~~(3) Specify gill net mesh length.~~

~~(4) Specify means/methods.~~

~~(5) Specify net number and length.~~

(1) specify time;

(2) specify area;

(3) specify means and methods, including:

(A) gill net mesh length, but the maximum size specified shall not exceed six and one-half inches in Internal Coastal Waters; and

(B) net number and length, but for gill nets with a mesh length four inches or greater, the maximum length specified shall not exceed 2,000 yards per vessel in Internal Coastal Waters regardless of the number of individuals involved; and

(4) specify season.

(c) It is unlawful to use fixed or stationary gill nets in the Atlantic Ocean, drift gill nets in the Atlantic Ocean for recreational purposes, or any gill nets in ~~internal waters~~ Internal Coastal Waters unless nets are marked by attaching to them at each end two separate yellow buoys which shall be of solid foam or other solid buoyant material no less than five inches in diameter and no less than five inches in length. Gill nets, which are not connected together at the top line, are considered as individual nets, requiring two buoys at each end of each individual net. Gill nets connected together at the top line are considered as a continuous net requiring two buoys at each end of the continuous net. Any other marking buoys on gill nets used for recreational purposes shall be yellow except one additional buoy, any shade of hot pink in color, constructed as specified in this Paragraph, shall be added at each end of each individual net. Any other marking buoys on gill nets used in commercial fishing operations shall be yellow except that one additional identification buoy of any color or any combination of colors, except any shade of hot pink, may be used at either or both ends. The owner shall be identified on a buoy on each end either by using engraved buoys or by attaching engraved metal or plastic tags to the buoys. Such identification shall include owner's last name and initials and if a vessel is used, one of the following:

(1) ~~Owner's~~ owner's N.C. motor boat registration ~~number,~~ number; or

(2) ~~Owner's~~ owner's U.S. vessel documentation name.

(d) It is unlawful to use gill nets:

(1) ~~Within~~ within 200 yards of any flounder or other finfish pound net set with lead and either pound or heart in use, except from August 15 through December 31 in all ~~coastal fishing waters~~ Coastal Fishing Waters of the Albemarle Sound, including its tributaries to the boundaries between ~~coastal and joint fishing waters,~~ Coastal and Joint Fishing Waters, west of a line beginning at a point 36° 04.5184' N - 75° 47.9095' W on Powell Point; running southerly to a point 35° 57.2681' N - 75° 48.3999' W on Caroon Point, it is unlawful to use gill nets within 500 yards of any pound net set with lead and either pound or heart in use; and

(2) ~~From~~ from March 1 through October 31 in the Intracoastal Waterway within 150 yards of any railroad or highway bridge.

(e) It is unlawful to use gill nets within 100 feet either side of the center line of the Intracoastal Waterway Channel south of the entrance to the Alligator-Pungo River Canal near Beacon "54" in Alligator River to the South Carolina line, unless such net is used in accordance with the following conditions:

(1) ~~No~~ no more than two gill nets per vessel may be used at any one time;

(2) ~~Any~~ any net used must be attended by the fisherman from a vessel who shall at no time be more than 100 yards from either net; and

(3) ~~Any~~ any individual setting such nets shall remove them, when necessary, in sufficient time to permit unrestricted ~~boat~~ vessel navigation.

(f) It is unlawful to use ~~drift gill nets in violation of 15A NCAC 03J .0101(2) and Paragraph (e) of this Rule.~~ runaround, drift, or other non-stationary gill nets, except as provided in subparagraph (e) of this rule;

(1) to block more than two-thirds of any natural or manmade waterway, sound, bay, creek, inlet or any other body of water; or

(2) in a location where it will interfere with navigation or with existing, traditional uses of the area other than navigation.

(g) It is unlawful to use unattended gill nets with a mesh length less than five inches in a commercial fishing operation in the gill net attended areas designated in 15A NCAC 03R .0112(a).

(h) It is unlawful to use unattended gill nets with a mesh length less than five inches in a commercial fishing operation from May 1 through November 30 in the ~~internal coastal and joint waters~~ Internal Coastal Waters and Joint Fishing Waters of the state designated in 15A NCAC 03R .0112(b).

~~(i) For gill nets with a mesh length five inches or greater, it is unlawful:~~

~~(1) To use more than 3,000 yards of gill net per vessel in internal waters regardless of the number of individuals involved.~~

~~(2) From June through October, for any portion of the net to be within 10 feet of any point on the shoreline while set or deployed, unless the net is attended.~~

(i) It is unlawful for any portion of a gill net with a mesh length five inches or greater to be within 10 feet of any point on the shoreline while set or deployed, unless the net is attended from June through October in Internal Coastal Waters.
(j) For the purpose of this Rule and 15A NCAC 03R .0112, shoreline is defined as the mean high water line or marsh line, whichever is more seaward.

History Note: *Authority G.S. 113-134; 113-173; 113-182; 113-221; 143B-289.52;*
Eff. January 1, 1991;
Amended Eff. August 1, 1998; March 1, 1996; March 1, 1994; July 1, 1993; September 1, 1991;
Temporary Amendment Eff. October 2, 1999; July 1, 1999; October 22, 1998;
Amended Eff. April 1, 2001;
Temporary Amendment Eff. May 1, 2001;
Amended Eff. April 1, 2016; April 1, 2009; December 1, 2007; September 1, 2005; August 1, 2004; August 1, 2002.

VII. PROPOSED MANAGEMENT OPTIONS

1) Status Quo
   - \+ No new regulations or enforcement are needed.
   - – The mediation process can be long and is not always successful in resolving the conflict.

2) Mediation for Specific Areas to Reduce Conflict Between Recreational Hook-and-Line Fishermen, Commercial Fishermen Using Runaround Gill Nets, and Shoreline Residents.
   - \+ Groups involved in competition assist in developing restrictions for area.
   - \+ Promotes cooperation among user groups.
   - \+ Restrictions can be designed to meet the needs of the local user groups involved in the conflict.
   - – Conflict not resolved immediately.
   - – Only works if both parties are willing to compromise.
   - – May take a series of meetings to develop appropriate strategy.

3) Gear Restrictions/Rule Change – Adopt a rule restricting runaround gill nets and non-stationary nets similar to the rule restricting stationary or fixed gill nets.
   - \+ May minimize user conflicts by restricting runaround gill nets in ways similar to those that govern stationary gill nets to avoid hazards to navigation and impeding access to piers and marinas.
   - \+ Can be applied statewide, which could prevent future user conflicts in other parts of the state.
   - – May be difficult to enforce when channels are not marked and officer is not on scene to observe violation.
   - – Only has an impact on one user group in the conflict.
   - – Could impact fisheries not otherwise involved (i.e. spot).

4) Area Closures
   - \+ Minimizes user conflicts by closing the commercial striped mullet fishery over the weekend and recreational fishery during the week.
   - \+ Reduces the amount of incidents of anglers damaging small mesh gill nets.
   - \+ Potential to reduce dead discards of finfish.
   - – Would impact areas where no user conflicts occur.

- Would negatively impact individuals not involved in conflict if closures are enforced throughout the State.
- Need to increase public awareness of new regulations.
- Increases enforcement responsibilities for Marine Patrol.

VIII. RECOMMENDATION

NCDMF:

Recognizing the need to resolve this particular conflict in a manner that does not violate the public trust rights of the fishermen and may reduce the residents' complaints, the NCDMF proposes the amendment of rule 15A NCAC 03J .0103 to add regulations for runaround or non-stationary gill nets similar to 15A NCAC 03J .0101 for fixed or stationary nets. This would make it unlawful to block more than two-thirds of any natural or manmade waterway, sound, bay, creek, inlet or any other body of water; or in a location where it will interfere with navigation or with existing, traditional uses of the area other than navigation. This should help to reduce the primary conflict of competition for limited space in creeks. Other conflicts such as lights, noise, and trespassing on private property by netters will continue to be handled on a case-by-case basis.

Finfish Advisory Committee (Striped Mullet FMP Advisory Committee):

The AC did not come to a consensus on this issue. A vote in support of Status Quo failed, 3-3-1.

MFC Selected Management Strategy:

Same as NCDMF recommendation.

Prepared by
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February 19, 2013 Draft 1

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March 7, 2013	Draft 2
March 31, 2014	Draft 3
April 7, 2014	Draft 4
April 16, 2014	Draft 5
May 5, 2014	Draft 6
May 27, 2014	Final

10.3 MANAGEMENT FRAMEWORK FOR THE NORTH CAROLINA STRIPED MULLET STOCK ISSUE PAPER[3]

I. ISSUE

Update to the management measures for striped mullet to maintain the sustainability of the striped mullet stock.

II. ORIGINATION

The Striped Mullet Fishery Management Plan (FMP) Plan Development Team (PDT) while developing Striped Mullet FMP Amendment 1.

III. BACKGROUND

The North Carolina striped mullet commercial fishery harvests an average of 1.94 million lb per year (1994–2011) and is the largest striped mullet fishery along the east coast of the United States. Striped mullet, both juveniles and adults, are harvested throughout the year. However, much of the effort occurs in the fall, targeting adult female (roe) striped mullet during their spawning migration to the ocean. The recreational fishery is likely smaller and mainly consists of cast-netted juveniles used for bait with some recreational gill netting of adult fish. An increase in fishing effort after a rise in roe value in the 1980s initially caused concern for the stock. Therefore, it was designated as a species of concern in the division's 1999 stock status report.

The original 2006 Striped Mullet FMP adopted a fishing mortality overfishing threshold of $F_{25\%}$ spawning potential ratio (SPR) and a fishing mortality target of $F_{30\%}$ SPR and determined overfishing was not occurring (NCDMF 2006). The FMP also established minimum and maximum commercial landings triggers that if exceeded would prompt a reassessment of the striped mullet stock before the normal five-year review outlined in statute as required by the Fisheries Reform Act.

As part of Amendment 1 to the Striped Mullet FMP, a stock assessment of the North Carolina striped mullet stock was conducted using the Stock Synthesis model, which incorporated data from commercial fisheries and three fishery-independent surveys from 1994 to 2011. For the current stock assessment, the PDT raised the fishing mortality target to $F_{35\%}$ SPR, from $F_{30\%}$ SPR adopted by the original 2006 striped mullet FMP (NCDMF 2006) and maintained the fishing mortality threshold at $F_{25\%}$ SPR. The fishing mortality target was increased due to the fishery targeting female fish during the spawning season, the potential importance of striped mullet as a forage species in the ecosystem, and because the small buffer between the target and threshold values could result in rebuilding plans with more restrictive harvest.

Stock Synthesis estimated a value of 0.93 for $F_{25\%}$ (threshold) and a value of 0.57 for $F_{35\%}$ SPR (target). These estimates are numbers-weighted values for ages 2–5 and so are consistent with the reported F values in the stock assessment. Predicted F in 2011 was 0.44. As such, overfishing is not occurring in the striped mullet stock ($F_{2011} < F_{25\%}$; Figure 10.2). Due to the poor stock-recruitment relationship, estimates of a biomass-based

[3] Presented to: PDT 5/19/14 and 7/10/14; AC 6/10/14 and 7/15/14; MRT 7/21/14 and 7/31/14.

reference point were considered unreliable. Therefore, status in relation to the overfished condition is considered unknown.

Although overfishing is not occurring fishing mortality has increased and recruitment has shown a declining trend in recent years. If this trend continues, a series of poor recruitment events occur, and/or there are shifts in market demand, management measures may be needed to reduce harvest. An *F*-based threshold based on a SPR = 25% ($F_{25\%}$ = 0.93), should be appropriate to maintain the recent harvest levels while preventing overfishing. While fishing mortality has increased in the last few years, the heaviest exploitation in the past 20 years occurred in 2000. Historically, the commercial fishery has sustained landings similar in scope to current levels (with wide fluctuations) for over 100 years, with the historical median landings equal to 2,137,502 lb and the 1994–2011 median equal to 1,727,425 lb (average = 1,942,346 million lb; see FMP Commercial Fishery section 6.1).

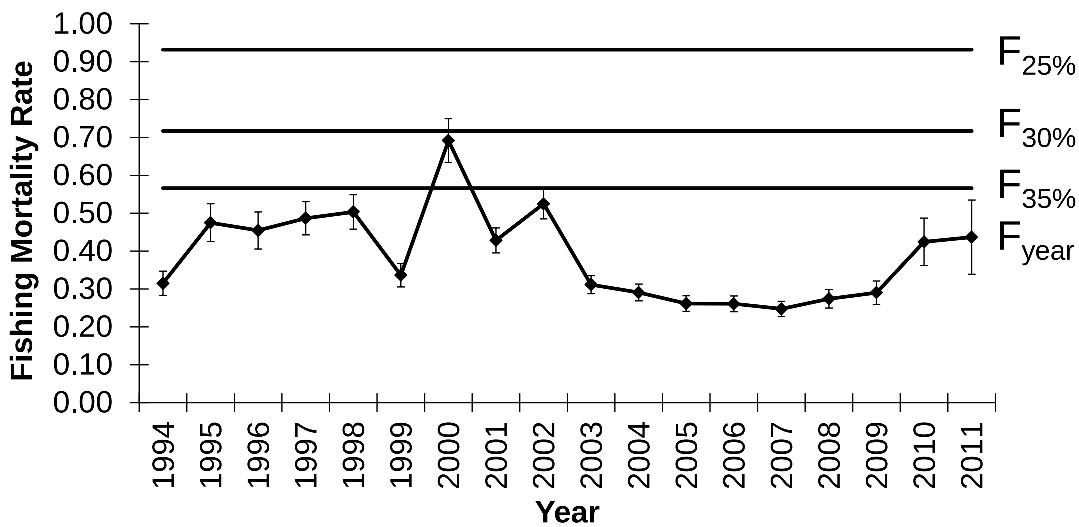

Figure 10.2. Annual predicted fishing mortality rates (numbers-weighted, ages 2–5) compared to estimated *F*-threshold ($F_{25\%}$) and *F*-target ($F_{35\%}$) adopted in the 2013 stock assessment and the *F*-target ($F_{30\%}$) in the 2006 Striped Mullet FMP. Error bars represent ± 1 standard deviation of fishing mortality rate.

This issue paper updates and reevaluates the management options presented in the “Striped Mullet Management Measures” issue paper from the 2006 Striped Mullet FMP (NCDMF 2006).

IV. AUTHORITY

G.S. 113-134 RULES
G.S. 113-182 REGULATION OF FISHING AND FISHERIES
G.S. 143B-289.52 MARINE FISHERIES COMMISSION-POWERS AND DUTIES
15A NCAC 03M .0502 Mullet
15A NCAC 03H .0103 Proclamation Authority of Fisheries Director

V. DISCUSSION

Several management tools are available to maintain a sustainable harvest in the striped mullet fishery. These may include landings triggers, quotas, size limits, seasonal closures, area closures, trip and/or creel limits, gear restrictions, and limited entry or some combination of these measures. Section 2.1 of the Fisheries Reform Act (G.S. 113-182.1) concerning Fishery Management Plans (FMPs) states the North Carolina Marine Fisheries Commission (MFC) can only recommend the General Assembly limit participation in a fishery if the MFC determines sustainable harvest in the fishery cannot otherwise be achieved. Sustainable harvest can be maintained with status quo therefore limited entry cannot be considered an option at this time. The management options presented in this paper are a starting point for discussion on maintaining sustainable harvest. Public input could provide additional options.

VI. POTENTIAL MANAGEMENT MEASURES

Status Quo

One management approach is *status quo*; maintain the current commercial landings triggers and the 2006 Striped Mullet FMP fishing mortality target and threshold. The 2006 Striped Mullet FMP established minimum and maximum commercial landings triggers. These triggers were set two standard deviations from the average of commercial landings from 1994–2002. Commercial landings below the minimum trigger of 1.30 million lb would initiate further analysis of the striped mullet stock data to determine if a sharp decrease in landings is attributed to stock decline or decreased fishing effort. Likewise, if commercial landings exceed the maximum landings trigger of 3.10 million lb the striped mullet stock would be reassessed to determine if it is sustainable and evaluate if market shifts have occurred that need to be addressed (Figure 10.3; NCDMF 2006). This option would also maintain the current fishing mortality threshold of $F_{25\%}$ SPR and target of $F_{30\%}$ SPR (Figure 10.2).

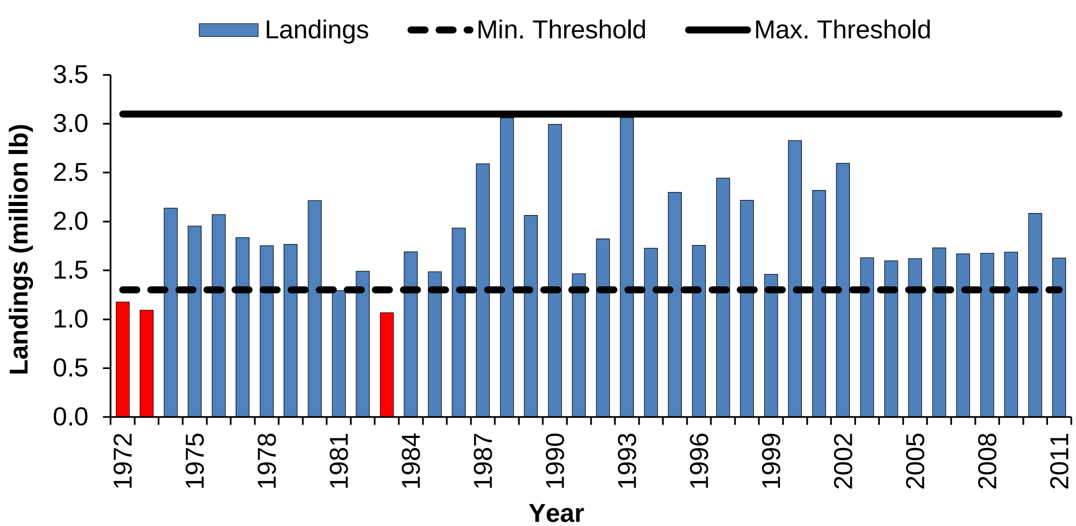

Figure 10.3. Annual commercial landings and value of the North Carolina striped mullet fishery with current minimum and maximum threshold triggers: 1972–2011. Years in red are past years where trigger would have been activated if it were in place.

For the recreational fishery, the possession limit of 200 mullet (striped and white mullet combined) per person per day would also remain unchanged. The striped mullet stock will be reassessed five years after final adoption of Amendment 1 (~ 2020) as required by the Fisheries Reform Act.

Update Triggers for Reassessment, Change Fishing Mortality Target, and Implement Adaptive Management

This option would result in no new immediate management measures to the striped mullet fishery, but would update the minimum and maximum commercial landings triggers (set two standard deviations above and below the average commercial landings as in the status quo option above) using commercial landings from 1994–2011. Commercial landings below the recomputed minimum trigger of 1.13 million lb would initiate further analysis of the data to determine if a sharp decrease in landings is attributed to stock decline or decreased fishing effort. Likewise, if commercial landings exceed the recomputed maximum landings trigger of 2.76 million lb, data would be analyzed to determine sustainability and evaluate if market shifts have occurred that need to be addressed (Figure 10.4). This option would also increase the fishing mortality target from $F_{30\%}$ SPR to $F_{35\%}$ SPR, as adopted by the PDT in the stock assessment, due to the fishery targeting female fish during the spawning season, the potential importance of striped mullet as a forage species in the ecosystem, and because the small buffer between the target and threshold values could result in rebuilding plans with more restrictive harvest.

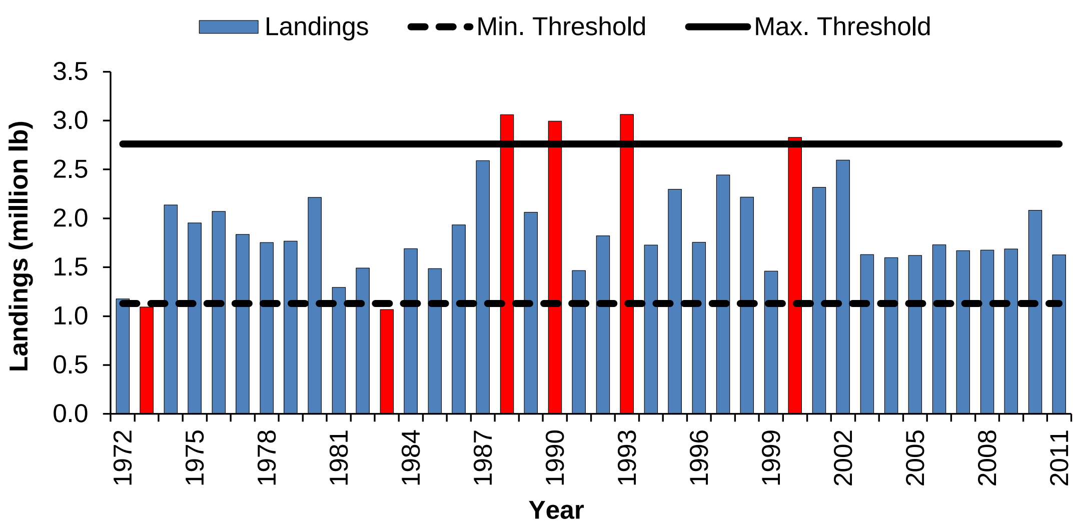

Figure 10.4. Annual commercial landings of the North Carolina striped mullet fishery with the updated minimum and maximum threshold triggers: 1972–2011. Years in red are past years where trigger would have been activated if it were in place.

For the recreational fishery, the possession limit of 200 mullet (striped and white mullet combined) per person per day would remain unchanged. The striped mullet stock will be reassessed five years after final adoption of Amendment 1 (~2020) as required by the Fisheries Reform Act, unless a trigger is activated and a review of the data indicates a new stock assessment is warranted sooner.

If a trigger is activated, adaptive management will be used to implement additional management measures if needed to maintain sustainable harvest. Any management measures will be developed by the PDT in conjunction with advisory committee and approved by the MFC prior to implementation using the proclamation authority of the Fisheries Director.

Quotas

A quota is the maximum amount of fish that can be legally landed within a specified time period. The intent for implementing a quota on any fishery is to prevent further expansion and reduce or stabilize harvest. The annual commercial landings of striped mullet have been relatively stable since 2003 and establishing a reasonable harvest quota would be relatively straightforward. The North Carolina commercial striped mullet fishery changed markedly in the late 1980s with increased demand from Asia for striped mullet roe. From 1972 to 1986, annual landings in the striped mullet fishery averaged 1.66 million lb, with a range of 1.07 to 2.22 million lb (Figure 10.4). Average annual landings from 1987 to 1993 were 2.44 million lb, with landings near or exceeding 3.00 million lb in 1988, 1990, and 1993. In 1988, landings exceeded 3.00 million lb for the first time in 28 years. There were wide fluctuations in landings from 1994–2002. Since 2003, average annual landings were 1.70 million lb, with a high of 2.08 million lb in 2010 and a low of 1.60 million lb in 2004 (see Commercial Fishery section 6.1).

Due to variability in recruitment, a quota may not prevent overfishing during years where there is poor recruitment. A quota has to be monitored with dealer reporting, which would be an additional burden to commercial fish house dealers and the NCDMF. There are currently over 800 participants involved in the fishery and about 200 dealers (see Socioeconomic section 8.0). A quota may also increase discards in fisheries not targeting striped mullet as any fish caught after the quota was reached would have to be discarded.

The Marine Recreational Information Program (MRIP) reported recreational angler harvest have varied greatly since 1989 (maximum = 877,595 lb in 2003 and minimum = 1,237 lb in 2008) with reported harvest of 52,093 lb in 2010 and 10,958 lb in 2011. The Recreational Commercial Gear License (RCGL) survey, conducted by NCDMF from 2002 through 2008, reported a total harvest of 290,586 lb of striped mullet by RCGL holders. However, the data are not adequate to evaluate the impacts of or at what level a quota should be set for the recreational fishery (see Recreational Fishery section 6.2).

Size Limits

Size regulations are a management tool based on the species' reproduction and life history. Minimum size limits allow fish to spawn at least once contributing to the growth of that fishes' population before capture. Maximum size limits are used to protect the larger fish that produce more eggs. Harvest slot limits are a size range in which fish may be kept. This protects both the smaller immature fish and the large females that may produce more eggs than smaller females. Protected slot limits consist of a size range in which fish must be released. The purpose of this type of limit is to protect medium-sized fish so that they may grow larger and to protect a size class that may be very prolific.

While size limits are effective management tools in other fisheries, it may not be effective in the striped mullet commercial fishery. Juvenile and adult striped mullet over a broad size range (60–640 mm fork length (FL); ~2.5–26 inches FL) occur in the commercial harvest, which includes trips targeting striped mullet and targeting other species (Figure 10.5).

Because almost all commercially caught striped mullet are marketable, discards of mullet in directed and other fisheries are extremely low. Implementing size limits for striped mullet will increase discards in both directed and other fisheries, and diminish conservation of the SSB. Special caution should be taken not to change the commercial fishery selectivity pattern towards the targeting of smaller-sized fish. If the fishery selectivity changes towards smaller, younger fish, the threshold *F* will be lowered, defeating the effectiveness of the management action.

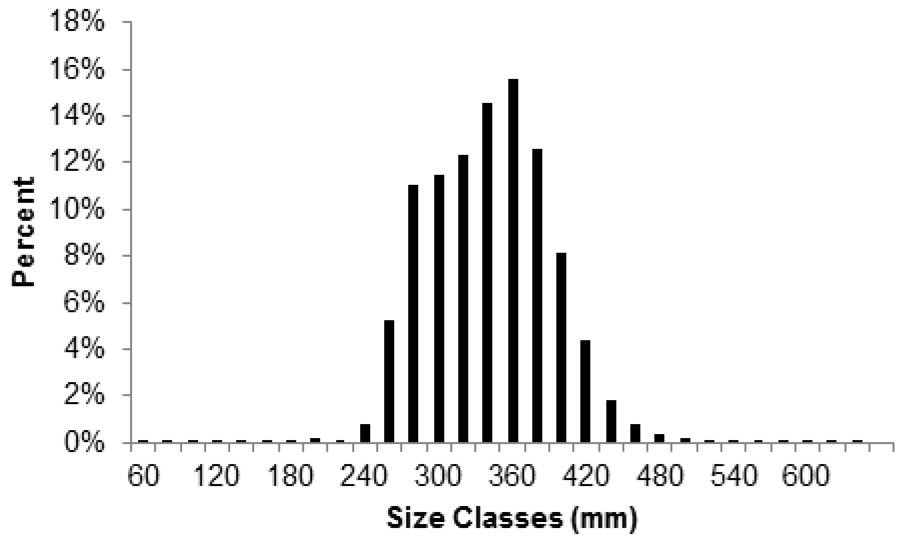

Figure 10.5. Length distribution (mm) of the North Carolina commercial striped mullet fishery: 1994–2011.

The estimated size at 50% maturity for female striped mullet was 299 mm FL (~11.8 inches; NCDMF 2013). Bichy (2004) estimated size at 50% maturity as 325 mm FL (~12.8 inches), but the time series was limited compared to NCDMF data (Bichy: 1996–2000, NCDMF: 1997–2011). From 1994–2011, approximately 18% (by number) of striped mullet sampled from commercial landings were less than 300 mm FL. Enacting a minimum size limit would have a large impact on the commercial bait cast-net portion of the fishery, where 99% of the striped mullet sampled in commercial cast nets were less than 300 mm FL. However, this fishery accounts for a minor portion of the overall commercial harvest (Table 10.1, Figure 10.6) and would likely result in minimal harvest reductions.

Table 10.1. Average annual landings (lb) by gear in the North Carolina commercial striped mullet fishery: 1994–2011.

Gear	Average Annual Landings (lb)
Gill Net (runaround)	1,072,022
Gill Net Set, <5-in mesh*	306,311
Gill Net Set (sink)	304,194
Gill Net Set (float)	235,706
Beach Seine	92,292
Gill Net Set, ≥5-in mesh*	83,506
Cast Net	34,265
Gill Net (drift)	9,044
Pound Net	8,171
Haul Seine	5,249
Others (20)	8,152

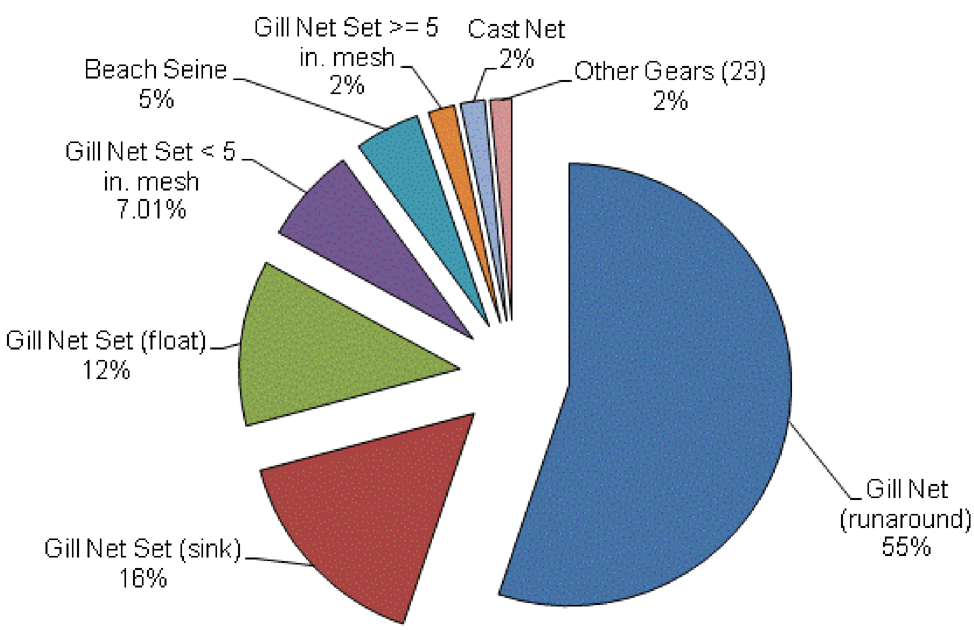

Figure 10.6. Average percent of annual landings by gear in the North Carolina striped mullet fishery: 1994–2011.

Size limits would also affect recreational anglers who are known to cast net young-of-the-year striped mullet (finger mullet) to use as bait. However, there are not adequate recreational harvest length data to evaluate the impacts of a size limit for the recreational fishery (see Recreational Fishery section 6.2).

Seasonal Closures

Seasonal closures are intended to protect a portion of the stock in order to increase recruitment with the least effect to fishermen. Most commercial fishing mortality of striped mullet occurs on roe (pre-spawned) individuals in July–December of each year. The months of December and January still have some spawning females available and landings have dropped within the fishery when there may be a reduced economic impact to fishermen. By calculating and reducing by the average harvest in the month of December the savings is additive to the annual SSB by the potential saving of mature pre-spawn females. However, savings from the month of January is not additive to the annual SSB because almost all fishing mortality occurs on pre-spawned females from July–December of each year. Eliminating harvest from the months of December and January would allow an average annual harvest reduction of 4.2% and 5.9%, respectively, based on the average of striped mullet commercially harvested (lb) from 1994–2011 (Table 10.2, Figure 10.7). A possible result of a seasonal closure is an increase in effort during the open period to compensate for the seasonal closure. Increased landings during the open period could minimize the savings of mature females from the seasonal closure because it could increase the harvest of smaller fish.

Economic effects on fishermen from a closure will vary by area. The month of December accounts for 3.5% of the annual striped mullet commercial value ($) and the month of January accounts for 4.3% by value (Table 10.3). A January closure would have the largest economic impacts on the Albemarle Sound area with 31.0% of the value of landings occurring in this area in January. The economic effects of a December closure would be more wide reaching and less impactful effect to one particular area with the largest economic impacts on the following areas in the month of December: Albemarle Sound (14.4% of total landings value), Inland Waterway (14.2% of total landings value), Neuse River (11.6% of total landings value), and Pamlico River (11.6% of total landings value; Table 10.3). If closures were to occur, catches would be eliminated for striped mullet in the directed fishery and in some other fisheries occurring in these areas.

The RCGL survey determined that from 2002 to 2008 the highest numbers of trips, accounting for 23.1% of all trips, were taken in October (8,889), and 65.8% of the total harvest of mullet (lb) occurred during the months of July (16.1%), August (18.6%), September (12.3%) and October (18.8%). However, the data are not adequate to evaluate the impacts of seasonal closures for the recreational fishery (see Recreational Fishery section 6.2).

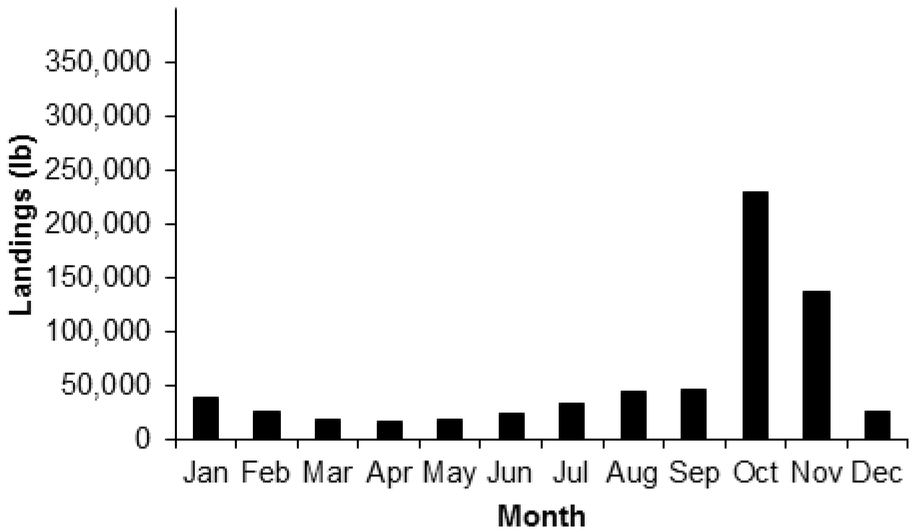

Figure 10.7. Average monthly commercial landings (lb) for the North Carolina striped mullet fishery: 1994–2011.

Table 10.2. Average commercial landings (lbs.) of striped mullet by area and month (all gears combined): 1994–2011.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	All
Pamlico Sound	7,098	5,178	3,206	5,477	8,539	17,831	24,650	48,068	38,072	137,461	60,717	6,057	362,353
	5.7%	6.2%	5.8%	11.0%	16.4%	27.6%	27.2%	34.9%	24.3%	18.3%	13.3%	6.9%	17.2%
Neuse River	16,326	10,304	8,782	9,358	13,861	12,197	13,868	14,980	14,534	79,039	43,708	11,244	248,201
	13.1%	12.4%	15.8%	18.8%	26.6%	18.9%	15.3%	10.9%	9.3%	10.5%	9.6%	12.8%	11.8%
Core Sound	2,877	1,824	977	1,454	2,274	4,886	10,134	17,404	12,829	128,029	53,871	3,327	239,884
	2.3%	2.2%	1.8%	2.9%	4.4%	7.6%	11.2%	12.6%	8.2%	17.0%	11.8%	3.8%	11.4%
Ocean 0–3 miles	1,272	956	550	576	462	638	1,564	8,030	36,090	158,516	109,022	3,746	321,421
	1.0%	1.1%	1.0%	1.2%	0.9%	1.0%	1.7%	5.8%	23.1%	21.1%	23.9%	4.3%	15.2%
Pamlico River	12,931	7,230	5,859	6,515	6,576	6,872	6,418	6,930	5,460	36,951	16,783	11,258	129,782
	10.4%	8.7%	10.5%	13.1%	12.6%	10.6%	7.1%	5.0%	3.5%	4.9%	3.7%	12.8%	6.1%
Croatan Sound	2,180	1,003	935	803	946	1,938	2,799	3,681	5,772	40,718	7,309	1,531	69,615
	1.8%	1.2%	1.7%	1.6%	1.8%	3.0%	3.1%	2.7%	3.7%	5.4%	1.6%	1.7%	3.3%
Inland Waterway	6,729	4,243	2,162	2,285	918	1,017	1,964	3,941	8,435	40,932	43,639	11,595	127,859
	5.4%	5.1%	3.9%	4.6%	1.8%	1.6%	2.2%	2.9%	5.4%	5.4%	9.6%	13.2%	6.1%
Bogue Sound	900	1,311	291	145	129	566	1,787	3,535	2,762	33,803	35,147	3,354	83,731
	0.7%	1.6%	0.5%	0.3%	0.2%	0.9%	2.0%	2.6%	1.8%	4.5%	7.7%	3.8%	4.0%
New River	5,431	4,004	4,556	4,978	3,786	3,348	3,272	3,267	3,863	11,424	12,817	3,722	64,468
	4.4%	4.8%	8.2%	10.0%	7.3%	5.2%	3.6%	2.4%	2.5%	1.5%	2.8%	4.2%	3.1%
Albemarle	40,635	27,333	17,724	12,037	8,357	7,369	13,464	14,129	13,089	37,979	18,950	13,918	224,984
	32.7%	32.8%	31.9%	24.2%	16.0%	11.4%	14.8%	10.3%	8.4%	5.0%	4.2%	15.9%	10.7%
Others (18)	27,849	19,877	10,522	6,201	6,242	8,011	10,845	13,771	15,558	47,372	53,911	17,859	238,017
	22.4%	23.9%	18.9%	12.4%	12.0%	12.4%	11.9%	10.0%	9.9%	6.3%	11.8%	20.4%	11.3%
Total	124,228	83,261	55,563	49,829	52,089	64,671	90,765	137,735	156,464	752,225	455,873	87,611	2,110,314
	5.9%	3.9%	2.6%	2.4%	2.5%	3.1%	4.3%	6.5%	7.4%	35.6%	21.6%	4.2%	100.0%

Table 10.3. Average commercial value ($) of striped mullet by area and month (all gears combined): 1994–2011.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	All
Pamlico Sound	3,002	2,170	1,390	2,254	3,558	7,490	10,424	20,158	16,471	87,356	40,118	2,835	197,226
	5.9%	6.2%	6.0%	11.0%	16.4%	27.9%	27.3%	35.5%	25.1%	17.8%	13.0%	7.0%	16.7%
Neuse River	6,877	4,303	3,687	3,876	5,793	5,092	5,771	6,401	6,023	50,695	28,129	4,705	131,352
	13.5%	12.4%	15.9%	18.9%	26.7%	18.9%	15.1%	11.3%	9.2%	10.3%	9.1%	11.6%	11.1%
Core Sound	1,230	775	408	585	966	2,035	4,178	7,338	5,409	84,992	37,539	1,563	147,018
	2.4%	2.2%	1.8%	2.9%	4.5%	7.6%	10.9%	12.9%	8.2%	17.3%	12.2%	3.8%	12.5%
Ocean 0–3 miles	558	350	239	217	176	255	694	3,519	14,762	106,935	78,733	2,244	208,682
	1.1%	1.0%	1.0%	1.1%	0.8%	0.9%	1.8%	6.2%	22.5%	21.8%	25.5%	5.5%	17.7%
Pamlico River	5,409	2,902	2,413	2,663	2,677	2,800	2,664	2,923	2,201	23,649	8,570	4,725	63,596
	10.6%	8.4%	10.4%	13.0%	12.4%	10.4%	7.0%	5.1%	3.4%	4.8%	2.8%	11.6%	5.4%
Croatan Sound	914	419	385	335	383	794	1,153	1,561	2,496	24,500	4,504	678	38,122
	1.8%	1.2%	1.7%	1.6%	1.8%	3.0%	3.0%	2.7%	3.8%	5.0%	1.5%	1.7%	3.2%
Inland Waterway	2,842	1,739	960	982	392	422	830	1,598	3,450	29,895	32,763	5,799	81,672
	5.6%	5.0%	4.1%	4.8%	1.8%	1.6%	2.2%	2.8%	5.3%	6.1%	10.6%	14.2%	6.9%
Bogue Sound	409	587	129	74	55	231	734	1,517	1,227	24,201	24,192	1,892	55,248
	0.8%	1.7%	0.6%	0.4%	0.3%	0.9%	1.9%	2.7%	1.9%	4.9%	7.8%	4.6%	4.7%
New River	2,302	1,690	1,918	2,051	1,598	1,402	1,393	1,383	1,566	7,369	9,156	1,677	33,505
	4.5%	4.9%	8.3%	10.0%	7.4%	5.2%	3.6%	2.4%	2.4%	1.5%	3.0%	4.1%	2.8%
Albemarle	15,812	11,049	7,227	4,865	3,484	3,061	5,625	5,625	5,486	21,127	9,665	5,872	98,898
	31.0%	31.8%	31.2%	23.7%	16.1%	11.4%	14.7%	9.9%	8.4%	4.3%	3.1%	14.4%	8.4%
Others (18)	11,683	8,759	4,436	2,613	2,579	3,291	4,757	4,757	6,608	30,062	34,999	8,734	123,278
	22.9%	25.2%	19.1%	12.7%	11.9%	12.2%	12.4%	8.4%	10.1%	6.1%	11.3%	21.4%	10.5%
Total	51,038	34,743	23,192	20,515	21,661	26,873	38,223	56,780	65,699	490,781	308,368	40,724	1,178,597
	4.3%	2.9%	2.0%	1.7%	1.8%	2.3%	3.2%	4.8%	5.6%	41.6%	26.2%	3.5%	100.0%

Area Closures

Area closures have been shown to provide benefits that include greater productivity of fish stocks due to increased densities, average sizes, and reproductive output by providing a safe haven for fish to live and reproduce. This type of closure is used to provide protection during spawning and in nursery areas where juvenile fish can develop and grow. Striped mullet are a catadromous species, migrating from freshwater to offshore marine waters in the fall to spawn. Because of this life history, striped mullet use a variety of habitats with variations in preference due to location, season, and life stage, and are found in most habitats identified by the North Carolina Coastal Habitat Protection Plan (CHPP) including: water column, wetlands, submerged aquatic vegetation (SAV), soft bottom, and shell bottom (Deaton et al. 2010). Therefore, identifying particular areas to serve as refuge would be difficult (see Life History section 5.1 and Environmental Factors section 9.1).

Historically, the majority of the annual commercial striped mullet harvest had come from state-jurisdiction ocean waters via the beach seine fishery. Around 1994, a sharp decline in landings from ocean waters occurred and annual ocean landings have remained depressed until present. However, the proportion of landings from other areas has generally increased, compensating for the landings decline from the ocean (see Commercial Fishery section 6.1). Commercial landings (1994–2011) are now harvested more evenly among several areas: Pamlico Sound (17.2%), Neuse River (11.8%), Core Sound (11.4%), Ocean 0–3 miles (15.2%), Pamlico River (6.1%), Croatan Sound (3.3%), Inland Waterway (6.1%), Bogue Sound (4.0%), New River (3.1%), and Albemarle Sound (10.7%; Table 10.2, Figure 10.8).

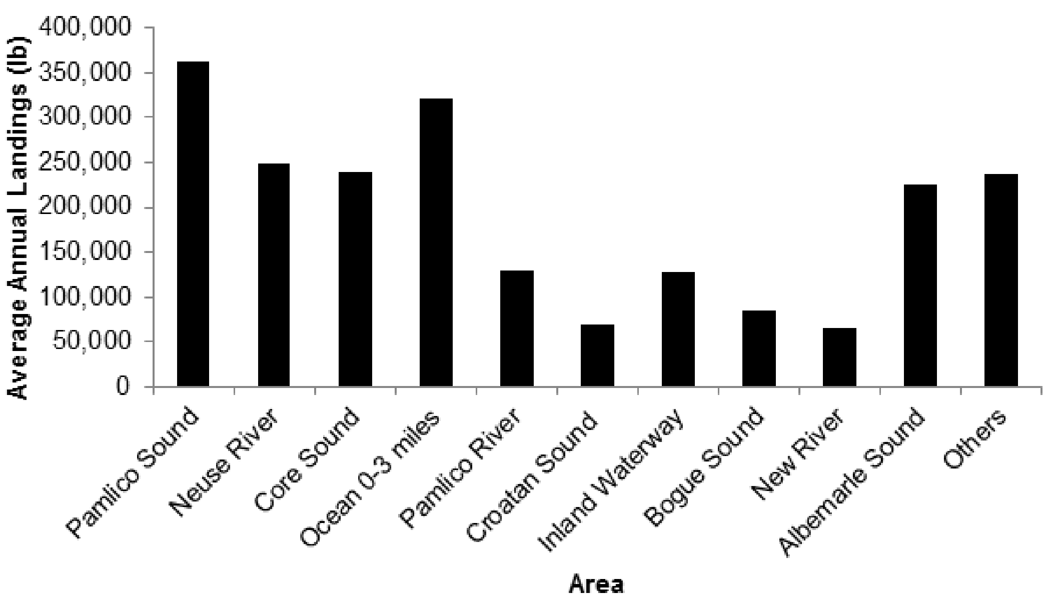

Figure 10.8.   Average annual commercial landings (lb) by area for the North Carolina striped mullet fishery: 1994–2011.

The RCGL survey determined the total poundage of mullet (white and striped) by weight harvested by RCGL holders for the coastal region were 41.1%, 19.6%, 18.9%, and 17.7% respectively for the Central, Northern, Pamlico, and Southern regions from 2002 to 2008.

However, the data is not adequate to evaluate the impacts of area closures for the recreational fishery (see Recreational Fishery section 6.2).

Trip/Creel Limits

Trip harvest or creel limits refers to numbers of fish you can keep each day as well as the total number you can have in your possession for the entire fishing trip. Limits vary widely depending on the fish species and its stock status and are set to help provide equitable distribution of harvest over time while ensuring a sustainable population for the future. Trip harvest limits may not work well for the striped mullet commercial fishery because a majority of the landings are taken in a very short period of time. Mixed market grade harvest occurs year-round, although more heavily in late summer to early fall and in January, probably associated with increased availability due to migratory schooling during these months. Ninety-eight percent of the annual red roe harvest and 95% of the white roe harvest occurs in October and November (Figure 10.9). Most spawning striped mullet will be graded as mixed after Thanksgiving, even though ripe fish are occasionally harvested into February–March. The roe market shifts from North Carolina to Florida in December. Most documented trips in the commercial striped mullet fishery are composed of small catches. Of the total number of trips harvesting striped mullet between 1994 and 2011, 70.2% were composed of catches with less than 100 lb landed. However, trips with less than 100 lb of striped mullet harvest accounted for only 9.3% of the total landings in weight between 1994 and 2011 (Figure 10.10). Furthermore, catches with less than five lb of striped mullet harvest were the most common trip type, accounting for 23% of total trips (Figure 10.11).

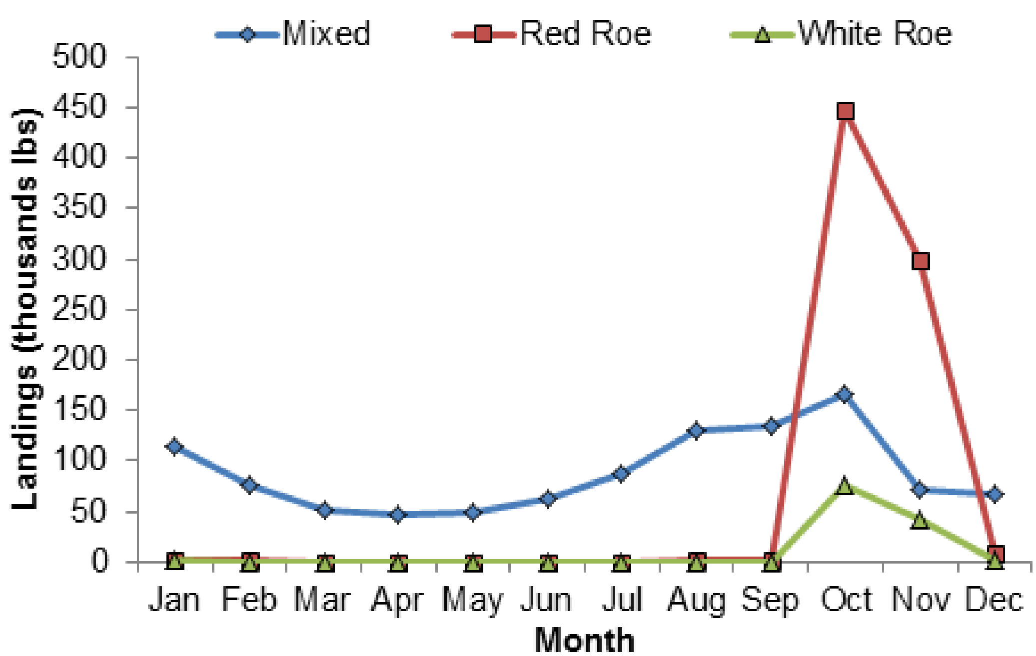

Figure 10.9. Average monthly commercial landings (thousands lb) for the three major market categories in the North Carolina striped mullet fishery: 1994–2011.

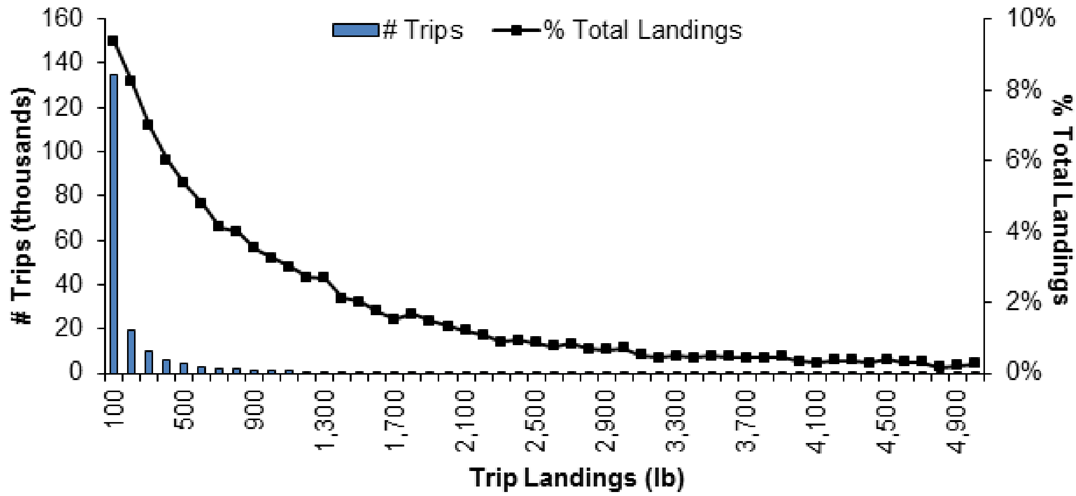

Figure 10.10. Total number of trips in each 100 lb size class of harvest and its percentage of the total landings of the North Carolina striped mullet fishery: 1994–2011 (e.g. 100(x-axis) – all trips with 1–100 lb of harvest).

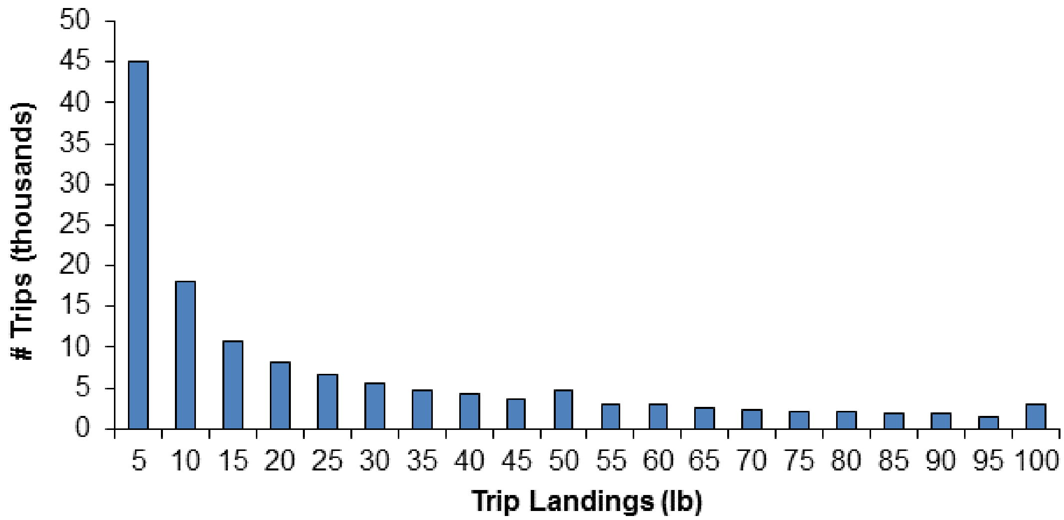

Figure 10.11. Total number of trips for each 5 lb weight class of landings for trips harvesting ≤100 lbs in the North Carolina striped mullet fishery: 1994–2011. Note: the 5 lb weight class represents all trips with 1–5 lbs landed.

Pronounced year-to-year fluctuations in red roe harvest are evident from 1994 to 2011 (Figure 10.12). Strong weather conditions (hurricanes, cold fronts) during the fall can profoundly affect landings from year to year. In addition to limiting fishing opportunities, hurricanes and hard winds can cause mature fish to exit inshore areas rapidly and prematurely. Hurricanes Fran (1996), Floyd (1999), Isabel (2003), and Irene (2011) likely caused fish to move offshore earlier than normal contributing to decreased landings in those years. A trip or vessel harvest limit would also prevent fishermen from taking advantage of periods of large catches due to wind and storm events and create regulatory discards if trip harvest limits are imposed.

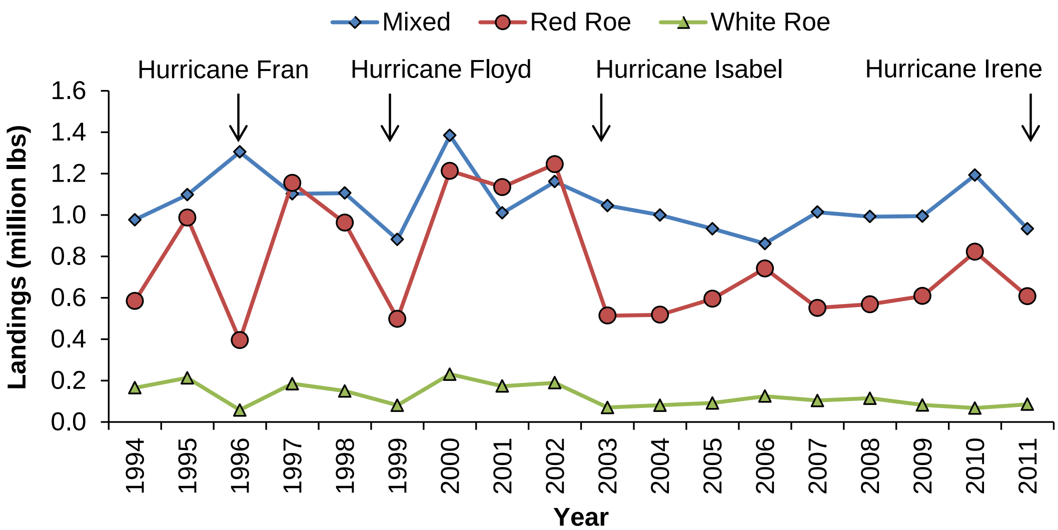

Figure 10.12. Annual landings for the three major market categories in the North Carolina striped mullet fishery: 1994–2011.

In the mid-1980s, there was a large demand increase due to an opening of Asian markets for striped mullet roe. This demand led to increases in pounds landed and significantly higher ex-vessel prices per pound. Beginning in the mid-1990s, ex-vessel prices began to drop due to a slowing of the Asian economy and fewer processors buying striped mullet and roe from North Carolina fishermen. Ex-vessel values followed this trend. The years 2010 and 2011 saw a rebound in both price and landings of striped mullet (Figure 12; also see Socioeconomics section 8.0). Since landings have been known to increase with increasing demand and higher ex-vessel prices per pound, a trip or vessel harvest limit could help maintain a sustainable harvest while still allowing fishermen to benefit economically.

The recreational fishery currently operates under a rule limiting the daily possession limit to 200 mullet (striped and white mullet combined) per person per day.

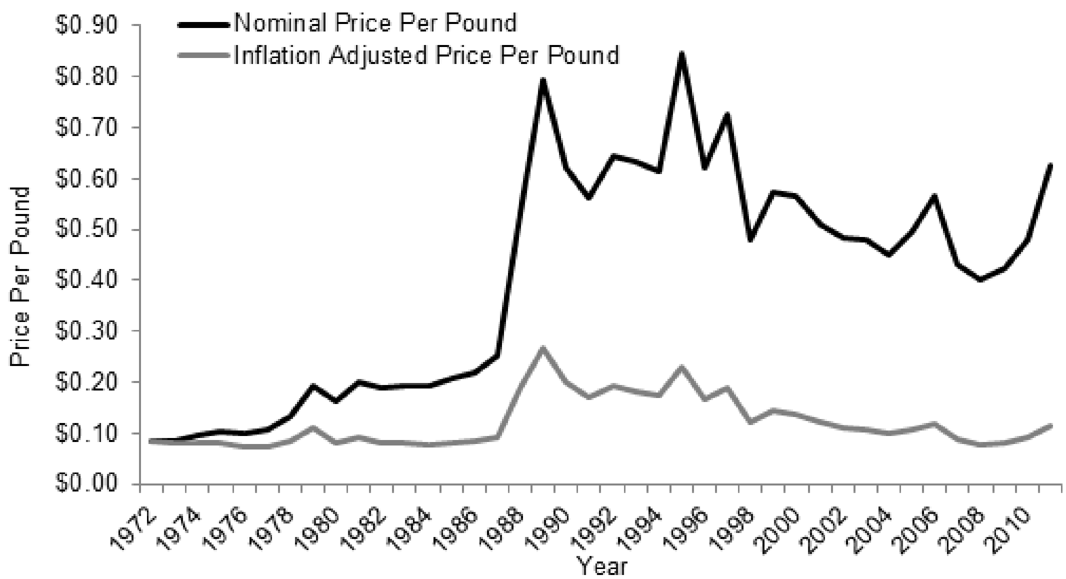

Figure 10.13. Average price per pound of striped mullet landings in North Carolina: 1972–2011 (NCTTP).

Gear Restrictions

Gear restrictions include limitations on the kind of fishing methods, or the design of the fishing gear that can be used and can serve the purpose of protecting juvenile fish and conserving stocks, preventing distribution to substrate, reducing bycatch, or reducing the proportion of low-value catch. In the striped mullet fishery, historically, seines and gill nets have been the two primary gear types involved. Seines accounted for most of the fishery harvest (62% of total landings) from 1950 to 1978 (gill nets were responsible for 37% of total landings). Gill nets replaced seines as the dominant gear type in the fishery in 1979 and the yearly proportion of the total fishery landings steadily increased.

Since 1994, an average of 92% of all striped mullet landings has been annually harvested by gill nets (runaround, set, and drift nets) while beach seines were responsible for only 5% of the average annual harvest. The runaround gill net is responsible for the greatest proportion (55%) of annual landings in the striped mullet fishery (1994–2011; Table 10.1, Figure 10.6). Since 2005, runaround gill nets have accounted for 60–70% of annual striped mullet landings. Set gill nets (combined sinking and floating) annually produced 37% of the harvest from 1994 to 2011 while cast nets only yielded 2% (see Commercial Fishery section 6.1). Gill nets are the only major gear in which restrictions would have the most impact in reducing harvest. There are two components to gill net gear restrictions: mesh size restrictions and net length limits.

The runaround gill net fishery targets striped mullet, and operates year round with most of the effort occurring from September through November when prices are high due to increased roe content of spawning females. Nets are typically 100–1,000 yards in length with a stretched mesh of 3 to 4 ½ inches. Soak times for this fishery are typically less than four hours and nets are attended during the entire operation.

Target species in the set gill net fishery (shallow water, small mesh) include striped mullet, spotted seatrout, weakfish, and bluefish. Nets are anchored overnight similar to the large mesh fishery for flounder that occurs in the same areas. Trips landing striped mullet typically set 100 to 1,000 yards of small mesh (3 to 4 ½ inches) gill net, which are retrieved by hand or net reels. In recent years, the NCDMF has enacted rules designating small mesh (< 5 inch stretched mesh) attendance areas from March 1 through October 31 to minimize red drum bycatch and subsequent discard mortality (Rule 15A NCAC 3J .0103 (h) in MFC Rules 2013). This rule requires fishermen using small mesh gill nets to remain within 100 yards of their net at all times in specified areas.

Also, since 2010, proclamations have been issued suspending section (i) (1) of rule 15A NCAC 3J .0103, reducing maximum gill net yardage to minimize incidental takes of protected species. The most recent proclamation (M-6-2014) makes it unlawful to use or possess more than 2,000 yards of large mesh gill net (defined as 4-inches to 6 ½-inches stretched mesh) per operation in northern areas and 1,000 yards of large mesh gill net in southern areas as well as establishing set time and soak time restrictions in some areas.

Few recreational anglers target striped mullet by hook-and-line. However, striped mullet are often caught by recreational anglers using cast net to use as bait fish for targeting a variety of inshore and offshore fish. According to the RCGL survey, from 2002 to 2008, approximately 38,555 trips using four different gear types were responsible for landing 290,586 lb of mullet during the period from 2002 to 2008. Small mesh gill nets accounted for 99.8% by pounds of all mullet harvested by RCGL holders followed by large meshed gill nets (0.2%), crab pots (<0.1), and seine. However, the data are not adequate to evaluate the impacts of gear restrictions for the recreational fishery (see Recreational Fishery section 6.2).

Additional Discussion

Reduction estimates for each potential management option were not presented at this time because the sustainability threshold for overfishing has not been exceeded. If the AC or the MFC would like to see the impact of a specific management option or options, reduction estimates, if quantifiable, will be provided upon request.

As previously discussed, for the current stock assessment, the PDT adopted a fishing mortality target of $F_{35\%}$ SPR (an increase from $F_{30\%}$ SPR) and left the fishing mortality threshold unchanged at $F_{25\%}$ SPR. The fishing mortality target was increased due to the fishery targeting female fish during the spawning season, the potential importance of striped mullet as a forage species in the ecosystem, and the small buffer between target and threshold F values which could result in rebuilding plans with more restrictive harvest.

The current stock assessment determined overfishing is not occurring in the striped mullet fishery ($F_{2011} < F_{25\%}$; Figure 1), but due to the poor stock-recruitment relationship status, overfished condition is considered unknown. Therefore, no new management measures imposing restrictions are required at this time. However, even though overfishing is not occurring, fishing mortality has increased and recruitment and spawning stock biomass have shown declining trends in recent years. If these trends continue, a series of poor recruitment events occur, and/or there are shifts in the market, management measures may be needed before the striped mullet stock is reassessed (five years after final adoption of Amendment 1, ~2020) as required by the Fisheries Reform Act. Management measures options 3–8 are provided to illustrate what these other management measure could consist of and could be included at this point if selected.

Additional management measures, if needed, could be developed and implemented under the authority of Amendment 1 via adaptive management. Selecting management options that put in place some preventative safeguards, such as landings triggers (that would prompt reanalysis of the data) and adaptive management will help to ensure the continued sustainability of the striped mullet fishery.

VII. MANAGEMENT OPTIONS AND IMPACTS

1) Status Quo
    + No rule changes or legislative actions
    + No additional restrictions on fishing practices
    + No additional enforcement responsibilities for Marine Patrol
    – Possibility of overfishing in the future resulting in an overfished stock status
    – Triggers not based on data used in the stock assessment

2) Update Triggers for Reassessment, Change Fishing Mortality Target, and Implement Adaptive Management
    + Triggers based on data used in the stock assessment
    + No rule changes or legislative actions
    + No additional restrictions on fishing practices
    + No additional enforcement responsibilities for Marine Patrol
    + Provides some measure of stock protection
    – Possibility of overfishing in the future resulting in an overfished stock status

3) Quotas
    + Controls harvest levels
    – Not sensitive to fluctuations in recruitment or availability of fish to the fishery
    – Additional reporting burden to commercial dealers
    – Requires additional resources from NCDMF to implement
    – Create regulatory discards
    – May restrict harvest more or less than necessary
    – Potential to go over quota due to short period of high landings

4) Size Limits
    + Reduces the number of smaller or larger fish harvested in the catch
    + Potential to increase recruitment
    – May not reduce the number of smaller or larger fish caught
    – Create regulatory discards
    – Change selectivity of commercial fishery towards smaller which could lead to growth overfishing
    – Increases enforcement responsibilities for Marine Patrol

5) Seasonal Closure
    + No additional resources required to implement
    + No additional reporting burden on fishermen or dealers
    + Reduces effort from current level
    – Effort may increase during open seasons reducing the effectiveness of the closure
    – May adversely affect some fisheries and fishermen more than others
    – Weather may prevent fishing during open periods

- Reduction in fishing mortality may not be achieved
- Increases enforcement responsibilities for Marine Patrol
- Create regulatory discards during the closed season

6) Area Closure
   + No additional resources required to implement
   + No additional reporting burden on fishermen or dealers
   + Reduces effort from current level
   - Weather may prevent fishing during open periods
   - Effort may increase in open areas reducing the effectiveness of the closure
   - Reduction in fishing mortality may not be achieved
   - Overfishing may still occur if recruitment is low
   - May adversely impact some fisheries and fishermen more than others
   - Increases enforcement responsibilities for Marine Patrol
   - Create regulatory discards in the closed area

7) Trip/Creel Harvest Limits
   + Reduces harvest per trip in the fishery
   - Create regulatory discards
   - May adversely affect some fisheries and fishermen more than others.
   - Would not guarantee reduction in fishing mortality
   - Increases enforcement responsibilities for Marine Patrol

8) Gear Restrictions
   a) Mesh Size Restrictions
      + Will reduce number of smaller or larger fish caught and harvested
      - Increases enforcement responsibilities for Marine Patrol
      - Change selectivity of commercial fishery towards smaller which could lead to growth overfishing
   b) Net Length Restrictions
      + Would maintain effort at a consistent level for each participant
      + Reduces the yardage of nets in the water
      - Some areas of the state may be more heavily impacted than others
      - Increase the burden on law enforcement

VIII. RECOMMENDATION

NCDMF:

The NCDMF recommends option 2 – Update Triggers for Reassessment, Change Fishing Mortality Target, and Implement Adaptive Management. This option would update the commercial landings management triggers using the data used in the current stock assessment (1994-2011), would increase the fishing mortality target from $F_{30\%}$ SPR to $F_{35\%}$ SPR, as adopted by the PDT in the stock assessment, due to the fishery targeting female fish during the spawning season, the potential importance of striped mullet as a forage species in the ecosystem, and because the small buffer between the target and threshold values could result in rebuilding plans with more restrictive harvest, and implement adaptive management for the striped mullet stock.

Finfish Advisory Committee (Striped Mullet FMP Advisory Committee):

Same as NCDMF recommendation.

MFC Selected Management Strategy:

Same as NCDMF recommendation.

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11.0 RECOMMENDED MANAGEMENT STRAEGIES AND RESEARCH RECOMMENDATIONS

11.1 MANAGEMENT STRATEGIES

The preferred management strategies listed below are organized according to the General Problem Statements in subsection 4.2. An overall discussion of the environmental factors is in section 9.0 with recommended management strategies for habitat and water quality found in subsection 9.4.1.

11.1.1 Gill Net Attendance in the Newport River Trawl Net Prohibited Area

11.1.1.1 Issue/Purpose

As part of the 2006 Shrimp FMP, a portion of the Newport River upstream of the line from Hardesty Farm subdivision to Penn Point (Hardesty Farm line) was designated a TNPA under MFC Rule 15A NCAC 03R .0106 (7). Whereas this designation served the desired purpose of prohibiting shrimp trawling upstream of that line, it was done without consideration of the existing special secondary nursery area (SSNA) designation which allows for seasonal opening of an area now inside a TNPA. In 2011, the Newport River TNPA was then added to the small mesh gill net attendance areas under MFC Rule 15A NCAC 03R .0112 (b) (1) and the implications to the striped mullet fishery were not considered. There are two issues that need to be resolved: 1) correct the existence of a SSNA which can be opened to trawling within a TNPA and 2) address an inconsistency between the current rule and the intended gill net attendance requirements for this area brought about by the designation of the Newport River TNPA as a small mesh gill net attendance area.

Since there is a small mesh gill net striped mullet fishery in Newport River in the fall, the aforementioned issue two falls under the purview of the Striped Mullet Fishery Management Plan Amendment 1. The current draft Shrimp FMP Amendment 1 recommends that the Habitat and Water Quality Advisory Committee be tasked by the MFC to assess all SSNAs that have not been open by proclamation in recent years. This would be the appropriate forum and FMP to address issue one of correcting the overlap of the SSNA within a TNPA.

11.1.1.2 Management Options

1) Status quo
2) Remove the Newport River TNPA [Rule 15A NCAC 03R .0106 (7)] from Marine Fisheries Rule 03R .0112 (b) (1), but leave it subject to 03R .0112 (b) (5), which requires attendance from May 1 through September 30.

Option two would require rule changes by the MFC.

11.1.1.3 Recommended Management Strategy

The MFC recommends option two to resolve the gill net attendance issue. This would bring current regulations in line with enforcement actions for this area and remove the unintended consequences of the TNPA designation on the striped mullet and other small mesh gill net fisheries. The removal of the SSNA designation for waters contained in the TNPA in the

Newport River should be examined further as part of the Shrimp FMP Amendment 1 review of SSNAs by the Habitat and Water Quality Advisory Committee.

11.1.2 Management Measures to Address User Conflict in the Striped Mullet Runaround Gill Net Fishery

11.1.2.1 Issue/Purpose

Determine management measures to reduce conflicts occurring in confined creeks and in the vicinity of docks and marinas between recreational hook-and-line fishermen, striped mullet commercial fishermen using runaround gill nets, and shoreline residents.

11.1.2.2 Management Options

1) Status quo – continue to handle user conflicts on case-by-case basis
2) Mediation for Specific Areas to Reduce Conflict Between Recreational Hook-and-Line Fishermen, Commercial Fishermen Using Runaround Gill Nets, and Shoreline Residents
3) Gear Restrictions/Rule Change – adopt a rule restricting runaround gill nets and non-stationary nets similar to the rule restricting stationary or fixed gill nets
4) Area Closures

Option three would require rule changes by the MFC.

11.1.2.3 Recommended Management Strategy

Recognizing the need to resolve this particular conflict in a manner that does not violate the public trust rights of the fishermen and may reduce the residents' complaints, the MFC selected option three and proposes the amendment of rule 15A NCAC 03J .0103 to add regulations for runaround or non-stationary gill nets similar to 15A NCAC 03J .0101 for fixed or stationary nets. This would make it unlawful to block more than two-thirds of any natural or manmade waterway, sound, bay, creek, inlet or any other body of water; or in a location where it will interfere with navigation or with existing, traditional uses of the area other than navigation. This should help to reduce the primary conflict of competition for limited space in creeks. Other conflicts such as lights, noise, and trespassing on private property by netters will continue to be handled on a case-by-case basis.

11.1.3 Striped Mullet Management Measures

11.1.3.1 Issue/Purpose

Update the management measures for striped mullet to maintain the sustainability of the striped mullet stock.

The North Carolina striped mullet commercial fishery harvests an average of 1.94 million lb per year (1994–2011) and is the largest striped mullet fishery along the east coast of the United States. Striped mullet, both juveniles and adults, are harvested throughout the year. However, much of the effort occurs in the fall, targeting adult female (roe) striped mullet during their spawning migration to the ocean. The recreational fishery is likely smaller and mainly consists of cast-netted juveniles used for bait with some recreational gill netting of adult fish. An increase in fishing effort after a rise in roe value in the 1980s initially caused concern for the stock. Therefore, it was designated as a species of concern in the division's

1999 stock status report. The first stock assessment included in the 2006 Striped Mullet FMP found the stock was not undergoing overfishing and the stock was reclassified as viable. The 2013 NCDMF stock assessment (Appendix 2) determined the stock is not experiencing overfishing and classified the striped mullet stock as viable.

<u>11.1.3.2 Management Options</u>

1) Status Quo – maintain current commercial landings triggers for reassessment and fishing mortality target and threshold ($F_{25\%}$ SPR and $F_{30\%}$ SPR) set by the 2006 Striped Mullet FMP.
2) Update commercial landings triggers for reassessment using commercial landings used in the most recent stock assessment (1994–2011), change fishing mortality target from $F_{30\%}$ SPR to $F_{35\%}$ SPR, and implement adaptive management.
3) Quota
4) Size Limit
5) Seasonal Closure
6) Area Closure
7) Trip/Creel Harvest Limits
8) Gear Restrictions
    a. Mesh Size Restrictions
    b. Net Length Restrictions

<u>11.1.3.3 Recommended Management Strategy</u>

The MFC recommends option 2 to update triggers for reassessment, change fishing mortality target, and implement adaptive management. This option would update the commercial landings management triggers using the data used in the current stock assessment (1994-2011), would increase the fishing mortality target from $F_{30\%}$ SPR to $F_{35\%}$ SPR, as adopted by the PDT in the stock assessment, due to the fishery targeting female fish during the spawning season, the potential importance of striped mullet as a forage species in the ecosystem, and because the small buffer between the target and threshold values could result in rebuilding plans with more restrictive harvest, and implement adaptive management for the striped mullet stock.

11.2 SUMMARY OF MANAGEMENT ACTIONS

11.2.1 Rules

11.2.2 Legislative Action

No legislative action is required.

11.3 SUMMARY OF RESEARCH RECOMMENDATIONS

The following research recommendations were compiled to help achieve the Goal and Objectives listed in subsection 4.1.2. The PDT reviewed and prioritized the research recommendations in accordance with the suggestion by the Biological Review Team research priority subcommittee. The AC reviewed the draft research recommendations and provided input to prioritize these recommendations as well. The Management Review Team determined the final ranking. The prioritization of each research recommendation is designated either a high, medium, or low priority. A low ranking does not infer a lack of importance but is either already being addressed by others or provides limited information for aiding in management decisions. A high ranking indicates there is a substantial need, which may be time sensitive in nature, to provide information to help with management decisions.

11.3.1 NCDMF Data Gathering

- Increase sampling of the commercial bait mullet cast net fishery to improve the estimates of striped mullet and white mullet harvest (Low).
- Increase the number of age samples from both fisheries-dependent and fisheries-independent sources (Medium).
- Restart fishery-independent cast net sampling (NCDMF Program 121) to improve estimates of the proportion of striped mullet and white mullet in this fishery (Low).
- Initiate a fishery-independent adult striped mullet survey in the Core and Bogue sound areas where approximately 20% of the striped mullet harvest occurs (High).
- Analyze the data from the CRFL recreational cast net and seine survey to better characterize the recreational striped mullet fishery, including the social and economic elements (Low).

11.3.2 Biological

- Improve recreational fisheries statistics provided by the Marine Recreational Information Program (MRIP; formerly MRFSS) or some other program to reliably characterize the magnitude and length and age structure of recreational fisheries losses (Low).
- Develop a reliable fisheries-independent index of juvenile abundance (High).
- Investigate how catch-ability of striped mullet by NCDMF Program 146 is affected by variations in salinity and conductivity and expand survey to other coastal rivers and tributaries (Medium).
- Initiate a plankton survey covering all inlets to determine inlet use by striped mullet (Low).
- Initiate a tagging program to provide estimates of stock size, *F,* and *M* that are not dependent on assumptions about steepness (High).
- Initiate a study to estimate fecundity and update the current maturity schedule microscopically (Medium).
- Investigate the disappearance of males from the population after age-3 (300mm FL) (Low).
- Initiate an acoustic tagging study to determine spatial and temporal variations in habitat use throughout the state to help provide better indices for stock assessments (Low).
- Initiate a survey to estimate RCGL landings of striped mullet in order to estimate recreational landings, as well as the social and economic elements of the striped mullet fishery (Medium).

11.3.3 Education

- Implement public outreach on waste reduction of striped mullet in the commercial and recreational fisheries (Low).

11.3.4 Habitat and Water Quality

Specific research recommendations for habitat and water quality from the CHPP (Deaton et al. 2010) can be found in subsection 9.4.2 of the Environmental Factors section of this document. The CHPP is currently undergoing revisions and is expected to be completed in 2015. Updated research recommendations for improving habitat and water quality should be found there once completed.

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13.0 APPENDICES

13.1 APPENDIX 1. GLOSSARY OF BIOLOGICAL TERMS

Adipose eyelid – vertical folds of adipose (fatty) tissue that protect the cornea.
Anal fin – (see Figure 1).
Annulus – a conspicuous dark band on concentric bony structures (e.g. scales, otoliths) of fishes caused by a period of slow growth similar to growth rings on a tree. Age can be determined by annuli, if fish undergo predictable, yearly, periods of slow growth (e.g. cold winters in temperate climates).
Atrectic – degenerating.
Benthic – occurring on the bottom of a water body (e.g. sea floor, river floor).
Branchial – of, or relating to, the gills.
Carnivorous – feeding on animal tissue.
Catadromous – spending most of the life cycle in freshwater, yet spawning in marine water.
Caudal fin – (see Figure 1).
Detritus – dead plant or animal matter.
Detritivore – organism that feeds on detritus.
Diatomaceous microalgae – unicellular algae with cell walls made of silica.
Diel – occurring each day.
Dorsal fin – (see Figure 1).
Epiphyte – plant (or alga) that grows on the surface of another plant.
Euryhaline – able to tolerate a wide range of salinity changes.
Fecundity – the number of eggs in the ovaries of a female fish, a common measure of reproductive potential in fishes.
Gill lamellae – feather like structures in gill tissue that exchange gases between the gills and the aquatic environment.
Gill rakers – cartilaginous or bony teeth-like projections on the gill arches of fishes that aid in capture or retention of prey.
Gonadosomatic Index (GSI) – weight of the gonads expressed as a percentage of the body weight, a common approach to documenting gonad development (Nielsen and Johnson 1992).
Gravid – carrying eggs.
Herbivorous – feeding on plant tissue.
Hermaphroditic – containing both male and female reproductive parts.
In vitro – in an environment outside of the living body; under laboratory conditions.
Isochronal – producing offspring in one batch.
Iteroparous – producing offspring over several periods (e.g. seasons, years).
Marine snow – suspended particles in the water column made of accumulated detritus, mineral grains, phytoplankton, and microorganisms bound in a mucous matrix (Larson and Shanks 1996).
Oil globule – first occurs during development of the egg and persists on the yolk during the yolk sac larval stage; absorbed as energy for developing larva.
Oogenesis – the process of developing ova (eggs).
Opercle – bony plate that covers the gills (see Figure 1).
Osmoregulation – regulation of constant internal water concentration, even if the external environment fluctuates.
Otolith – one of three calcareous (made of calcium) "ear stones" in fishes, which function in equilibrium and detection of sound vibrations.
Pectoral fin – (see Figure 1).

Pelvic fin – (see Figure 1).
Phytoplankton – very small floating or suspended plant life in aquatic ecosystems (e.g. diatoms, microscopic blue-green algae).
Relative fecundity – the number of eggs carried by a fish divided by its body weight.
Spermatogenesis – the process of producing mature sperm cells.
Stenohaline – able to tolerate only a narrow range of salinity changes.
Trophic level – classification of organisms in an ecosystem according to feeding relationships, from first level autotrophs (i.e. plants, algae) through succeeding levels of herbivores, carnivores and decomposers (Smith 1980).
Vitellogenic – during a stage of reproductive development when vitellogenin (a major yolk protein) is incorporated into the oocytes (egg cells).
Yolk sac – pouch containing yolk reserves carried by early stage, free-swimming fish larvae.
Young-of-the-year (YOY) – First year of life for finfishes, also known as age 0.
Zooplankton – floating or weakly swimming animals in aquatic ecosystems (e.g. copepods, early stage fish larvae).

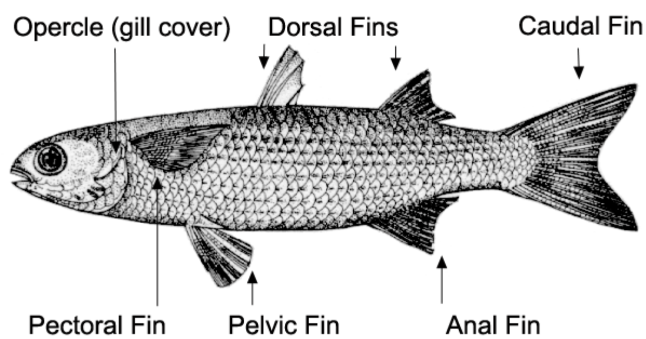

Figure 1. Diagram of fins and opercle.

13.2 APPENDIX 2. STOCK ASSESSMENT OF STRIPED MULLET (MUGIL CEPHALUS) IN NORTH CAROLINA WATERS

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

2013

Prepared by

North Carolina Division of Marine Fisheries

Striped Mullet Plan Development Team

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EXECUTIVE SUMMARY

The North Carolina Fisheries Reform Act requires that fishery management plans be developed for the state's commercially and recreationally 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.

In April 2006, the North Carolina Division of Marine Fisheries adopted a Fishery Management Plan for the striped mullet resource. Amendment 1 to the Fishery Management Plan is currently in development and this stock assessment was performed in support of the amendment.

A population assessment of the North Carolina striped mullet stock was conducted using the Stock Synthesis model, which incorporated data from commercial fisheries and three fishery-independent surveys from 1994 to 2011. Spawning stock biomass increased from 2003 through 2007 and has since declined. Recruitment has also declined in recent years, though a slight increase was observed in 2011. Fishing mortality (F) has increased in recent years, but F in the terminal year (F_{2011} = 0.437) was below both the fishing mortality target ($F_{35\%}$ = 0.566) and threshold ($F_{25\%}$ = 0.932). Based on these results, the stock is not undergoing overfishing. A poor stock-recruit relationship resulting in unreliable biomass-based reference points prevents determining if the stock is currently overfished.

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1.0 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).

In April 2006, the North Carolina Division of Marine Fisheries (NCDMF) adopted a Fishery Management Plan (FMP) for the striped mullet resource. A stock assessment was completed as part of that FMP. The results of the assessment concluded that overfishing was not occurring. Stock status in regard to the overfished definition could not be reliably determined and was considered uncertain.

The current stock assessment was developed as part of Amendment 1 to the Striped Mullet FMP.

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 (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 occur 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 (Ekman) 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, 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).

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 vast 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 (Bachelor 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

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). Maximum reported sizes ranged from 771 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 slowing down during the time they retain 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 Juvenile

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 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

Available otolith-based annual age data were fit with a von Bertalanffy age-length model to estimate the model parameters for both male and female striped mullet. The original fits of the sex-specific von Bertalanffy growth model included few age-0 fish because the majority (72.9%) of age-0 fish was unsexed. The resulting parameter estimates were considered unrealistic for striped mullet. Exclusion of the unsexed age-0 fish from the growth model fit resulted in a higher estimate of L_∞ and a lower estimate of K for the males relative to the females (male: L_∞ = 65.4 cm, K = 0.0771; female: L_∞ = 51.7 cm, K = 0.238). These estimates did not make sense given the observed data (females appear to grow larger than males and grow at a slower rate than males; Figures 1.1, 1.2), the results of previous studies (Table 1.1), and the biology of the species. For these reasons, the unsexed age-0 fish were included in the fits for both the males and females. Estimates of L_∞, K, and t_0 were within the range of estimates from previous studies for both sexes and were considered more realistic for the species (Table 1.1; Figures 1.1, 1.2).

Parameters of the allometric 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. 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 generally, it is 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.

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).

Information on sex collected from the fishery-independent sampling programs described in section 2.2 were pooled to calculate an overall sex ratio (M:F). The computed sex ratio was 0.383 (27.7% males and 72.3% females). The χ^2 goodness-of-fit test with Yate's correction for continuity was applied to test whether the observed sex ratio departed from a 1:1 (male: female) ratio (Zar 1999). The results suggested that the sex ratio was significantly different from a 1:1 ratio (χ^2 = 1,838, df = 1, $P < 0.001$).

Maturity of female striped mullet was estimated using data collected from various NCDMF fisheries-dependent and -independent programs. Maturity at length (M_l) was modeled as:

$$M_l = \frac{1}{1 + e^{\alpha(l-\beta)}}$$

where l is length, α is the slope, and β is the inflection point.

The parameters α and β were estimated via logistic regression. The estimated value for α was -0.269 and the estimated value for β was 29.0 cm (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. In the previous NCDMF assessment of striped mullet (Wong 2006), age-specific M values were calculated for males and females by time period (January–June and July–December) using the method of Lorenzen (1996), which is based on the relationship of body weight to natural mortality. Estimated M values ranged from 0.438 to 2.93 over ages 0 to 6+ for males and from 0.364 to 2.51 for females (Table 1.3).

For the current assessment, several indirect methods were applied to available data (refer to section 2) to calculate estimates of both age-constant and age-specific *M* for striped mullet. There are a number of methods to estimate an age-constant *M* based on the relationship of natural mortality to various life history characteristics. The equations derived by Hoenig (1983) correspond to Alagaraja's (1984) method and the commonly used rule-of-thumb approach ($M = 3 / t_{MAX}$; assumes 5% of individuals are still alive at the maximum age). These approaches predict *M* based solely on the maximum observed age in the population, t_{MAX}. Hewitt and Hoenig (2005) updated the earlier approach using a larger dataset and derived the following: $M = 4.22 / t_{MAX}$. Alverson and Carney's (1975) approach is based on von Bertalanffy growth and requires estimates of the growth coefficient, *K*, and t_{MAX} to determine *M*. Jensen (1996) derived a simple theoretical relationship between *M* and the von Bertalanffy *K* ($M = 1.50 \times K$). Using Pauly's (1980) data for 175 species, Jensen (1996) showed the simple relationship: $M = 1.60 \times K$.

Several approaches have been developed to provide indirect estimates of *M* at age (Peterson and Wroblewski 1984; Boudreau and Dickie 1989; Lorenzen 1996, 2005). Lorenzen's (1996) approach, used here, requires estimates of parameters from the von Bertalanffy age-length growth function, estimates of parameters from the allometric length-weight relationship, and the range of ages over which *M* will be estimated.

The approaches described above were used to compute both age-constant and age-specific estimates of *M* for striped mullet by sex. Values for the life history parameters required by the equations were derived from data compiled for this assessment. The oldest age observed in the available data was 14 years for males and 13 years for females. As such, values of 14 and 13 years were assumed for males and females, respectively, as the maximum ages for the natural mortality estimation methods that require t_{MAX}. Estimation of parameters for the von Bertalanffy growth function and for the allometric length-weight relationship is discussed in section 1.2.4.4 of this report.

The estimates of age-constant *M* based on life history parameters ranged from 0.00921 to 2.30 for males and from 0.137 to 1.05 for females (Table 1.4). Estimates of age-specific *M* decreased with increasing age for both male and female striped mullet (Table 1.5). For males, *M* decreased from 0.807 at age 0 to 0.488 at age 14. Age-specific *M* for females decreased from 0.802 at age 0 to 0.378 at age 13.

1.2.7 Food & Feeding Habits

The striped mullet is recognized as an important ecological bridge among a wide range of trophic levels. It connects 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). 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). Salinity seems to play a major role on habitat use and distribution of both adult and juvenile mullet (Cardona 2000). They are a highly euryhaline fish and live in a wide range of salinities, based on size and maturity (Pattillo et al. 1999; Cardona 2000). The availability of suitable food may also influence habitat use by striped mullet (Moore 1974). They 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. Once in estuarine waters, striped mullet 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. Larval striped mullet will then pass through inlets into the estuarine nursery areas.

1.3.2 Nursery & Juvenile Habitat

Juvenile striped mullet spend a majority of their time in estuarine rivers and marshes, with abundance highest in May and lowest in September (Bretsch and Allen 2006). These juvenile striped mullet use wetlands for foraging and refuge from predators. Within these marshes, striped mullet have been observed in 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).

1.3.3 Adult Habitat

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). 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 will move offshore to their spawning grounds.

1.3.4 Habitat Issues & Concerns

Suitable and adequate 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 suitable estuarine habitat and water quality are probably one of the most important factors in providing sustainable striped mullet stocks. All of the 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 striped mullet estuarine immigration, terminal groins may act as a threat to 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

Historically, the striped mullet fishery had a prominent role in the early 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 fishery operated at over 3 million lb annually during the late 1800s (Figure 1.6). Peak landings of over 6.7 million lb and 5 million lb were harvested in 1902 and 1908 (Chestnut and Davis 1975). The fishery was highly seasonal and occurred primarily during the fall spawning migration, but landings occurred throughout the year (Taylor 1951; Woodward 1956). Enormous catches—greater than 1 million lb of mullet landings 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 1.1 million lb annually (Chestnut and Davis 1975).

The North Carolina striped mullet fishery changed markedly in the late 1980s. From 1972 to 1986, annual landings in the mullet fishery averaged 1.66 million lb and ranged from 1.07 to 2.22 million lb. Average annual landings from 1987 to 1993 were 2.44 million lb and landings were near or exceeded 3 million lb in 1988, 1990, and 1993. 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, landings exceeded 3 million lb for the first time in 28 years. The price for striped mullet remained high until 1997 (Figure 1.7). Since then, the price has decreased (but generally remained higher than pre-1988 prices) due to decreased demand from Asia and consolidation of competing exporters.

Landings values were converted to 2011 dollar values using conversion factors based on the annual average consumer price index (CPI) values, which were obtained from the U.S. Bureau of Labor Statistics (pers. comm.).

Seines and gill nets are the primary gear used to harvest striped mullet in North Carolina. From 1887 to 1978, 60% of the commercial harvest was from seines and 39% from gill nets (Chestnut and Davis 1975; NCDMF, unpublished data). Since 1979, gill nets (runaround, set, and drift) have replaced seines as the dominant gear type in the fishery. From 1994 to 2002, 92% of striped mullet landings were attributed to gill nets and 48% of all landings were attributed to runaround gill nets. Since then gill nets have continued to be the dominant gear type, accounting for 93% of the landings from 2003 to 2011. Runaround gill nets accounted for 64% of striped mullet landings during this period.

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 (Nickerson1984). YOY mullets, 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 September and October. The fall harvest coincides with the southward migration of YOY striped and white mullet (NCDMF, unpublished data).

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 FMPs that apply specifically to the striped mullet fishery in North Carolina.

1.5.2 Management Unit Definition

The management unit includes the 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 adopted the FMP for striped mullet in joint and coastal waters of North Carolina. The major 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.

Very few regulations exist that pertain directly to striped mullet. Many of the regulations that can be applied to 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 per person per day for striped and white mullets combined
- 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 MFC'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:
        a. It shall be unlawful to possess more than 200 pounds of live fish or 100 pounds of dead fish.
        b. 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.

1.5.4 Current Regulations

Detailed information regarding North Carolina's current commercial and recreational fishery regulations is available on the NCDMF website (http://portal.ncdenr.org/web/mf/rules-and-regulations).

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.

In 2012, a proclamation was issued by the director of NCDMF to establish the season, specify net restrictions, and define areas in which stop nets could be used during the 2012 beach seine striped mullet fishery. The season for stop nets was from October 1, 2012 through November 30, 2012. Net restrictions included: a maximum of four stop nets could be used between Beaufort Inlet and Bogue Inlet at any one time, a combined fishing operation could not use more than two stop nets at any one time, stop nets could not exceed 400 yards in length (the inshore 100-yard portion and the offshore 50-yard portion had to be constructed of webbing a minimum of 8 inches stretched mesh and the remaining section of the net had to be constructed of webbing a minimum of 6 inches stretched mesh), and stop nets were not allowed within 880 yards of an existing stop net. The areas where stop nets were allowed included: 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. 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.

1.6 ASSESSMENT HISTORY

1.6.1 Review of Previous Method & Results

The most recent assessment of the striped mullet stock in North Carolina waters for management purposes was performed in association with the development of the original Striped Mullet FMP (NCDMF 2006; Wong 2006). The assessment applied a sex-specific 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.

1.6.2 Progress on Research Recommendations

The 2006 stock assessment identified several research needs for improving future assessments. Improvements in recreational fisheries statistics provided by the MRFSS were identified as needed to reliably characterize the magnitude of recreational fisheries losses (Wong 2006). Precision about the recreational statistics continues to be low due to small sample sizes (NMFS, Fisheries Statistics Division, Silver Spring, MD, pers. comm.; see also section 2.1.2). Planned changes to the national recreational fisheries survey are expected to improve the quality and accuracy of marine recreational fisheries data (see section2.1.2.4).

Another research need identified by Wong (2006) was a histology-based maturation study to further validate the female maturity ogive for the North Carolina stock. He also noted that a length or age versus fecundity relationship could further improve the determination of biological reference points for the stock. Bichy (2000, 2004) addressed these research needs in his research on the reproductive biology of striped mullet in North Carolina (see section 1.2.5).

Wong (2006) identified the need for further juvenile and adult fishery-independent surveys specifically designed to monitor striped mullet abundance. He recommended that existing fishery-independent surveys continue to monitor age-0 recruitment and adult abundance. The NCDMF Striped Mullet Trammel Net Survey (Program 145) was discontinued after 2002. An electrofishing survey targeting striped mullet was initiated in 2003 (Program 146; see section 2.2.1) to monitor the relative abundance of striped mullet in the Neuse River of North Carolina.

Finally, the 2006 assessment noted the development of a spawner-recruit relationship with increasing time will improve the determination of appropriate reference points for stock sustainability (Wong 2006).

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

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

2.1.1.2 Sampling Intensity

North Carolina dealers are required to record the transaction at the time of the transactions 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

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.

Another 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, the proportion of white mullet that occur in North Carolina's commercial landings is considered very small.

2.1.1.5 Development of Estimates

Commercial landings were calculated by year, by gear, and by market category (sex) using the NCDMF TTP data. Annual length- and age-frequency distributions were computed using 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.

2.1.1.6 Estimates of Commercial Fishery Statistics

The NCDMF TTP is considered a census of North Carolina landings. Annual commercial landings of striped mullet ranged from a low of 663 mt in 1999 to a high of 1,283 mt in 2000 (Figure 2.1). Landings from 2003 to 2011 varied little, averaging 772 mt per year over that time period. The majority (86%) of striped mullet landed in North Carolina has been harvested by estuarine gill nets (Figure 2.2). The majority of the landings have been unclassified, followed by red roe, or female, striped mullet (Figure 2.3).

The length frequencies of female striped mullet collected from the commercial fishery exhibited a slight increase in modal length over the available time series (Figure 2.4); modal length increased from 34 cm in 1997 to 36 cm in 2011. Male striped mullet also demonstrated an increase in modal length from 30 cm to 32 cm between 1997 and 2011 (Figure 2.5).

Age-frequency distributions derived from the commercial fishery suggest striped mullet aged 1 through 3 dominate commercial landings (Figures 2.6, 2.7). Small sample sizes, especially in recent years, make it difficult to assess trends in the commercial fishery age compositions over the time series.

2.1.2 Recreational Fishery Monitoring

The Marine Recreational Fisheries Statistics Survey (MRFSS) collects data from the ocean 0–3 miles from the coast and inside waters from south of the Albemarle Sound to the South Carolina border. From 2002–2008, the NCDMF collected data from recreational fishermen who are licensed to use limited amounts of commercial gear.

2.1.2.1 Survey Design and Methods

MRFSS

Data collection consists primarily of two complementary surveys: a telephone household survey and an angler-intercept survey. In 2005, the MRFSS began at-sea sampling of headboat (party boat) fishing trips. Data derived from the telephone survey are used to estimate the number of recreational fishing trips (effort) for each stratum (see following section). The intercept and at-sea headboat data are used to estimate catch-per-trip for each species encountered. The estimated number of angler trips is multiplied by the estimated average catch-per-trip to calculate an estimate of total catch for each survey stratum. A detailed description of the MRFSS sampling methods is provided in the MRFSS User's Manual (ASMFC 1994).

The MRFSS estimates are divided into three catch types depending on availability for sampling. The MRFSS classifies those fish brought to the dock in whole form, which are identified and measured by trained interviewers, as landings (Type A). Fish that are not in whole form (bait, filleted, released dead) when brought to the dock are classified as discards (Type B1), which are reported to the interviewer, but identified by the angler. Fish that are released dead during at-sea headboat sampling, which began in 2005, are also classified as Type B1 discards. The sum of Types A and B1 provides an estimate of total harvest for the recreational fishery. Anglers also report fish that are released live (Type B2) to the interviewer. Those fish that are released alive during the at-sea headboat survey are also considered Type B2 catch. Total recreational catch is considered the sum of the three catch types (A+B1+B2). The numbers of striped mullet of each catch type that were sampled by the MRFSS are presented in Table 2.1.

Recreational Commercial Gear License (RCGL) Survey

In July 1999, the NCDMF began offering a Recreational Commercial Gear License (RCGL), which allows recreational fishermen to use limited amounts of commercial gear. These fishermen are prohibited from selling their catch as it is intended solely for personal use. From 2002–2008, the NCDMF conducted a mail survey of RCGL holders to determine effort, harvest, and discard characteristics for species targeted with this license. The survey was sent to 30% of RCGL holders each month. While the survey was only active during this period, the RCGL is still available for purchase.

2.1.2.2 Sampling Intensity

MRFSS

The number of telephone interviews conducted during each wave varies based on the amount of fishing activity expected for the season (NMFS, pers. comm.). Telephone sampling effort is allocated among coastal counties in proportion to household populations. Specifically, the allocation is based on the ratio of the square root of the population within each county to the sum of the square roots of all county populations within the state. Intercept sampling is random and stratified by year, state, wave (two-month sampling period), and mode (type of fishing). A minimum of 30 intercepts are performed per stratum, though samples are allocated beyond the minimum in proportion to the average fishing pressure of the previous three years.

Recreational Commercial Gear License (RCGL) Survey

Specific monthly landings and effort data were solicited monthly through surveys issued to 30% of licensed RCGL holders from January 2002 through December 2008.

2.1.2.3 Biological Sampling

MRFSS

The MRFSS interviewers routinely sample fish of Type A catch that are encountered during the angler-intercept survey. 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 MRFSS. 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 length type appropriate to the morphology of the fish. The numbers of striped mullet biological samples taken by the MRFSS are summarized in Table 2.2.

Recreational Commercial Gear License (RCGL) Survey

No biological data were collected during the RCGL survey.

2.1.2.4 Potential Biases

MRFSS

The MRFSS estimates are based on a stratified random sampling design and so are designed to be unbiased. There have been a few instances when the random telephone survey was found to be unrepresentative and an average estimate of trips was substituted. Most recently, the 2002 telephone survey data were discarded for waves 2 and 3 and effort estimates were instead based on a three-year average (1999–2001) for those waves. The MRFSS advises that the weight estimates are minimum values and so may not accurately reflect the actual total weight of fish harvested. Other caveats associated with these data are discussed at the following web site: http://www.st.nmfs.gov/st1/recreational/queries/caveat.html.

Recent 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 National Research Council (NRC) convened a committee to perform the review, which was completed in 2006 (NRC 2006). The review resulted in a number of recommendations for improving the effectiveness and utility of sampling and estimation methods. In response to the recommendations, the NMFS initiated the Marine Recreational Information Program (MRIP)—a program designed to improve the quality and accuracy of marine recreational fisheries data. The MRIP program is being phased in gradually and will eventually replace the MRFSS. The objective of the MRIP program is to provide 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 will be reviewed periodically and undergo modifications as needed to address changing management needs.

An accurate estimate of the recreational striped mullet harvest is difficult to obtain as MRFSS/MRIP is designed to sample anglers who use rod and reel as mode of capture. Most anglers harvest striped mullet with cast nets for use as bait. Non-reporting and inaccurate estimation of bait numbers also contribute to the problem. Another confounding factor is the potential non-differentiation and/or misidentification of striped mullet and white mullet by recreational anglers (NCDMF 2006).

Recreational Commercial Gear License (RCGL) Survey

The RCGL survey used monthly surveys and relied on the memory of fishermen introducing the potential for recall bias. As in the commercial TTP data, 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. Non-reporting and misidentification of striped mullet and white mullet is another potential bias.

2.1.2.5 Development of Estimates

MRFSS

Recreational fisheries statistics for striped mullet were obtained from the MRFSS online data query (NMFS, pers. comm.). Information on sample sizes was retrieved from the MRFSS raw intercept files.

Estimates of harvest in terms of numbers are available for all three catch types (Type A, B1, and B2). Weight estimates are only available for recreational harvest (Type A+B1). Details describing how the MRFSS uses data collected from the telephone interviews and angler intercept survey to develop catch and effort estimates can be found in the MRFSS User's Manual (ASMFC 1994). Additional information regarding the MRIP methodology can be found online at http://www.st.nmfs.noaa.gov/recreational-fisheries/in-depth/.

In March 2012, a MRFSS/MRIP calibration workshop was held and the panel recommended that stock assessments use estimates calculated using the MRIP methodology. A follow-up workshop further recommended that estimates for years prior to 2004—years for which the data do not allow application of the MRIP methodology—should be calibrated to the MRIP estimates using a ratio of means estimator (Salz et al. 2012).

The ratio of means estimator is computed as:

$$\hat{R}_{RM} = \frac{\bar{C}_{MRIP}}{\bar{C}_{MRFSS}} = \frac{\sum_{y=2004}^{2011} \hat{C}_{y,MRIP}}{\sum_{y=2004}^{2011} \hat{C}_{y,MRFSS}}$$

where $\hat{C}_{y,MRIP}$ is the catch in year *y* estimated based on the MRIP methodology and $\hat{C}_{y,MRFSS}$ is the catch in year *y* estimated based on the MRFSS methodology.

Calibrated recreational catch estimates for years prior to 2004 were then calculated as:

$$\hat{C}_{y,\hat{R}} = \hat{R}\hat{C}_{y,MRFSS}$$

Recreational Commercial Gear License (RCGL) Survey

The RCGL data were analyzed to determine monthly landings, major gear types, and number of trips associated with the recreational harvest of striped mullet.

2.1.2.6 Estimates of Recreational Fishery Statistics

MRFSS

In terms of numbers, the recreational harvest (Type A + B1) of striped mullet in North Carolina ranged from a low of 1,347 in 1998 to a high of 695,570 in 2002 (Table 2.3; Figure 2.1). Harvest in weight was highest in 2003 at a value of 179.6 mt and was lowest in 1999 at a value of 0.3168 mt. The number of striped mullet released alive by recreational anglers fishing in North Carolina waters ranged from a low of 805 in 2010 to a high of 559,972 in 2002. In many years, the estimated number of live releases is not available due to lack of samples of Type B2 striped mullet (Table 2.1).

Recreational Commercial Gear License (RCGL) Survey

The months of July–October accounted for over 65% of the total striped mullet harvest by RCGL holders. Gill nets were the main gear recorded by RCGL fishermen targeting striped mullet (minimal landings, less than 0.05% was reported from other gears). Gill nets were subdivided into small mesh (<5 inch stretch mesh) and large mesh (≥5 inch stretched mesh). Small mesh gill nets accounted for 99.8% of all striped mullet harvested by RCGL fishermen.

RCGL holders made approximately 38,500 trips from 2002–2008 in which they harvested roughly 290,000 lb of striped mullet. The RCGL holder surveys did not specifically determine the final disposition of the striped mullet landed by these anglers. However, it is presumed they use the fish primarily as bait for other species, or for harvesting roe. Drying mullet and their roe for later consumption is popular with some coastal North Carolina residents.

2.2 FISHERIES-INDEPENDENT

2.2.1 Striped Mullet Electroshock Survey (Program 146)

2.2.1.1 Survey Design and Methods

The NCDMF Striped Mullet Electroshock Survey was initiated in 2003 to produce a fishery-independent index of relative abundance of 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 (Figure 2.8). The Neuse River area is an important year-round habitat and a major migration path for striped mullet in North Carolina.

Electroshock 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 Straton 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 was reduced to January through April and October through December; each station is sampled once per month.

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. 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

Program 146 is the only index the NCDMF has designed to target striped mullet. Currently this program has a relatively short time period and covers a small geographic area located within the Neuse River. Additionally, it does not correlate well with other programs. Electroshock gear can have biases in species composition, size distribution, and abundance (Reynolds 1983; McInerny and Cross 1996).

2.2.1.5 Development of Estimates

To provide the most relevant index, data were limited to those collected during January through April, when the majority of striped mullet occurred in the Neuse River. Since the survey primarily catches adult striped mullet, juveniles were excluded from the calculations. Length and age compositions were computed based on the same data.

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, applying a correlation analysis, or both. 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 using the appropriate statistical test. Non-significant covariates were removed using backwards selection to find the best-fitting predictive model for each species. The model chi-square statistic was calculated for the best-fitting model to determine if the overall model is statistically significant.

2.2.1.6 Estimates of Survey Statistics

Available covariates were year, month, area, temperature, salinity, and dissolved oxygen. Year, month, and area were treated as categorical variables in the models. Since effort was constant across sampling events, the modeled response variable was counts of striped mullet. Plots of the potential explanatory variables and the striped mullet frequencies suggested there were no obvious outliers (Figure 2.9). Correlation analysis indicated a strong correlation among year, month, and temperature. Removal of month resolved the problem of collinearity.

The final negative binomial provided a better fit (χ^2 = 72,197, $p < 0.0001$) and substantially better estimate of dispersion than the Poisson distribution for the Program 146 data. The estimate of dispersion for the final model was 1.91. The final best-fitting negative binomial GLM included year, area, and salinity as covariates (Tables 2.4, 2.5). This final model was found to provide an overall significant fit to the data (χ^2 = 125.59, df = 11, $p = 0.0001$).

The GLM-standardized index for the Program 146 data was variable and no overall trend was discernible over the time series (Figure 2.10).

The length-frequency distributions of adult striped mullet collected by Program 146 suggest a slight expansion into larger sizes over the short time period (Figures 2.11, 2.12).

The female striped mullet age-frequency distributions suggest the survey catch is dominated by 2-, 3-, and 4-year-old fish (Figure 2.13). Trends in age-frequency distributions of male striped mullet over time are difficult to interpret due to extremely small sample sizes (less than 10 in most years; Figure 2.14).

2.2.2 Striped Bass Independent Gill-Net Survey (Program 135)

2.2.2.1 Survey Design and Methods

In October 1990, the NCDMF initiated the Striped Bass Independent Gill-Net Survey, also known as Program 135 (P135). The survey was designed to monitor the striped bass population in the Albemarle Sound and Roanoke River.

The survey follows a random stratified design, stratified by geographic area. This survey divides the water bodies comprising the Albemarle region into six sample zones that are further subdivided into one-mile square quadrants with an average of 22 quadrants per zone (Figure 2.15). The survey gear is a multi-mesh monofilament gill net. Four gangs of twelve meshes (2.5-, 3-, 3.5-, 4-, 4.5-, 5-, 5.5-, 6-, 6.5-, 7-, 8-, 10-inch stretch) of gill nets are set in each quadrant by the fishing crew, one two-gang set is weighted to fish at the bottom (sink net), and the other is floating unless the area is unsuitable for gill-net sampling (marked waterways and areas with excessive submerged obstructions). Alternate zones and quadrants are randomly selected in the event that the primary selection cannot be fished. A fishing day is defined as the two crews fishing the described full complement of nets for that segment for one day. One unit of effort is defined as each 40-yard net fished for 24 hours.

2.2.2.2 Sampling Intensity

The sampling year is divided into three segments: fall-winter, spring, and summer. Summer sampling was discontinued in 1993. The areas fished, sampling frequency, and sampling effort are altered seasonally to sample the various segments of the striped bass population.

2.2.2.3 Biological Sampling

All striped bass are measured and additional data are recorded while other species collected are counted and sub-sampled for length, age, and sex information.

2.2.2.4 Potential Biases

Program 135 is specifically designed to target striped bass. However, striped mullet are counted and sub-sampled for length (mm) when collected. Gill nets are the only gear used in this program which could exclude some smaller species/individuals and species that evade the nets.

2.2.2.5 Development of Estimates

To provide the most relevant index, data were limited to those collected from mesh sizes 2.5” to 5.5” during November through February, when and where the majority of striped mullet occurred. Since the survey primarily catches adult striped mullet, juveniles were excluded from the calculations. Length and age compositions were computed based on the same data.

The GLM method used to model the relative abundance of adult 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 135.

2.2.2.6 Estimates of Survey Statistics

Available covariates were year, month, quadrant, depth, and surface temperature. Year, month, and quadrant were treated as categorical variables in the models. Since effort was constant across sampling events, the modeled response variable was counts of striped mullet. Plots of the potential explanatory variables and the striped mullet frequencies suggested there were no obvious outliers (Figure 2.16). Correlation analysis indicated a strong correlation between depth and month, depth and quadrant, and depth and surface temperature. Month was also strongly correlated with surface temperature. Depth and month were not considered in modeling to avoid problems of collinearity.

The negative binomial provided a better fit (χ^2 = 3,984, p < 0.0001) and substantially better estimate of dispersion than the Poisson distribution for the Program 135 data. The estimate of dispersion for the final model was 1.17. The final best-fitting negative binomial GLM included year and quadrant as covariates (Tables 2.6, 2.7). This final model was found to provide an overall significant fit to the data (χ^2 = 114.33, df = 22, p < 0.0001).

The GLM-standardized index for Program 135 is variable with spikes in relative abundance occurring at variable time intervals (Figure 2.17). The spikes have been increasing in magnitude since 1994. If the spikes are ignored, there is no discernible trend in relative abundance over time.

The length-frequency distributions of adult female striped mullet show a slight shift in modal length from 32 cm in 1998 to 30 cm in 2011 (Figure 2.18). The modal length of adult male striped mullet varies over time though no distinct trend is present (Figure 2.19). Trends in the length compositions are difficult to interpret due to the variation in sample sizes among years; the number of adult females sampled ranged from 21 to 297 individuals per year and the number of males samples ranged from 8 to 396 individuals per year over the time period.

Trends in age-frequency distributions over time are difficult to interpret due to small sample sizes (less than 30 in most years; Figures 2.20, 2.21).

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

2.2.3.1 Survey Design and Methods

The Fisheries-Independent Gill-Net Survey, also known as Program 915 (P915), began on March 1, 2001 and includes Hyde and Dare counties (Figure 2.22). In July 2003, sampling was expanded to include the Neuse, Pamlico, and Pungo rivers (Figures 2.23, 2.24). Additional areas in the Southern District were added in April 2008.

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

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

2.2.3.2 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) in the river systems.

2.2.3.3 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.

2.2.3.4 Potential Biases

Although striped mullet are 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 take into account the nearshore and offshore 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).

2.2.3.5 Development of Estimates

To provide the most relevant index, data were limited to those collected from shallow river areas during October through November, when and where the majority of striped mullet occurred. Since the survey primarily catches adult striped mullet, juveniles were excluded from the calculations. Length and age compositions were computed based on the same data.

The GLM method used to model the relative abundance of adult striped mullet in Programs 146 and 135 (see section 2.2.1.5) was also used to model the relative abundance of adult striped mullet in Program 915.

2.2.3.6 Estimates of Survey Statistics

Available covariates were year, month, stratum, temperature, salinity, and dissolved oxygen. Year, month, and stratum were treated as categorical variables in the models. Since effort was constant across sampling events, the modeled response variable was counts of striped mullet. Plots of the potential explanatory variables and the striped mullet frequencies suggested there were no obvious outliers (Figure 2.25). Correlation analysis indicated a strong correlation between temperature and month so month was removed from consideration.

The negative binomial provided a better fit (χ^2 = 1,991, $p < 0.0001$) and substantially better estimate of dispersion than the Poisson distribution for the Program 915 data. The final model was nearly equi-dispersed; the estimated dispersion value was 1.03. The final best-fitting negative binomial GLM included year, salinity, and dissolved oxygen as covariates (Tables 2.8, 2.9). This final model was found to provide an overall significant fit to the data (χ^2 = 27.883, df = 9, p = 0.0001).

The GLM-standardized index for the Program 915 data exhibited a slightly increasing trend over time and a peak in relative abundance occurred in 2007 (Figure 2.26).

Length-frequency distributions of adult striped mullet suggest a slight expansion into larger sizes over the short time period (Figures 2.27, 2.28).

The trend in age-frequency distributions over time is difficult to interpret due to the low sample sizes that occurred in the earlier years of the available time series (Figures 2.29, 2.30).

3.0 ASSESSMENT

3.1 OVERVIEW

3.1.1 Scope

The unit stock for the current assessment is considered all striped mullet occurring within North Carolina coastal waters.

3.1.2 Current vs. Previous Method

An approach similar to Stock Synthesis was applied in the previous NCDMF assessment of the striped mullet stock (Wong 2006). The model used was a sex-specific length- and age-based forward projection model applied to the 1994–2002 time period and was developed using Microsoft Excel. The model incorporated commercial landings and recreational harvest as well as ages from the commercial and recreational fisheries. One fisheries-dependent index was derived from the commercial set gill-net fishery. Juvenile abundance indices were derived from the NCDMF Alosine Seine Survey (Program 100) and the NCDMF Juvenile Red Drum Seine Survey (Program 123). Indices of adult abundance were derived from the NCDMF Striped Bass Independent Gill-Net Survey (Program 135) and the NCDMF Striped Mullet Trammel Net Survey (Program 145, 1999–2002). The model also incorporated length data from the NCSU Albemarle Sound Seine Survey (one year), the NCDMF Striped Bass Independent Gill-Net Survey, and the NCDMF Striped Mullet Trammel Net Survey.

The current method applied the Stock Synthesis software to data from the commercial fisheries and from Programs 135, 915, and 146. Staff responsible for the recreational statistics recommended against using recreational data in the current assessment due to the high uncertainty associated with the data (C. Wilson, NCDMF, pers. comm.). The seine surveys—Programs 100 and 123—were not included in the stock assessment largely due to the high percentage of zero hauls relative to striped mullet observed in both programs. In Program 100, the number of zero hauls has ranged from 75% to 80% and in Program 123, the number of zero hauls has ranged from 61% to 93%. The high percentage of zero hauls is thought to be related to the schooling behavior of striped mullet. Due to the high percentage of zero hauls, the index was only reflective of a few large catches. Closer examination of the data revealed high percent standard errors, so it was determined that these programs are most likely not true representations of the striped mullet population and were not used in the current stock assessment. Program 145 was designed to monitor striped mullet abundance in the shallow waters of Core Sound, Adams Creek, and Newport River. This program was active only a short time from 1999–2002. This program was extremely selective for a narrow size range, with 92% of striped mullet caught ranging from 220–279 mm fork length. Due to the short time series and limited spatial coverage, this survey was not used in the current stock assessment.

Table 3.1 compares data sources used in the previous and current assessments.

3.2 CONTINUITY RUN

The working group felt a continuity run was not warranted given the concerns regarding catchability of striped mullet by seine gear and the uncertainty associated with the recreational fishery statistics.

3.3 STOCK SYNTHESIS

3.3.1 Description

The striped mullet stock was modeled using Stock Synthesis text version 3.24f (Methot 2000, 2011; NFT 2011; Methot and Wetzel 2013). Stock Synthesis was also used to calculate reference points. The Stock Synthesis model can incorporate information from multiple fisheries, multiple surveys, and both length and age composition data. The structure of the model allows for a wide range of model complexity depending upon the data available. The strength of the synthesis approach is that it explicitly models both the dynamics of the population and the processes by which one observes the population and its fisheries. That is, the comparison between the model and the data is kept close to the natural basis of the observations, instead of manipulating the observations into the format of a simpler model. Another important advantage is that the Stock Synthesis model can allow for (and estimate) selectivity patterns for each fishing fleet and survey. Please refer to the model documentation for details on model assumptions and equations (see Methot 2000, 2011; Methot and Wetzel 2013).

The data file and the control file for the base model run can be found in Appendices 1 and 2, respectively.

3.3.2 Dimensions

The time period modeled was 1994 to 2011. The model incorporated one fishing fleet—the commercial fishery—and three fishery-independent surveys—Programs 135, 915, and 146.

3.3.3 Structure & Configuration

3.3.3.1 Catch

The model incorporated commercial landings of striped mullet in North Carolina as reported in the NCDMF TTP. No commercial discards were included in the model as they are considered minimal. The available statistics for North Carolina's recreational fishery for striped mullet are considered very uncertain. As such, recreational fishery statistics were not included in the assessment model.

3.3.3.2 Indices

The model incorporated annual indices of relative abundance (and associated empirical standard errors) derived from Programs 135, 915, and 146. A single catchability coefficient (q) was estimated for each survey and assumed to be time-invariant. All survey indices were assumed to have a nonlinear relation to abundance, requiring an extra parameter to be estimated for each survey.

3.3.3.3 Average Body Weight

The annual average body weight and associated CV was input for the commercial fishery and each survey. Average body weights for the surveys were calculated using the same reference data used to develop the indices. That is, the average body weights for Program 135 were calculated from data on adults collected from mesh sizes 2.5” to 5.5” during November through February. Average body weights for Program 915 were calculated from data on adults collected from the shallow river areas during October through November. Finally, average body weights for Program 146 were calculated from data on adults collected during January through April.

3.3.3.4 Length Composition

Annual sex-specific length frequencies were input for the commercial fishery and each survey. As with the average body weight data, the survey length frequencies were calculated using the same reference data used to develop the indices.

3.3.3.5 Age Composition

Annual sex-specific age compositions were input for the commercial fishery and each survey. 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: (1) it avoids the double use of fish for both age and size information because the age information is considered conditional on the length information; (2) it contains more detailed information about the relationship between size and age so provides stronger ability to estimate growth parameters, especially the variance of size at age; and (3) the conditional age-at-length approach can directly match the protocols of the sampling program when age data are collected using a length-stratified approach (Methot 2011).

As with the average body weight data and length frequencies, the 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 14.

3.3.3.6 Average Length at Age

Annual sex-specific average lengths at age and associated sample sizes were input for the commercial fishery and each survey. As with the other biological data, the survey average lengths at age were calculated using the same reference data used to develop the indices.

3.3.3.7 Biological Parameters

All biological parameters were assumed to be sex-specific.

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 0.464 (see section 1.2.6). The model was allowed to estimate *M* at age 2 for males.

Growth

The von Bertalanffy age-length growth option is parameterized in terms of length at a given reference age, L_∞, and K. The selected reference age was age 2. The von Bertalanffy parameters were fixed in the model at the values estimated in this report (see section 1.2.4.4; Table 1.1) due to the lack of data for age-0 fish provided to the model.

Parameters of the allometric length-weight relationship were fixed for both males and females. The assumed values were those estimated in this report as described in section 1.2.4.4 (Table 1.2).

Maturity

The length logistic maturity option was selected for defining female maturity. The maturity parameters were fixed in the model at the values estimated in section 1.2.5.

Fecundity

The selected fecundity option was that which causes eggs to be equivalent to spawning biomass.

3.3.3.8 Stock-Recruitment

A Beverton-Holt stock-recruitment relationship was assumed. Recruitment varied log-normally about the curve. The steepness parameter (*h*) was fixed at 0.9 because there was not enough contrast in the time series to estimate this value reliably (R. Methot, NOAA Fisheries, pers. comm.). Virgin recruitment (R_0) was estimated by the model.

3.3.3.9 Initial Age Structure

Non-equilibrium conditions were assumed for the initial age structure.

3.3.3.10Selectivity

Selectivity can be cast as age or length specific in the Stock Synthesis model; here, the length-specific option was selected. The recommended double normal selectivity pattern was assumed for the commercial fishery and for the fishery-independent surveys. The commercial fishery was assumed to have a dome-shaped pattern due to the dominance of the runaround gill net in the fishery. Runaround gill nets tend to exclude the smallest striped mullet and the largest individuals don't get gilled by the gear. The selectivity patterns for Programs 135 and 915 were assumed to have an asymptotic shape so the parameters defining the top, descending width, and initial and final selectivity values were fixed. Parameters defining the peak and ascending width were estimated by the model. All selectivity parameters for Program 146 were freely estimated.

3.3.4 Optimization

The objective function for the base model included likelihood contributions from the catch, survey indices, average body weight, length compositions, age compositions, length at age, initial equilibrium catch, and recruitment deviations. The total likelihood is the weighted sum of the individual components. All likelihood components were given equal weight (assigned a lambda weight of 1.0).

3.3.5 Diagnostics

Standardized residuals provide an indication of how well the data fit the model. Standardized residuals were calculated for the fishery-independent indices, length composition, and age composition data. In a perfectly fit model, the standardized residuals are normally distributed with mean 0 and standard deviation 1. Normal quantile plots (Q-Q plots) and distribution tests were applied to determine whether the standardized residuals were normally distributed.

3.3.6 Uncertainty & Sensitivity Analyses

In the base model, each component of the likelihood function was given a weight of one. The contribution of a data source can be manipulated by changing this value. Here, the uncertainty of the base model results was explored by assessing the contribution of different sources of information using this approach. The contribution of Program 135 was examined in one sensitivity run by reducing the emphasis (assigned a lambda weight of 0.001) of all inputs (index, average body weight, length compositions, age compositions, length at age) derived from this survey. Similar sensitivity runs were performed for Program 915 and Program 146. In another sensitivity run, all data associated with all the fishery-independent surveys (indices, biological data) were removed by reducing the associated lambda weights to 0.001. The contribution of the biological data (average body weight, length compositions, age compositions, length at age) collected from the commercial fishery was evaluated by essentially removing these data (assigning a lambda weight of 0.001). The contribution of each type of biological data (length compositions, age compositions, length at age) from all sources was also explored through this approach.

The sensitivity of the base model to assumptions about the stock-recruitment relationship was also investigated. The base model run assumed steepness was equal to 0.9. Additional runs were performed for a range of steepness values from 0.5 to 1.0.

Finally, a retrospective analysis was run to examine the consistency of estimates over time. This type of analysis gives an indication of how much recent data have changed our perspective of the past (Harley and Maunder 2003).

3.3.7 Results

The Stock Synthesis model of the striped mullet stock was structured to have one fishery and three fishery-independent surveys and was applied to the 1994 to 2011 time period.

Stock Synthesis allows several options for reporting *F*. Based on a recommendation from the model developer (R. Methot, pers. comm.), the *F* values reported here represent a real annual *F* calculated as a numbers-weighted *F* (see Methot 2011) for ages 2–5, the age range that comprises 95% of the commercial catch. Note that the *F* that is traditionally reported is apical *F*—the maximum *F* over all ages. Predicted *F*s ranged from a low of 0.247 in 2007 to a high of 0.692 in 2000 (Table 3.2; Figure 3.1). Predicted *F*s were variable from the beginning of the time series through 2002. The predicted *F*s then showed a gradual decline followed by a slow increase through 2011.

Predicted annual recruitment suggests there were relatively strong year classes in 1995 and 1999 (Table 3.3; Figure 3.2A). Predicted recruitment showed an overall decline from 2005 through 2010 and increased in 2011. Annual estimates of spawning stock biomass (SSB) showed little trend from 1994 through 2003 (Table 3.3; Figure 3.2B). SSB increased from 2003 to 2007 and has since declined.

Predicted population numbers at age and length for females and males are presented in Tables 3.4 through 3.11. There is some indication that the age and length distributions may be showing evidence of an expansion relative to the early 2000s.

The selectivity pattern for the commercial fishery was assumed to follow a dome shape while the selectivity patterns for Programs 135 and 915 were assumed to be asymptotic (Figure 3.3). All selectivity patterns for Program 146 were freely estimated and the predicted pattern was a dome.

The predicted survey indices captured the overall trend for all surveys (Figure 3.4) but did not capture the inter-annual variability. No trends were apparent in the survey standardized residuals (Figure 3.5). Also, Q-Q plots and associated tests for normality indicated that the survey standardized residuals were normally distributed (Figure 3.6).

The Stock Synthesis model did a fair job of predicting average individual body weights for the commercial fishery and the surveys (Figure 3.7). While the predicted values didn't match well with the observed point estimates in all cases, the predicted values were within the range of observed variability except for Program 135 in 2000 and 2011.

The model performed reasonably well in predicting the length-frequency distributions for the commercial fishery (Figures 3.8, 3.9), Program 135 (Figures 3.10, 3.11), Program 915 (Figures 3.12, 3.13), and Program 146 (Figures 3.14, 3.15). The standardized residuals for the length compositions tended to be higher for the females than the males for the commercial fishery (Figure 3.16) and the surveys (Figures 3.17–3.19). There appears to be a pattern of underestimation of mid-size (~36 cm) female striped mullet and overestimation of the smallest and largest sizes for the commercial fishery and all the surveys.

Predicted age-frequency distributions did not fit as well as the length-frequency distributions (Figures 3.20–3.27). The standardized residuals of the age compositions indicated a tendency for the model to overestimate the youngest ages and overestimate the older ages (Figures 3.28–3.31). The exception is the male age composition residuals from Program 915, which shows the opposite pattern (Figure 3.30B).

Model predicted lengths at age appeared to provide good fits to the observed data (Figures 3.32–3.39).

The model was allowed to predict *M* at age 2 for male striped mullet. Predicted *M* at age 2 for males was 0.628 (Table 3.12).

The model estimates of *F*, recruitment, and SSB were relatively insensitive to removal of fisheries-independent survey indices (Figure 3.40). Removal of both the indices and biological data collected from the surveys resulted in higher estimates of *F*, lower estimates of recruitment, and lower estimates of SSB (Figure 3.41). When the biological data collected from the commercial fishery was removed, trends were somewhat similar to those produced by the base model, but absolute values were different (Figure 3.42). Removing the commercial fishery biological data produced higher estimates of *F*, except in the final years, when estimates were lower than those estimated in the base run. Estimates of recruitment were either higher or lower than those in the base run. SSB estimates were higher than the base run in the earliest and latest years but were lower than the base run during the intervening years. The removal of all age data led to higher estimates of *F*, lower estimates of recruitment (except in final years), and lower estimates of SSB (Figure 3.43). Ignoring the length-at-age data had a negligible effect on model results. Removal of the length data produced estimates that were orders of magnitude different than those estimated in the base run.

Model estimates of *F*, recruitment, and SSB were not markedly affected by changing assumptions about steepness (Figure 3.44). The retrospective analysis indicated a tendency for the model to overestimate terminal *F* and underestimate terminal SSB (Figure 3.45).

Stock Synthesis estimated a value of 0.932 for the fishing mortality threshold ($F_{25\%}$) and a value of 0.566 for the fishing mortality target ($F_{35\%}$; Figure 3.46). Predicted values of annual *F* were lower than the threshold throughout the time series and were lower than the target in all years except for 2000. Biomass-based reference points were not considered reliable (see next section) and so estimates are not presented here.

3.4 DISCUSSION OF RESULTS

The striped mullet resource has been fished since at least the late 1800s. The results of the model suggest recruitment and SSB have been generally declining in recent years, though recruitment showed a small increase in the most recent year. Commercial landings have been relatively unchanged during the last nine years of the time series and *F* has shown a slight increase in the last four years. Note that estimates in the most recent years are the most uncertain.

The model performed reasonably well in fitting the survey indices and the length-frequency data. The fits to the age-frequency distributions were not as good likely due to the smaller sample sizes associated with the observed age distributions as well as the lack of contrast observed in the survey indices. Fits to the average individual body weights were also likely complicated by the high variance associated with the observed data.

The residual patterns seen in the length and age compositions are thought to be a result of not accounting for sex-specific selectivity in the fishery and the surveys. It is recommended that this be explored in future assessment models.

The Stock Synthesis estimate of *M* at age 2 for males (0.628; Table 3.12) was higher than the estimate computed external to the model (0.509; Table 1.5). Preliminary model runs suggested lack of contrast in SSB and recruitment, so the steepness parameter was fixed. Steepness strongly influences MSY-based reference points (Brooks et al. 2010) and fixing steepness limits the way the data can inform the reference point (Mangel et al. 2013). For this reason, estimated biomass-based reference points were considered unreliable.

The sensitivity analyses demonstrated that removing the length-frequency data had the greatest impact on the model estimates. The length-at-age data did not appear very informative to the model and, despite the associated small sample sizes, the age data had a noticeable impact on the results. The retrospective analysis showed a tendency for the model to overestimate terminal *F* and underestimate terminal SSB, suggesting the stock may be in better shape than predicted.

In this assessment, annual estimates of *F* ranged from 0.247 to 0.692 during 1994 to 2011. Bacheler et al. (2005) estimated mortality for striped mullet in North Carolina based on the results of a tagging study that was performed during 1997 through 2001. Their tagging models yielded total mortality (*Z*) estimates ranging from 1.71 to 2.12 and estimates of *F* ranged from 0.65 to 2.22 depending on the time interval in the model. These estimates apply to female striped mullet that are 300 mm in fork length and larger, which corresponds to fish approximately age 1 and older. Though these estimates are not directly comparable to those generated by the Stock Synthesis model (*F* for age 1 and older females vs. *F* for ages 2–5 sexes combined), there is some overlap.

A more recent study by Wong (2007) collected biological samples from the Bogue Banks commercial stop net/beach seine harvest in 2005 and 2006. Annual age compositions were produced and catch curve analyses were applied to estimate annual *Z*s. The catch curve analyses were applied to striped mullet age 3 and older and resulted in estimates of Z = 0.76 in 2005 and Z = 0.52 in 2006. Wong's estimated F values for 2005 and 2006 were 0.48 and 0.25. Stock Synthesis estimated F = 0.261 in both 2005 and 2006. As before, the estimates in the Wong study and those produced by Stock Synthesis are not directly comparable (F for age 3 and older in the Bogue Banks stop net/beach seine fishery vs. F for ages 2–5 in the entire commercial fishery), but the estimates for 2006 were similar.

A major concern with this assessment is the lack of contrast and high variability associated with the survey indices and lack of contrast in the commercial landings data. Lack of contrast leads to parameter uncertainty; models require variation in stock size and fishing effort to reliably estimate parameters (Hilborn and Walters 1992).

4.0 STATUS DETERMINATION CRITERIA

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

The 2006 NCDMF FMP for striped mullet adopted a fishing mortality threshold of $F_{25\%}$ and a fishing mortality target of $F_{30\%}$ (NCDMF 2006). For the current assessment, the working group adopted a fishing mortality target of $F_{35\%}$. The fishing mortality target was increased to 35% due to the fishery targeting female fish during the spawning season, potential forage importance of the striped mullet to the ecosystem, and proximity of the target to the threshold. Stock Synthesis computed a value of 0.932 for $F_{25\%}$ and a value of 0.566 for $F_{35\%}$. These estimates are numbers-weighted values for ages 2–5 and so are consistent with the reported F values. Predicted F in 2011 was 0.437. As such, overfishing is not occurring in the striped mullet stock ($F_{2011} < F_{25\%}$; Figure 3.46).

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 is considered unknown.

5.0 SUITABILITY FOR MANAGEMENT

Stocks assessments performed by the NCDMF in support of management plans are subject to an extensive review process. Internal reviews are conducted by various groups within the NCDMF including the species Plan Development Team, the Biological Review Team Technical Committee, and the Management Review Team. External reviews are designed to provide an independent peer review and are conducted by experts in stock assessment science and experts in the biology and ecology of the species. The goal of the external review is to ensure the results are based on sound science and provide a valid basis for management.

The initial assessment concluded that overfishing was occurring in the striped mullet stock. That assessment was peer reviewed in May 2013. The peer reviewers agreed that the assessment provided 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; however, there were several concerns offered by the peer reviewers that the working group felt should be addressed. One concern was the low value of *K* estimated for male striped mullet in the von Bertalanffy age-length model. The working group felt the unrealistic value resulted from the lack of age-0 fish included in the fit of the von Bertalanffy model. The model was refit to data that included age-0 fish and resulted in more realistic von Bertalanffy parameter estimates for both males and females (see section 1.2.4.4). This change had a big impact on the fishing mortality reference points. Another concern was the exclusion of the Program 146 survey data from the assessment model. This survey targets striped mullet and the peer reviewers did not feel the reasons for initially excluding the survey were valid. The working group decided to incorporate an index and biological data derived from this survey into the model. Another change that was made was to the selectivity pattern for the commercial fishery; in the current assessment, commercial fishery selectivity was assumed to have a dome-shaped pattern whereas the initial assessment allowed the model to freely estimate all selectivity parameters. The impact of this assumption was evaluated by performing a run in which selectivity for the commercial fishery was assumed to have an asymptotic pattern. There was very little impact on estimates of annual *F*, recruitment, and SSB and negligible impact on the fishing mortality reference points when commercial fishery selectivity was assumed to follow an asymptotic pattern. The changes discussed here are reflected in the current document and resulted in a change in stock status; the results now indicate that overfishing is not occurring in the stock.

One of the peer reviewers was interested in incorporating a fishery-dependent index into the assessment model. The working group did not feel a fishery-dependent index developed from the available data would be reflective of trends in population abundance. There is no information available on unsuccessful trips, which is needed to develop a reliable index of abundance. Additionally, fishery-dependent indices are only reflective of trends in fished areas. Despite these issues, a model was run that incorporated a fishery-dependent index derived from the set gill-net fishery. Including the fishery-dependent index had no measurable impact on the model results.

Following the suggestion of the peer reviewers, additional model diagnostics and sensitivity runs were also performed and are included in the current assessment.

The peer reviewers were asked to review the changes and comment on whether they still agreed the assessment provided a valid basis for management for at least the next five years. The peer reviewers were comfortable with the changes and agreed that the assessment provided a valid basis for management for at least the next five years given the available data and current knowledge. Suggestions for improvements to the next assessment will be taken under consideration at that time.

6.0 RESEARCH RECOMMENDATIONS

The following research recommendations are offered (no particular order) to improve the next assessment of the North Carolina striped mullet stock:

- Improved recreational fisheries statistics provided by the MRFSS (now MRIP) or some other program to reliably characterize the magnitude and length and age structure of recreational fisheries losses
- Development of a reliable fisheries-independent index of juvenile abundance

- Increase the number of age samples from both fisheries-dependent and fisheries-independent sources
- Investigate how catchability of striped mullet by Program 146 is affected by variations in salinity and conductivity
- Initiate an adult striped mullet survey in the Core and Bogue sound areas where approximately 20% of the striped mullet harvest occurs
- Explore the NOAA Bridge Net Survey as a possible larval/juvenile abundance index for striped mullet
- Consider sex-specific selectivity curves in future modeling work
- 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 *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 *M*s for fish of this size based on a meta-analysis

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8.0 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	0.5	-0.38	Wong 2006
North Carolina	1996–2011	Various	FI & FD	6,831	Female	45.2	0.503	-1.06	current study
North Carolina	1996–2011	Various	FI & FD	2,820	Male	33.6	1.11	-0.703	current study

Table 1.2. Estimated parameter values of the allometric 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	current study
North Carolina	1996–2011	Various	FI & FD	2,465	Male	1.92E-05	2.92	current study

Table 1.3. Age- and sex-specific estimates of instantaneous natural mortality assumed in the previous NCDMF stock assessment of striped mullet (Wong 2006). Estimates were computed using the method of Lorenzen (1996).

	Male		Female	
Age	**Jan–Jun**	**Jul–Dec**	**Jan–Jun**	**Jul–Dec**
0	2.93	1.27	2.51	1.08
1	0.891	0.725	0.759	0.615
2	0.632	0.574	0.535	0.484
3	0.535	0.507	0.45	0.425
4	0.486	0.471	0.407	0.394
5	0.46	0.451	0.384	0.376
6+	0.444	0.438	0.369	0.364

Table 1.4. Sex-specific estimates of age-constant, instantaneous natural mortality for striped mullet using various life history-based methods.

Source	**Equation**	**Male**	**Female**
Alverson and Carney 1975	$M = 3K/[\exp(0.38*K*t_{MAX}) - 1]$	0.009	0.137
Hoenig 1983	$M = \exp[1.44 - 0.982*\log_e(t_{MAX})]$	0.316	0.340
Hoenig 1983; rule-of-thumb	$M = -\log_e(0.05)/t_{MAX}$ □ $3/t_{MAX}$	0.214	0.230
Ralston 1987	$M = 0.0189 + 2.06*K$	2.300	1.050
Jensen 1996 (theoretical)	$M = 1.50*K$	1.660	0.754
Jensen 1996 (derived from Pauly 1980)	$M = 1.60*K$	1.770	0.805
Hewitt and Hoenig 2005	$M = 4.22/t_{MAX}$	0.301	0.325

Table 1.5. Sex-specific estimates of age-specific, instantaneous natural mortality for striped mullet calculated using the method of Lorenzen (1996).

Age	Male	Female
0	0.807	0.802
1	0.559	0.549
2	0.509	0.464
3	0.495	0.425
4	0.490	0.405
5	0.489	0.393
6	0.488	0.387
7	0.488	0.383
8	0.488	0.381
9	0.488	0.379
10	0.488	0.379
11	0.488	0.378
12	0.488	0.378
13	0.488	0.378
14	0.488	

Table 2.1. Numbers of striped mullet samples reported by the MRFSS angler-intercept survey and at-sea headboat survey, by catch type, 1981–2011.

Year	Landings (Type A)	Dead Discards (Type B1)		Released Alive (Type B2)	
	Intercept	Intercept	Headboat	Intercept	Headboat
1981	2	10		0	
1982	104	136		0	
1983	112	13		0	
1984	32	182		100	
1985	20	124		30	
1986	3	44		0	
1987	495	30		0	
1988	282	250		24	
1989	234	112		5	
1990	42	212		0	
1991	30	57		6	
1992	648	163		15	
1993	110	101		10	
1994	224	3		13	
1995	85	27		4	
1996	40	23		0	
1997	76	0		0	
1998	2	7		0	
1999	10	3		0	
2000	7	72		259	
2001	38	2,244		1,075	
2002	441	3,273		1,407	
2003	38	1,815		595	
2004	0	286		0	
2005	10	0	0	0	0
2006	14	3	0	0	0
2007	47	24	0	0	0
2008	14	0	0	0	0
2009	35	0	0	0	0
2010	118	97	0	2	0
2011	34	99	0	4	0

Table 2.2. Numbers of striped mullet available for biological sampling in the MRFSS angler-intercept survey and at-sea headboat survey, by survey component, 1981–2011.

	Intercept (Type A only)		Headboat (Type B only)
Year	Weighed	Measured	Measured
1981	2	2	
1982	19	29	
1983	30	30	
1984	4	12	
1985	2	1	
1986	3	3	
1987	44	46	
1988	20	27	
1989	33	14	
1990	21	21	
1991	13	13	
1992	4	4	
1993	15	17	
1994	36	36	
1995	3	12	
1996	3	5	
1997	42	43	
1998	2	2	
1999	3	4	
2000	2	2	
2001	33	33	
2002	63	63	
2003	23	23	
2004	0	0	
2005	8	10	0
2006	2	2	0
2007	0	0	0
2008	3	4	0
2009	10	10	0
2010	12	12	0
2011	8	8	0

Table 2.3. Estimated amount of striped mullet harvested (Type A+B1) and released alive (Type B2) by recreational anglers in North Carolina waters, 1981–2011.

	Harvest (Type A + B1)		Released Alive (Type B2)
Year	Number	Weight (mt)	Number
1981	9,847	3.445	
1982	119,228	61.69	
1983	67,825	10.34	
1984	131,639	18.51	284,020
1985	114,844	27.34	44,235
1986	14,185	3.229	
1987	380,788	23.46	
1988	132,048	27.69	11,962
1989	44,389	18.51	1,547
1990	34,976	19.37	
1991	7,781	2.545	2,673
1992	178,350	85.5	7,883
1993	36,904	8.064	5,735
1994	35,661	35.87	6,751
1995	15,993	5.023	1,916
1996	6,837	0.9082	
1997	11,343	8.245	
1998	1,347	0.3806	
1999	1,508	0.3168	
2000	15,219	3.826	112,254
2001	396,941	139.2	389,216
2002	695,570	91.86	559,972
2003	477,374	179.6	349,711
2004	2,169	0.7203	
2005	4,310	2.116	
2006	3,996	1.447	
2007	98,352	28.87	
2008	1,895	0.5611	
2009	9,545	2.476	
2010	37,485	23.63	805
2011	25,295	4.97	950

Table 2.4. Estimated coefficients of predictors and their standard errors for the negative binomial GLM fit to the striped mullet data collected from Program 146.

Coefficient	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	3.66131	0.30127	12.153	< 2e-16
Year—2005	-0.39516	0.36770	-1.075	0.2825
Year—2006	0.03822	0.36590	0.104	0.9168
Year—2007	-0.74744	0.39552	-1.890	0.0588
Year—2008	0.11615	0.38193	0.304	0.7610
Year—2009	-0.59578	0.37873	-1.573	0.1157
Year—2010	-0.75837	0.35717	-2.123	0.0337
Year—2011	0.17677	0.36567	0.483	0.6288
Area—HAN	1.62669	0.30545	5.326	0.0000
Area—NEW	-1.07527	0.26568	-4.047	0.0001
Area—SLO	2.60412	0.30483	8.543	< 2e-16
Salinity	-0.09544	0.04652	-2.052	0.0402

Table 2.5. Results of the final model selection for the fit of the negative binomial GLM fit to the striped mullet data collected from Program 146.

Dropped Term	df	Deviance	AIC	LRT	Pr(> [illegible]^2)
None		422.99	3,396.70		
Year	7	436.4	3,396.10	13.406	0.06281
Area	3	531.55	3,499.30	108.56	< 2e-16
Salinity	1	426.46	3,398.20	3.471	0.06245

Table 2.6. Estimated coefficients of predictors and their standard errors for the negative binomial GLM fit to the striped mullet data collected from Program 135.

Coefficient	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	0.64552	0.53353	1.210	0.226313
Year—1995	1.09412	0.66992	1.633	0.102426
Year—1996	0.57643	0.69852	0.825	0.409254
Year—1997	-0.30052	0.65097	-0.462	0.644335
Year—1998	1.50366	0.73712	2.040	0.041358
Year—1999	-1.55861	0.82416	-1.891	0.058603
Year—2000	0.35177	0.63087	0.558	0.577119
Year—2001	0.64248	0.56976	1.128	0.259477
Year—2002	0.10373	0.60934	0.170	0.864833
Year—2003	0.83698	0.62537	1.338	0.180776
Year—2004	1.70456	0.60434	2.821	0.004794
Year—2005	1.02102	0.60718	1.682	0.092650
Year—2006	-0.53085	0.68926	-0.770	0.441201
Year—2007	0.30780	0.67636	0.455	0.649052
Year—2008	-0.59902	0.71681	-0.836	0.403340
Year—2009	1.63379	0.61128	2.673	0.007524
Year—2010	2.20975	0.64649	3.418	0.000631
Year—2011	-0.43384	0.68511	-0.633	0.526573
Quad—3	-0.03187	0.34115	-0.093	0.925566
Quad—4	0.17796	0.39432	0.451	0.651755
Quad—5	0.37345	0.34175	1.093	0.274501
Quad—6	-0.89110	0.45192	-1.972	0.048629
Quad—7	-2.23739	0.32218	-6.944	3.80E-12

Table 2.7. Results of the final model selection for the fit of the negative binomial GLM fit to the striped mullet data collected from Program 135.

Dropped Term	df	Deviance	AIC	LRT	Pr(> [illegible]^{2})
None		429.44	1,957.4		
Year	17	493.71	1,987.7	64.269	2.041E-07
Quad	5	497.57	2,015.6	68.136	2.502E-13

Table 2.8. Estimated coefficients of predictors and their standard errors for the negative binomial GLM fit to the striped mullet data collected from Program 915.

Coefficient	**Estimate**	**Std. Error**	**z value**	**Pr(>|z|)**
Intercept	1.56566	0.42343	3.698	0.000218
Year—2005	-0.42025	0.30034	-1.399	0.161728
Year—2006	-0.44090	0.30322	-1.454	0.145929
Year—2007	0.86678	0.34837	2.488	0.012843
Year—2008	0.11049	0.36349	0.304	0.761157
Year—2009	0.24380	0.33736	0.723	0.469886
Year—2010	0.41120	0.30587	1.344	0.178828
Year—2011	0.55243	0.31843	1.735	0.082766
Salinity	-0.05048	0.01990	-2.537	0.011194
DO	0.12685	0.04361	2.909	0.003628

Table 2.9. Results of the final model selection for the fit of the negative binomial GLM fit to the striped mullet data collected from Program 915.

Dropped Term	**df**	**Deviance**	**AIC**	**LRT**	**Pr(> ^{2})**
None		291.53	1685.6		
Year	7	313.64	1693.7	22.1147	0.002427
Salinity	1	296.88	1688.9	5.3520	0.020698
DO	1	300.15	1692.2	8.6256	0.003315

Table 3.1. Comparison of data sources used in the previous (Wong 2006) and current assessments.

	Wong (2006)					Current Assessment				
Data Source	Landings	Juvenile Index	Adult Index	Length	Age	Landings	Juvenile Index	Adult Index	Length	Age
Commercial Fishery	X		X		X	X			X	X
Recreational Fishery	X				X					
NCSU Albemarle Sound Seine Survey				X						
NCDMF Alosine Seine Survey (Program 100)		X								
NCDMF Juvenile Red Drum Seine Survey (Program 123)		X								
NCDMF Striped Mullet Electroshock Survey (Program 146)								X	X	X
NCDMF Striped Bass Independent Gill-Net Survey (Program 135)			X	X				X	X	X
NCDMF Striped Mullet Trammel Net Survey (Program 145)[4]			X	X						
NCDMF Fisheries-Independent Gill-Net Survey (Program 915)								X	X	X

[4] The NCDMF Trammel Net Survey ended in 2002

Table 3.2. Predicted annual *F*s (numbers-weighted, ages 2–5) and associated standard deviations from the base run of the Stock Synthesis model.

Year	*F*	SD[*F*]
1994	0.315	0.0319
1995	0.475	0.0499
1996	0.455	0.0489
1997	0.487	0.0437
1998	0.504	0.0454
1999	0.336	0.0310
2000	0.692	0.0575
2001	0.428	0.0328
2002	0.525	0.0398
2003	0.311	0.0239
2004	0.291	0.0224
2005	0.261	0.0206
2006	0.261	0.0207
2007	0.247	0.0201
2008	0.274	0.0244
2009	0.290	0.0308
2010	0.424	0.0629
2011	0.437	0.0978

Table 3.3. Predicted numbers of age-0 recruits and weights of SSB and associated standard deviations from the base run of the Stock Synthesis model.

Year	Recruits (000s)	SD[Recruits]	SSB (mt)	SD[SSB]
1994	4,377	1,173	1,605	180
1995	14,851	1,762	1,632	166.3
1996	9,176	1,240	1,162	142
1997	10,309	1,142	1,505	130.9
1998	6,424	970	1,348	120.3
1999	17,302	1,478	1,272	120
2000	10,267	1,147	1,267	111.1
2001	12,201	1,150	1,506	117.6
2002	10,021	1,024	1,500	111.9
2003	12,188	1,128	1,466	115.6
2004	12,057	1,150	1,580	122.5
2005	12,644	1,233	1,793	139.4
2006	9,201	1,015	1,963	154.5
2007	10,308	1,118	2,063	162.7
2008	8,480	1,152	1,939	162.7
2009	7,847	1,407	1,852	177.5
2010	2,261	630	1,663	203.4
2011	5,117	2,518	1,299	242.1

Table 3.4. Predicted numbers (thousands) of females at age at the beginning of the year from the base run of the Stock Synthesis model.

Year	Age														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1994	2,189	2,414	1,214	484	191	77	31	13	5	2	1	0	0	0	0
1995	7,425	958	1,244	527	209	84	34	14	6	3	1	0	0	0	0
1996	4,588	3,251	469	447	186	76	31	13	5	2	1	0	0	0	0
1997	5,155	2,008	1,604	174	164	70	29	12	5	2	1	0	0	0	0
1998	3,212	2,257	975	561	60	57	25	10	4	2	1	0	0	0	0
1999	8,651	1,406	1,092	337	190	21	20	9	4	2	1	0	0	0	0
2000	5,133	3,787	719	460	141	81	9	9	4	2	1	0	0	0	0
2001	6,101	2,247	1,726	200	123	39	23	3	3	1	1	0	0	0	0
2002	5,010	2,671	1,111	644	74	46	15	9	1	1	0	0	0	0	0
2003	6,094	2,193	1,283	374	212	25	16	5	3	0	0	0	0	0	0
2004	6,028	2,668	1,130	557	162	94	11	7	2	1	0	0	0	0	0
2005	6,322	2,639	1,386	505	249	74	43	5	3	1	1	0	0	0	0
2006	4,601	2,767	1,384	642	235	118	35	21	3	2	1	0	0	0	0
2007	5,154	2,014	1,452	642	299	111	57	17	10	1	1	0	0	0	0
2008	4,240	2,256	1,062	685	304	144	54	28	9	5	1	0	0	0	0
2009	3,924	1,856	1,180	487	315	142	68	26	14	4	3	0	0	0	0
2010	1,130	1,718	965	530	219	144	66	32	12	6	2	1	0	0	0
2011	2,559	495	856	371	201	85	57	26	13	5	3	1	0	0	0

Table 3.5. Predicted numbers (thousands) of males at age at the beginning of the year from the base run of the Stock Synthesis model.

	Age														
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1994	2,189	2,157	1,023	418	166	65	25	10	4	2	1	0	0	0	0
1995	7,425	856	1,030	440	176	69	27	11	4	2	1	0	0	0	0
1996	4,588	2,905	403	397	163	64	25	10	4	2	1	0	0	0	0
1997	5,155	1,795	1,370	158	150	61	24	9	4	1	1	0	0	0	0
1998	3,212	2,017	843	519	58	54	22	9	3	1	1	0	0	0	0
1999	8,651	1,257	946	317	188	20	19	8	3	1	0	0	0	0	0
2000	5,133	3,384	599	400	131	77	8	8	3	1	0	0	0	0	0
2001	6,101	2,008	1,560	199	125	40	23	3	2	1	0	0	0	0	0
2002	5,010	2,387	948	615	76	47	15	9	1	1	0	0	0	0	0
2003	6,094	1,960	1,117	352	218	26	16	5	3	0	0	0	0	0	0
2004	6,028	2,384	936	480	148	91	11	7	2	1	0	0	0	0	0
2005	6,322	2,358	1,141	410	206	63	39	5	3	1	1	0	0	0	0
2006	4,601	2,473	1,132	510	180	90	27	17	2	1	0	0	0	0	0
2007	5,154	1,800	1,188	506	224	78	39	12	7	1	1	0	0	0	0
2008	4,240	2,016	865	536	225	99	35	17	5	3	0	0	0	0	0
2009	3,924	1,659	967	384	234	97	43	15	7	2	1	0	0	0	0
2010	1,130	1,535	794	424	165	100	41	18	6	3	1	1	0	0	0
2011	2,559	442	726	318	164	63	38	16	7	2	1	0	0	0	0

Table 3.6. Predicted numbers (thousands) of females at age at mid-year from the base run of the Stock Synthesis model.

	Age														
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1994	1,448	1,733	800	318	127	51	21	9	4	2	1	0	0	0	0
1995	4,913	670	746	313	126	51	21	9	4	2	1	0	0	0	0
1996	3,036	2,284	286	270	114	47	19	8	3	1	1	0	0	0	0
1997	3,411	1,399	948	102	97	42	17	7	3	1	1	0	0	0	0
1998	2,125	1,570	573	326	35	34	15	6	3	1	0	0	0	0	0
1999	5,724	1,005	709	218	124	14	13	6	3	1	0	0	0	0	0
2000	3,396	2,557	379	238	74	43	5	5	2	1	0	0	0	0	0
2001	4,036	1,580	1,055	121	76	24	14	2	2	1	0	0	0	0	0
2002	3,315	1,851	645	370	43	27	9	5	1	1	0	0	0	0	0
2003	4,032	1,574	845	246	141	17	11	4	2	0	0	0	0	0	0
2004	3,989	1,923	756	372	109	64	8	5	2	1	0	0	0	0	0
2005	4,183	1,911	943	344	171	51	30	4	2	1	0	0	0	0	0
2006	3,044	2,005	943	438	161	82	25	15	2	1	0	0	0	0	0
2007	3,410	1,462	998	442	207	78	40	12	7	1	1	0	0	0	0
2008	2,805	1,632	719	464	208	99	38	19	6	4	0	0	0	0	0
2009	2,596	1,339	791	326	213	97	47	18	9	3	2	0	0	0	0
2010	748	1,212	598	326	136	90	42	20	8	4	1	1	0	0	0
2011	1,693	348	525	226	124	53	36	17	8	3	2	1	0	0	0

Table 3.7. Predicted numbers (thousands) of males at age at mid-year from the base run of the Stock Synthesis model.

	Age														
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1994	1,369	1,491	671	271	107	42	16	6	3	1	0	0	0	0	0
1995	4,644	587	639	268	106	42	16	6	3	1	0	0	0	0	0
1996	2,870	1,995	252	244	100	39	15	6	2	1	0	0	0	0	0
1997	3,224	1,230	844	95	90	36	14	6	2	1	0	0	0	0	0
1998	2,009	1,381	517	312	34	32	13	5	2	1	0	0	0	0	0
1999	5,411	867	615	204	120	13	12	5	2	1	0	0	0	0	0
2000	3,211	2,298	345	224	72	42	5	4	2	1	0	0	0	0	0
2001	3,816	1,380	979	122	77	24	14	2	1	1	0	0	0	0	0
2002	3,134	1,633	577	366	45	28	9	5	1	1	0	0	0	0	0
2003	3,812	1,355	733	228	141	17	11	3	2	0	0	0	0	0	0
2004	3,771	1,650	619	315	96	59	7	4	1	1	0	0	0	0	0
2005	3,954	1,634	763	271	136	41	25	3	2	1	0	0	0	0	0
2006	2,878	1,714	757	338	119	59	18	11	1	1	0	0	0	0	0
2007	3,224	1,248	798	337	149	52	26	8	5	1	0	0	0	0	0
2008	2,652	1,397	577	354	148	65	23	11	3	2	0	0	0	0	0
2009	2,454	1,148	641	252	153	64	28	10	5	1	1	0	0	0	0
2010	707	1,056	503	264	102	62	26	11	4	2	1	0	0	0	0
2011	1,600	304	457	197	101	39	23	10	4	1	1	0	0	0	0

Table 3.8. Predicted numbers (thousands) of females at length at the beginning of the year from the base run of the Stock Synthesis model.

Year	Length (cm)																													
	10	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**	**50**	**52**	**54**	**56**	**58**	**60**	**62**	**64**	**66**	**68**
1994	2,034	156	33	116	302	527	618	496	295	180	177	225	270	285	264	218	163	111	70	41	22	11	5	2	1	0	0	0	0	0
1995	6,901	515	24	46	120	211	250	210	148	132	170	231	281	298	278	231	174	119	76	44	24	12	5	2	1	0	0	0	0	0
1996	4,264	324	47	155	406	707	825	648	353	159	102	116	144	163	164	148	120	89	60	37	21	10	5	2	1	0	0	0	0	0
1997	4,791	360	33	96	251	439	517	421	264	185	201	256	298	300	262	202	140	89	54	31	17	8	4	2	1	0	0	0	0	0
1998	2,985	227	33	108	282	492	577	461	271	159	150	189	229	243	226	186	137	92	56	32	16	8	4	1	1	0	0	0	0	0
1999	8,040	600	31	67	176	308	362	295	186	133	148	193	231	240	219	177	129	86	53	30	16	8	3	1	1	0	0	0	0	0
2000	4,771	362	55	181	473	824	962	757	417	194	132	151	182	198	190	162	125	88	56	33	18	9	4	2	1	0	0	0	0	0
2001	5,670	426	37	108	281	491	579	470	293	201	215	273	315	315	272	204	137	83	47	25	13	6	3	1	0	0	0	0	0	0
2002	4,657	352	41	128	334	582	682	545	319	184	171	216	260	275	255	208	152	100	60	33	16	8	3	1	0	0	0	0	0	0
2003	5,664	425	37	105	274	479	563	453	274	175	177	225	267	277	251	201	145	95	58	32	17	8	3	1	0	0	0	0	0	0
2004	5,603	422	42	128	333	582	682	544	319	185	172	217	262	278	260	216	161	110	68	39	21	10	4	2	1	0	0	0	0	0
2005	5,876	442	43	126	330	576	676	543	325	201	199	254	304	321	297	244	182	124	78	45	24	12	5	2	1	0	0	0	0	0
2006	4,276	324	41	132	346	604	709	568	339	209	206	264	320	341	321	268	203	140	89	53	28	14	6	3	1	0	0	0	0	0
2007	4,790	360	33	96	252	440	519	422	265	187	209	276	337	360	339	286	218	152	98	59	32	16	7	3	1	0	0	0	0	0
2008	3,941	298	35	108	282	492	578	463	276	171	172	225	280	308	301	264	210	153	102	62	35	18	8	4	1	0	0	0	0	0
2009	3,647	275	29	89	232	406	477	386	238	160	173	228	279	302	289	249	196	142	96	60	34	18	8	4	1	0	0	0	0	0
2010	1,051	82	23	82	215	375	441	355	216	141	149	196	242	265	257	224	178	130	88	55	32	17	8	3	1	0	0	0	0	0
2011	2,378	178	10	24	62	109	131	113	86	86	119	164	202	218	209	180	141	102	69	43	25	13	6	3	1	0	0	0	0	0

Table 3.9. Predicted numbers (thousands) of males at length at the beginning of the year from the base run of the Stock Synthesis model.

	Length (cm)																													
Year	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**	**50**	**52**	**54**	**56**	**58**	**60**	**62**	**64**	**66**	**68**
1994	2,096	96	41	198	509	692	505	225	130	180	325	574	333	104	37	11	3	0	0	0	0	0	0	0	0	0	0	0	0	0
1995	7,111	314	18	78	202	277	208	114	109	180	333	596	344	105	37	11	3	0	0	0	0	0	0	0	0	0	0	0	0	0
1996	4,394	199	56	266	684	929	668	265	86	83	192	435	233	51	15	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1997	4,937	220	35	164	424	577	427	208	155	225	335	515	316	123	49	15	4	1	0	0	0	0	0	0	0	0	0	0	0	0
1998	3,076	139	39	185	475	646	471	206	111	155	302	501	296	92	31	9	2	0	0	0	0	0	0	0	0	0	0	0	0	0
1999	8,285	366	26	115	296	404	299	145	107	163	286	489	287	93	34	11	2	0	0	0	0	0	0	0	0	0	0	0	0	0
2000	4,916	223	65	310	797	###	780	314	112	115	231	451	252	67	22	7	2	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	5,842	261	39	184	474	646	478	233	176	257	381	535	339	140	55	17	4	1	0	0	0	0	0	0	0	0	0	0	0	0
2002	4,799	216	46	219	563	765	556	242	127	176	348	564	335	105	35	11	2	0	0	0	0	0	0	0	0	0	0	0	0	0
2003	5,836	260	38	180	462	629	461	212	135	193	332	558	330	109	40	12	3	1	0	0	0	0	0	0	0	0	0	0	0	0
2004	5,773	258	46	218	562	764	556	241	126	169	321	576	332	99	34	10	2	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	6,054	271	46	216	556	756	552	247	144	199	351	623	361	114	41	13	3	1	0	0	0	0	0	0	0	0	0	0	0	0
2006	4,406	198	48	227	583	793	579	257	145	201	371	667	384	117	41	13	3	1	0	0	0	0	0	0	0	0	0	0	0	0
2007	4,936	220	35	165	425	578	426	201	139	209	385	706	404	121	43	13	3	1	0	0	0	0	0	0	0	0	0	0	0	0
2008	4,061	182	39	185	475	646	471	207	113	159	326	669	369	95	32	10	2	0	0	0	0	0	0	0	0	0	0	0	0	0
2009	3,758	168	32	152	391	533	391	180	116	169	313	633	352	98	35	11	3	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	1,083	51	29	141	362	492	360	163	99	143	281	575	317	85	29	9	2	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	2,450	109	9	41	105	143	110	66	74	127	240	484	269	75	26	8	2	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 3.10. Predicted numbers (thousands) of females at length at mid-year from the base run of the Stock Synthesis model.

Year	Length (cm)																													
	10	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**	**50**	**52**	**54**	**56**	**58**	**60**	**62**	**64**	**66**	**68**
1994	36	172	421	487	276	111	117	210	317	381	376	322	265	228	205	180	146	107	70	42	23	11	5	2	1	0	0	0	0	0
1995	122	582	1,425	1,643	895	244	70	86	132	167	182	184	185	189	186	170	139	103	68	41	23	11	5	2	1	0	0	0	0	0
1996	75	359	881	1,019	568	198	159	271	403	471	438	335	227	157	124	107	90	70	50	32	18	9	4	2	1	0	0	0	0	0
1997	84	404	990	1,142	629	193	108	172	260	317	319	283	242	213	189	160	123	86	54	31	16	8	4	2	1	0	0	0	0	0
1998	53	252	617	713	398	138	110	190	284	339	330	275	217	180	157	136	109	79	52	30	16	8	3	1	1	0	0	0	0	0
1999	142	678	1,660	1,914	1,04	290	95	125	188	231	236	216	193	178	165	145	116	84	54	32	17	8	4	1	1	0	0	0	0	0
2000	84	402	986	1,140	636	222	178	304	451	528	491	375	253	171	129	106	86	64	43	26	14	7	3	1	1	0	0	0	0	0
2001	100	478	1,171	1,352	744	227	123	194	293	357	358	316	268	233	204	170	129	87	53	29	14	7	3	1	0	0	0	0	0	0
2002	82	393	962	1,111	615	200	135	224	334	399	386	320	250	203	176	151	121	87	56	32	17	8	3	1	0	0	0	0	0	0
2003	100	477	1,170	1,350	743	226	122	193	290	350	348	303	253	220	197	170	135	96	61	36	19	9	4	2	1	0	0	0	0	0
2004	99	472	1,158	1,336	738	233	143	233	349	418	408	344	276	232	205	180	145	106	70	42	23	11	5	2	1	0	0	0	0	0
2005	103	495	1,214	1,401	773	242	144	233	350	423	419	362	302	263	238	208	169	123	81	48	26	13	6	2	1	0	0	0	0	0
2006	75	360	884	1,021	567	192	143	244	367	443	439	380	317	278	254	225	185	137	91	55	30	15	7	3	1	0	0	0	0	0
2007	84	404	990	1,142	629	195	112	181	275	337	347	320	291	276	264	240	198	148	100	61	34	17	8	3	1	0	0	0	0	0
2008	69	332	814	941	521	171	119	199	299	361	359	314	268	243	230	212	180	139	97	61	35	18	8	4	1	0	0	0	0	0
2009	64	307	753	870	481	154	99	165	249	303	308	278	247	230	220	202	170	130	90	57	33	17	8	4	1	0	0	0	0	0
2010	19	89	217	252	145	66	81	148	223	270	271	239	207	189	180	165	140	108	76	48	28	15	7	3	1	0	0	0	0	0
2011	42	200	491	566	309	87	32	46	72	94	108	117	127	137	140	131	111	85	59	37	22	11	5	2	1	0	0	0	0	0

Table 3.11. Predicted numbers (thousands) of males at length at mid-year from the base run of the Stock Synthesis model.

	Length (cm)																													
Year	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**	**50**	**52**	**54**	**56**	**58**	**60**	**62**	**64**	**66**	**68**
1994	36	245	561	422	124	92	209	346	392	348	350	524	267	53	9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1995	123	832	1,902	1,419	352	60	83	137	164	180	262	487	254	50	8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1996	76	514	1,175	881	242	129	280	461	508	393	281	384	174	23	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1997	85	578	1,320	987	257	88	173	286	331	319	344	455	246	62	11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1998	53	360	823	617	169	89	194	320	361	311	303	436	221	42	7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1999	143	970	2,216	1,654	413	80	122	202	234	228	271	435	227	47	8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2000	85	575	1,315	986	272	148	322	531	587	458	327	384	179	30	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	101	684	1,563	1,168	303	100	194	321	373	362	395	495	273	72	13	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	83	562	1,284	961	256	110	229	378	426	364	349	491	250	48	8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2003	101	683	1,561	1,167	302	98	190	315	360	330	348	513	266	56	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	100	676	1,544	1,155	304	115	232	382	431	371	357	532	267	50	8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	105	709	1,619	1,211	317	115	229	379	431	384	387	579	295	59	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006	76	516	1,179	883	238	113	241	397	451	399	402	618	313	60	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2007	85	578	1,320	987	257	89	175	290	335	319	373	639	327	63	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2008	70	475	1,086	813	217	94	196	324	366	321	332	592	291	48	8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2009	65	440	1,005	752	199	79	161	267	305	282	312	553	277	50	8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	19	127	290	219	68	64	148	245	279	250	268	478	237	41	7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	42	287	655	489	123	26	43	72	88	108	179	385	197	36	6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 3.12. Predicted rates of age-specific natural mortality from the base run of the Stock Synthesis model. The natural mortality rate for females at age 2 was fixed in the model.

Age	Male	Female
0	0.938	0.826
1	0.709	0.561
2	0.628	0.464
3	0.620	0.438
4	0.618	0.423
5	0.617	0.415
6	0.617	0.410
7	0.617	0.407
8	0.617	0.406
9	0.617	0.405
10	0.617	0.404
11	0.617	0.404
12	0.617	0.403
13	0.617	0.403
14	0.617	0.403

9.0 FIGURES

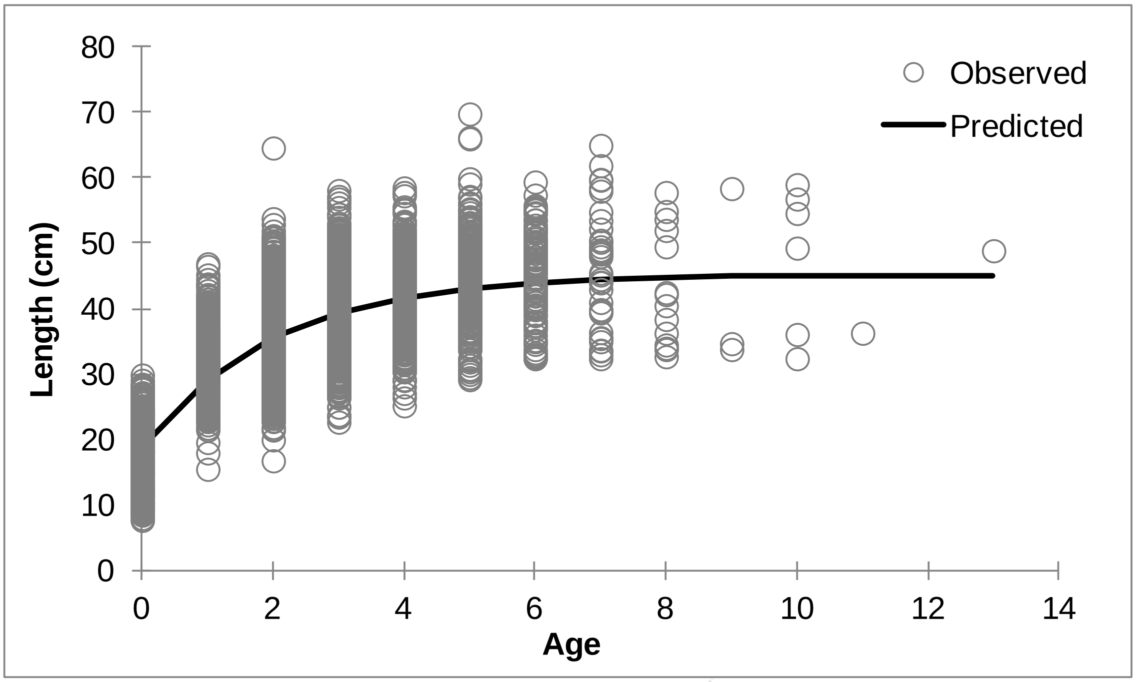

Figure 1.1. Fit of von Bertalanffy age-length model to female striped mullet data collected in North Carolina.

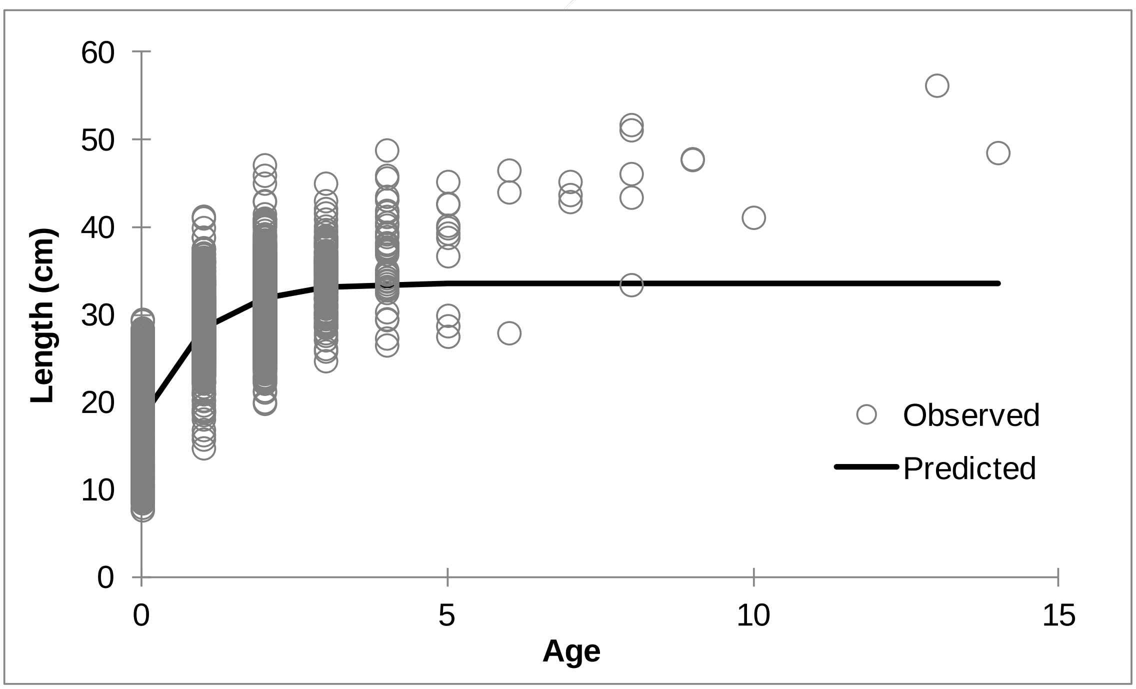

Figure 1.2. Fit of von Bertalanffy age-length model to male striped mullet data collected in North Carolina.

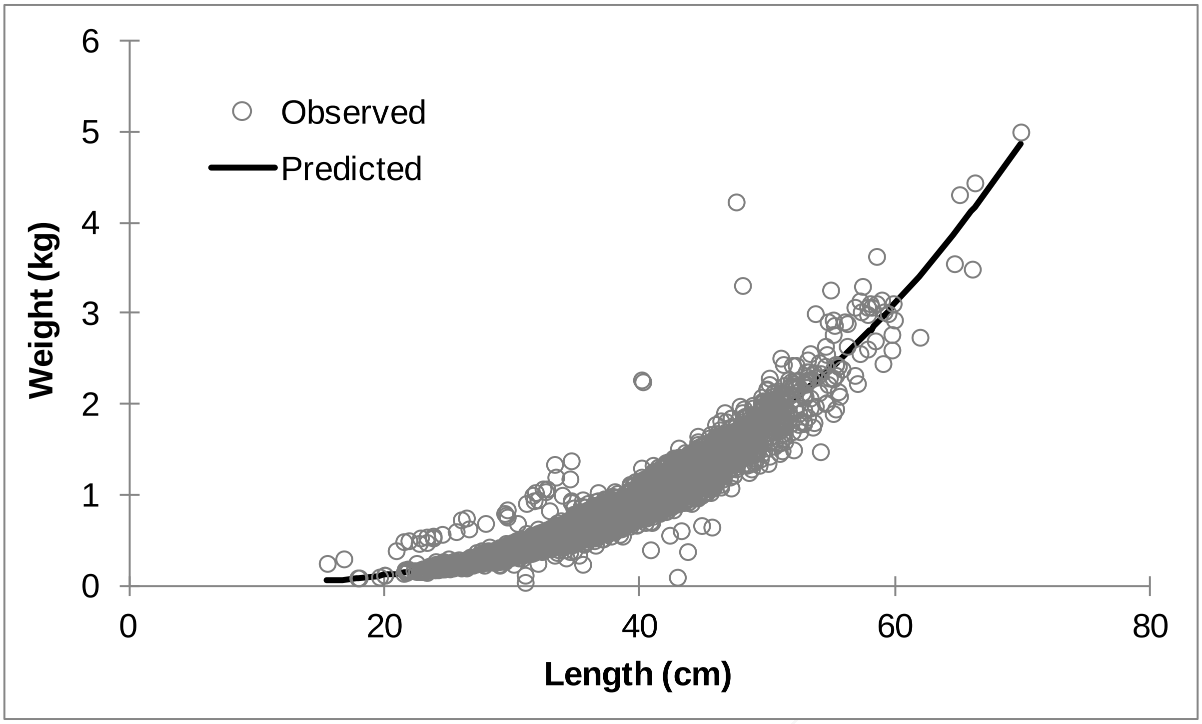

Figure 1.3. Fit of allometric length-weight model to female striped mullet data collected in North Carolina.

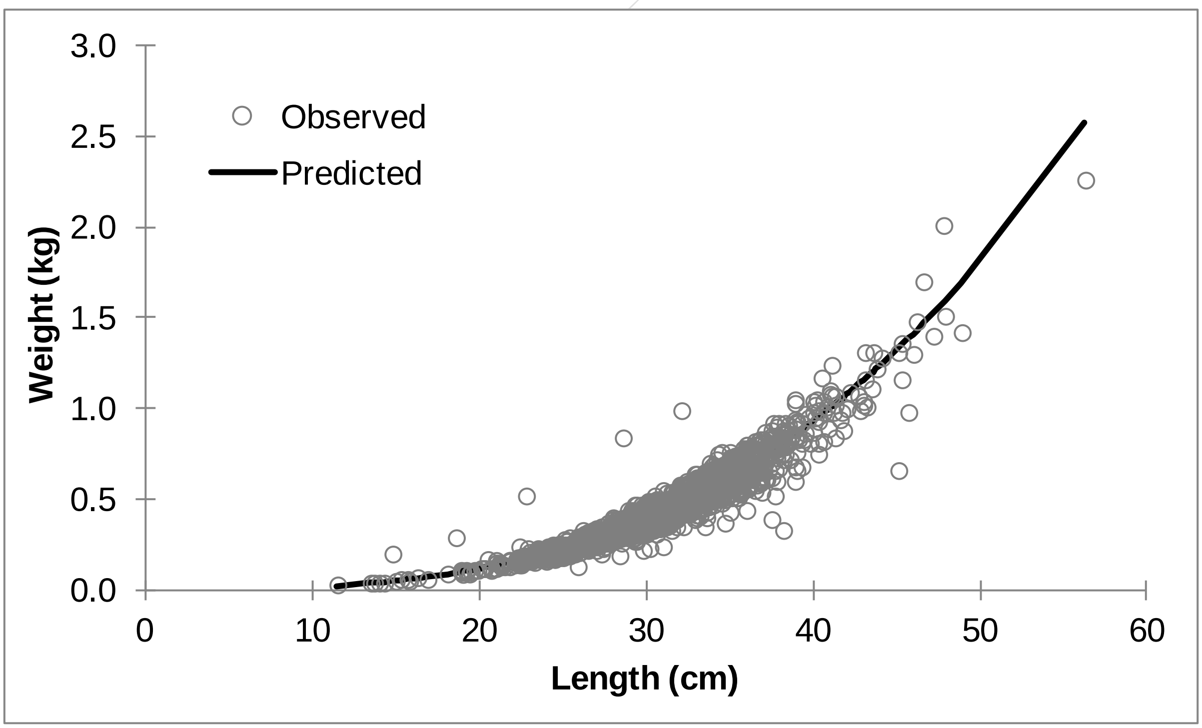

Figure 1.4. Fit of allometric length-weight model to male striped mullet data collected in North Carolina.

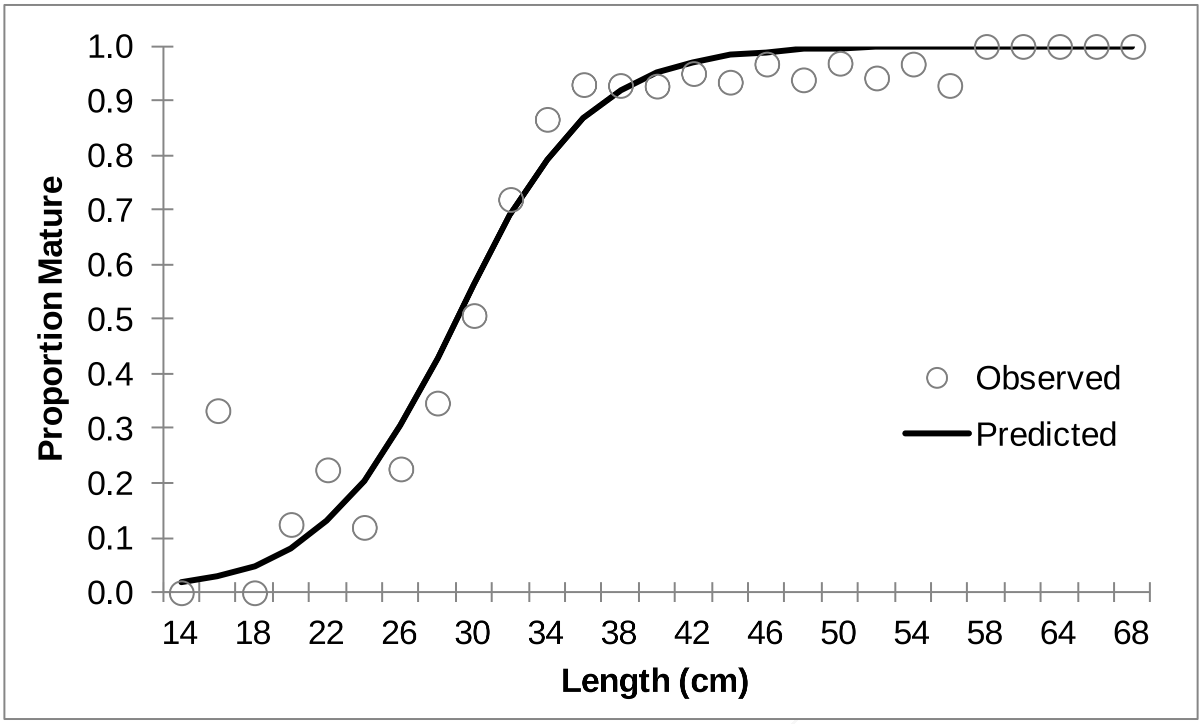

Figure 1.5. Fit of maturity curve to female striped mullet data collected in North Carolina.

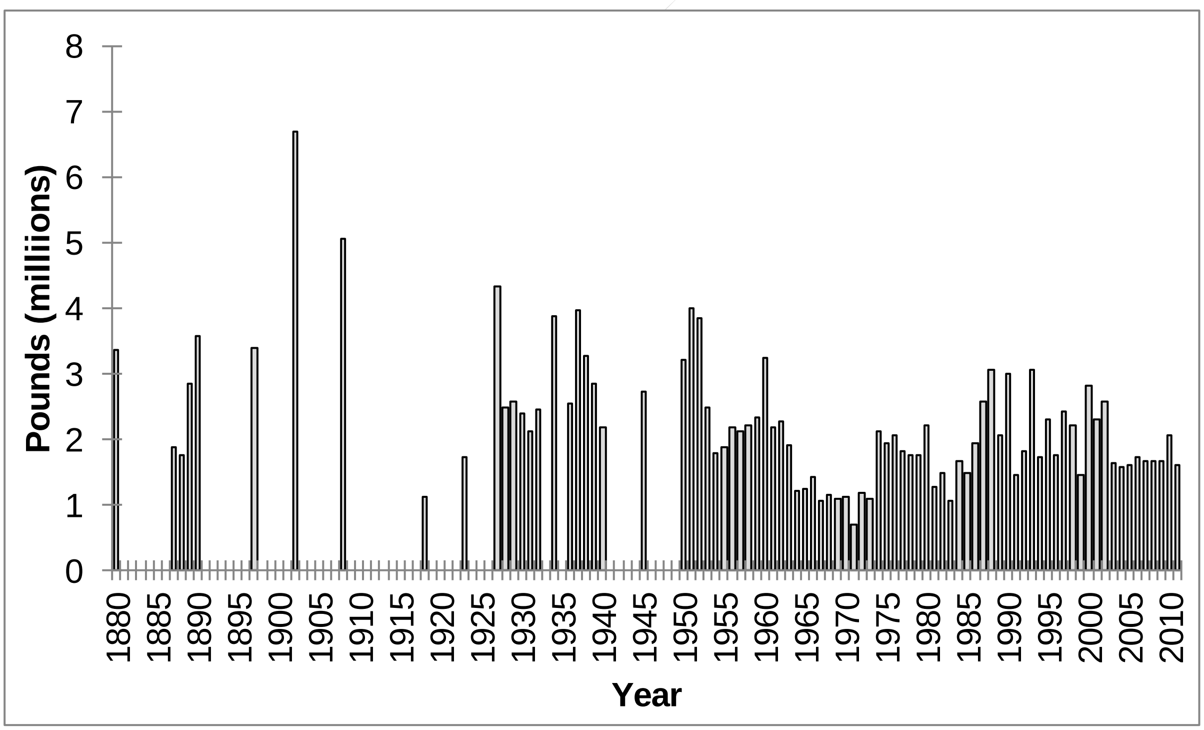

Figure 1.6. Annual commercial landings of striped mullet in North Carolina, 1880–2011. Note that commercial landings data were not available for all years.

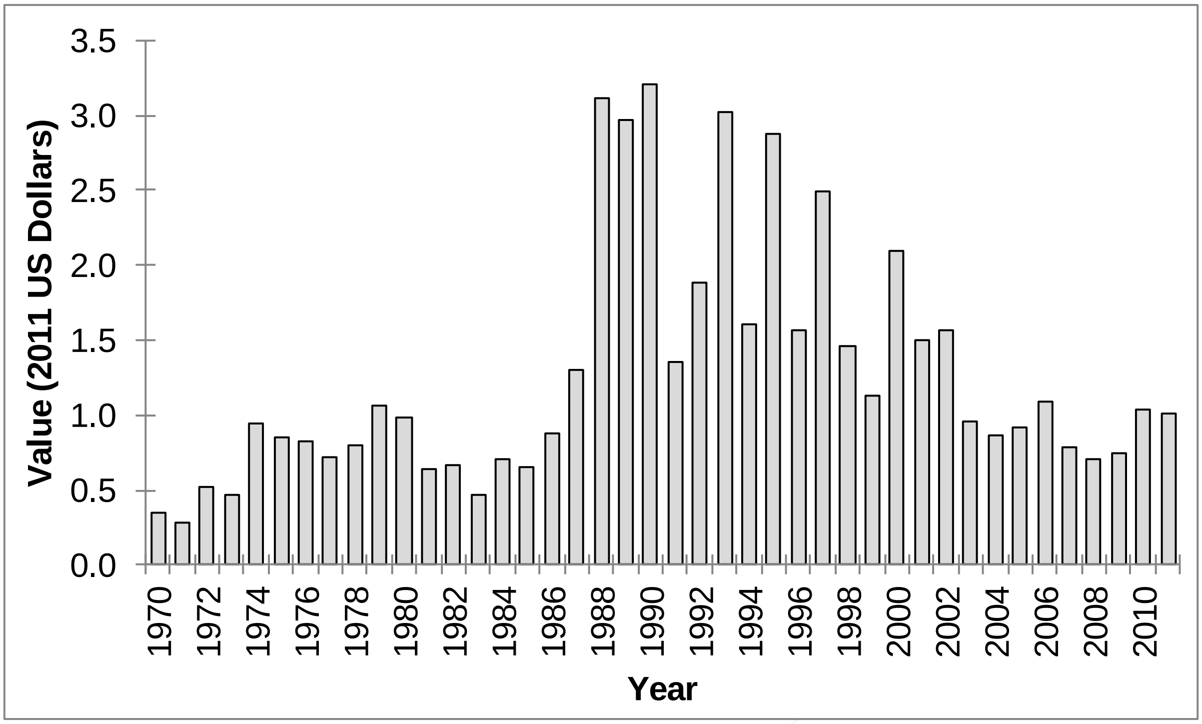

Figure 1.7. Annual value of striped mullet commercial landings in North Carolina, 1970–2011. Note that all values have been converted to 2011 US dollars.

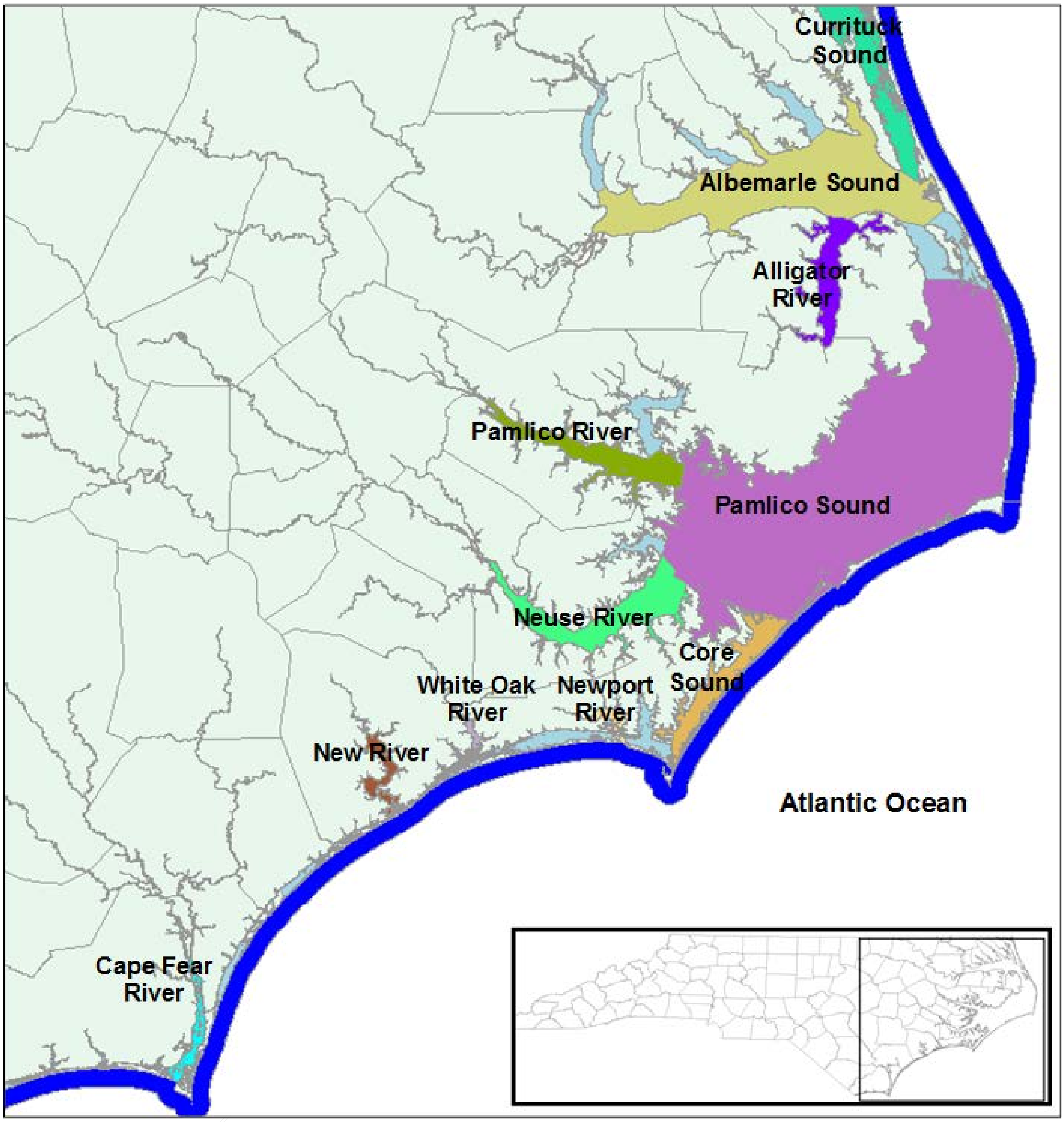

Figure 1.8. Major water bodies within and around North Carolina. The dark blue area represents the extent of the state's coastal fishing waters, which extend to three miles offshore.

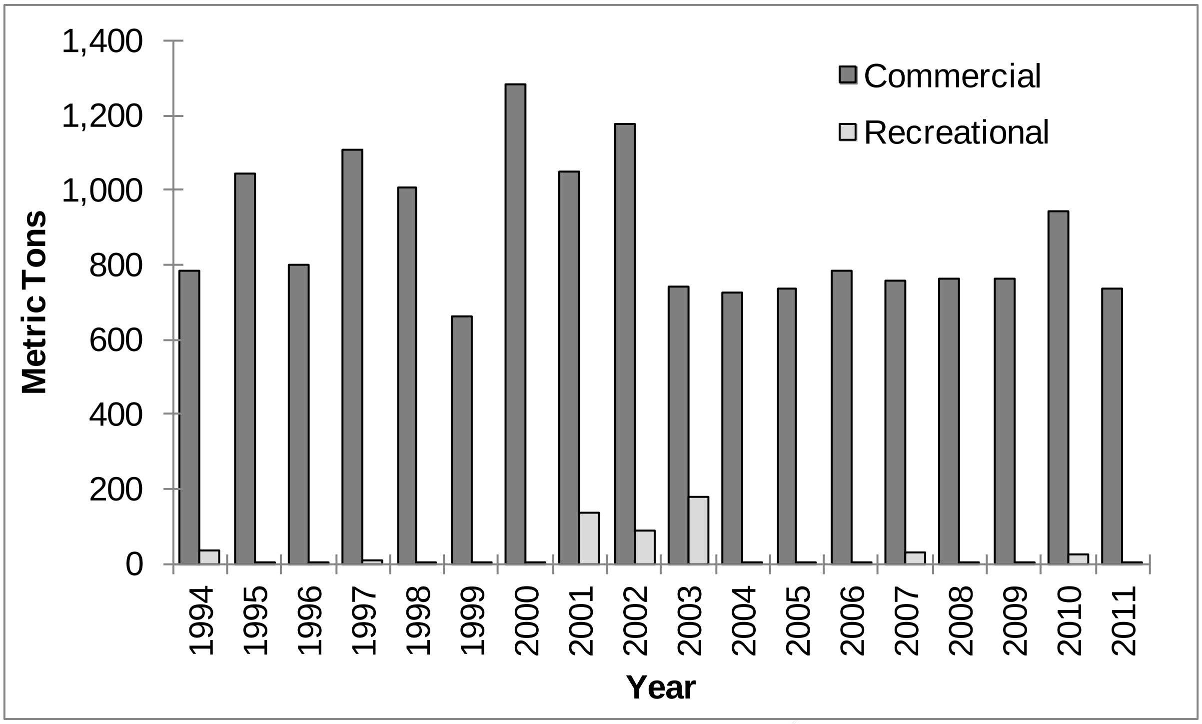

Figure 2.1. Annual commercial landings and recreational harvest (Type A + B1) of striped mullet in North Carolina, 1994–2011.

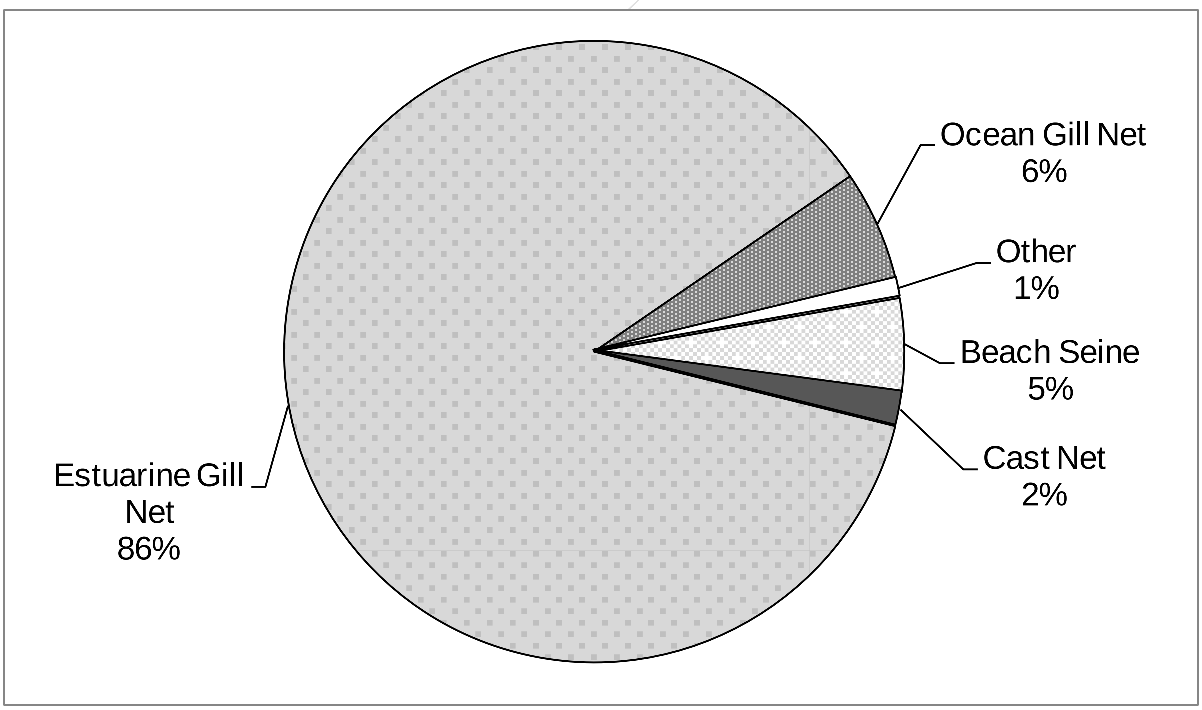

Figure 2.2. Percentages of North Carolina's commercial landings of striped mullet attributed to major gear types, 1994–2011.

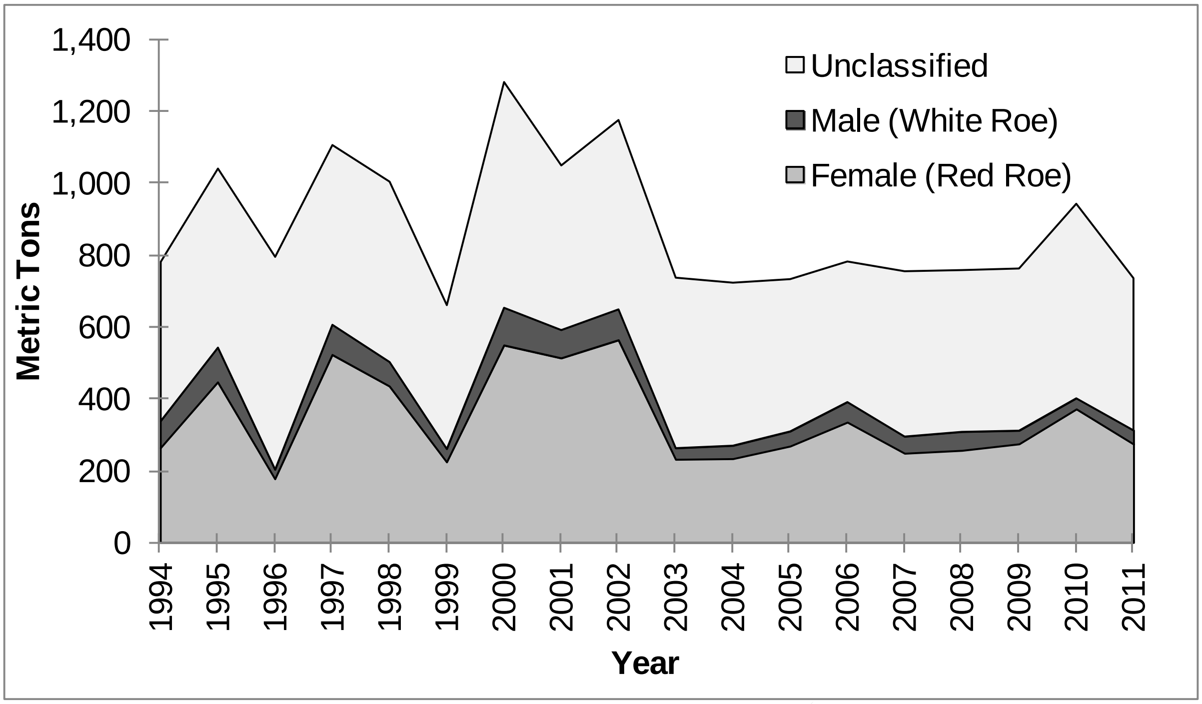

Figure 2.3. Annual commercial landings of striped mullet in North Carolina, by sex, 1994–2011.

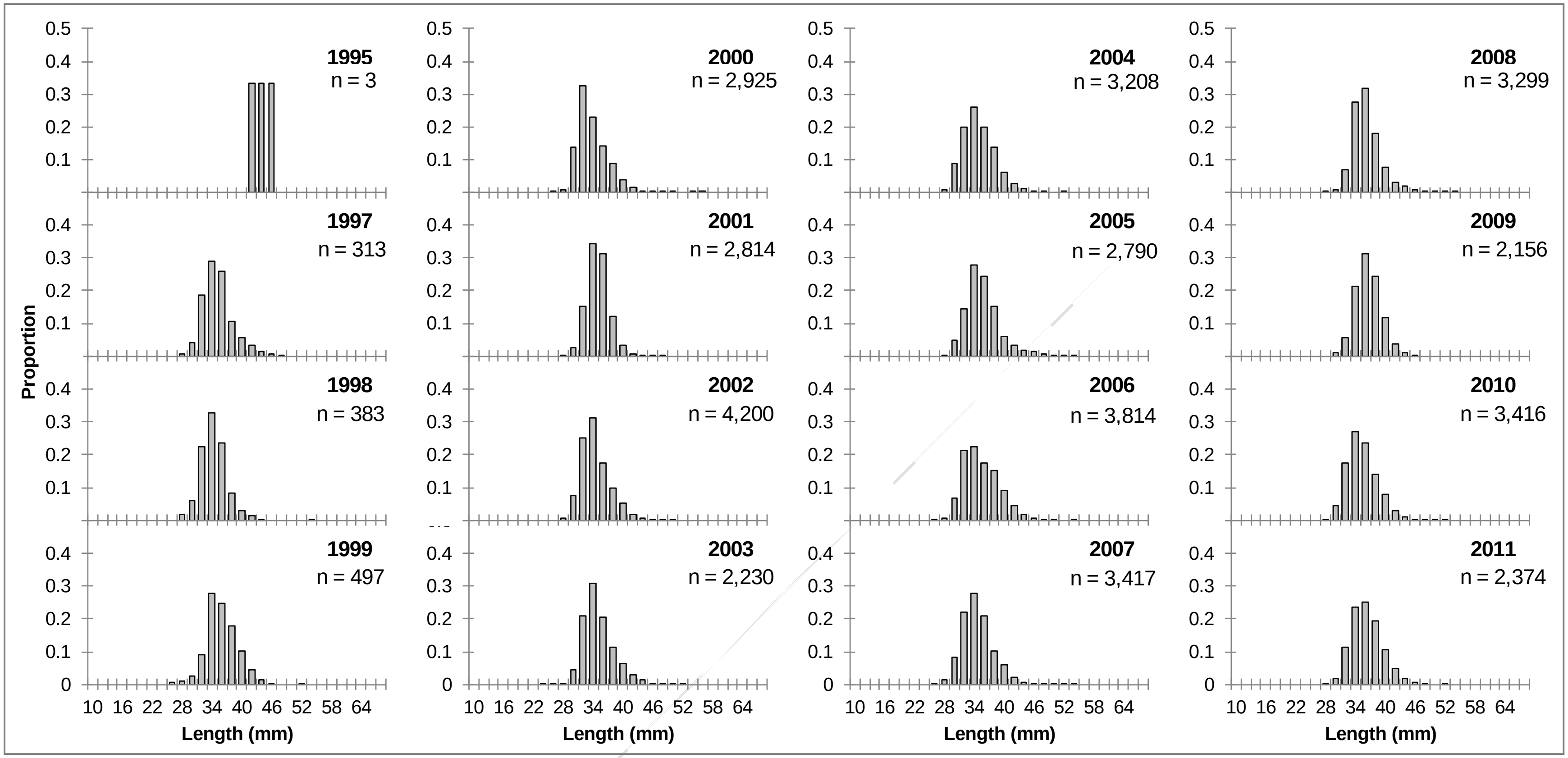

Figure 2.4. Annual length-frequency distributions of female striped mullet sampled from North Carolina commercial fisheries' landings, 1995–2011. There were no length data available for 1996 from the commercial fishery.

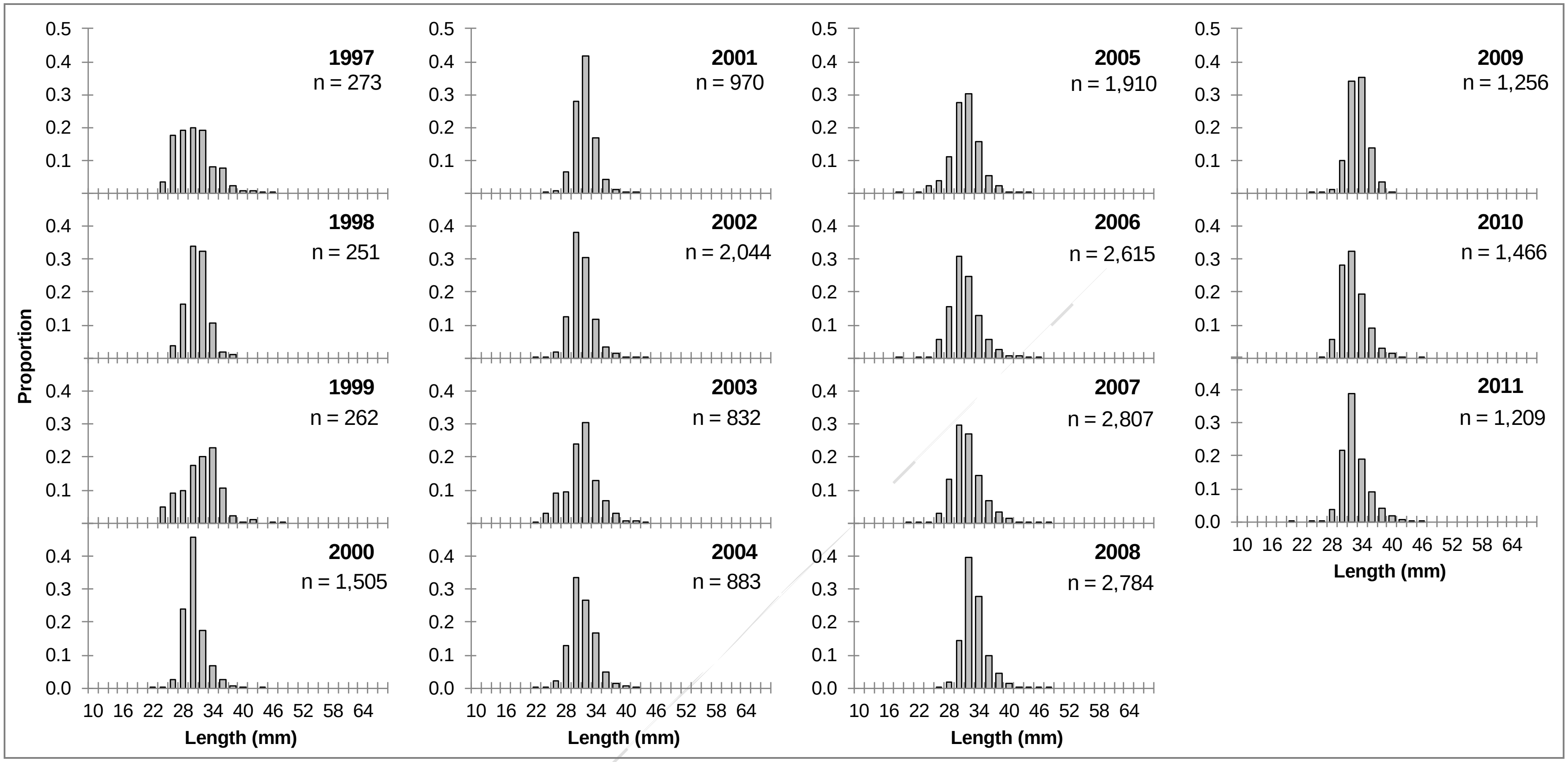

Figure 2.5. Annual length-frequency distributions of male striped mullet sampled from North Carolina commercial fisheries' landings, 1997–2011.

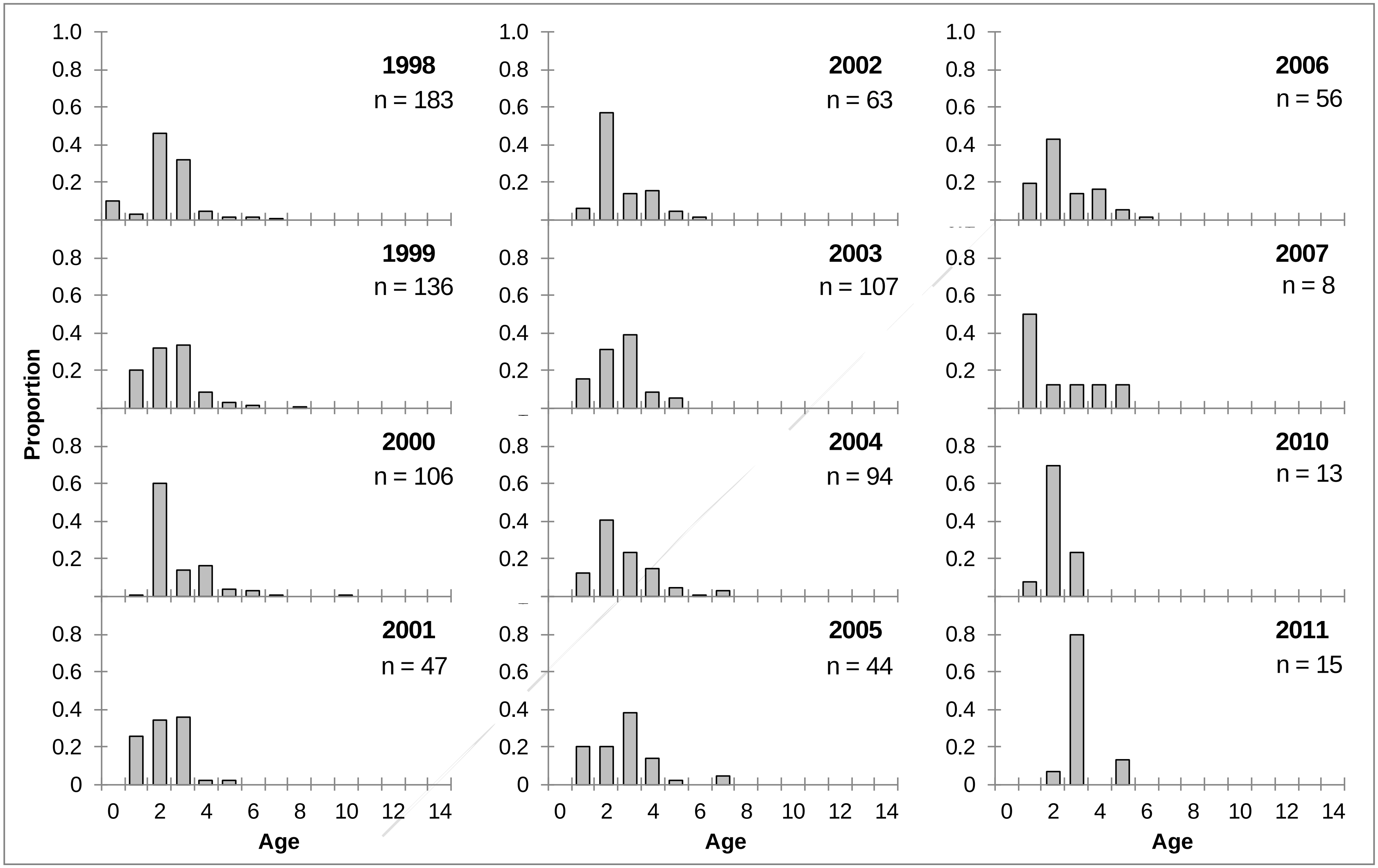

Figure 2.6. Annual age-frequency distributions of female striped mullet sampled from North Carolina commercial fisheries' landings, 1998–2011. There were no age data available for 2008 and 2009 from the commercial fishery.

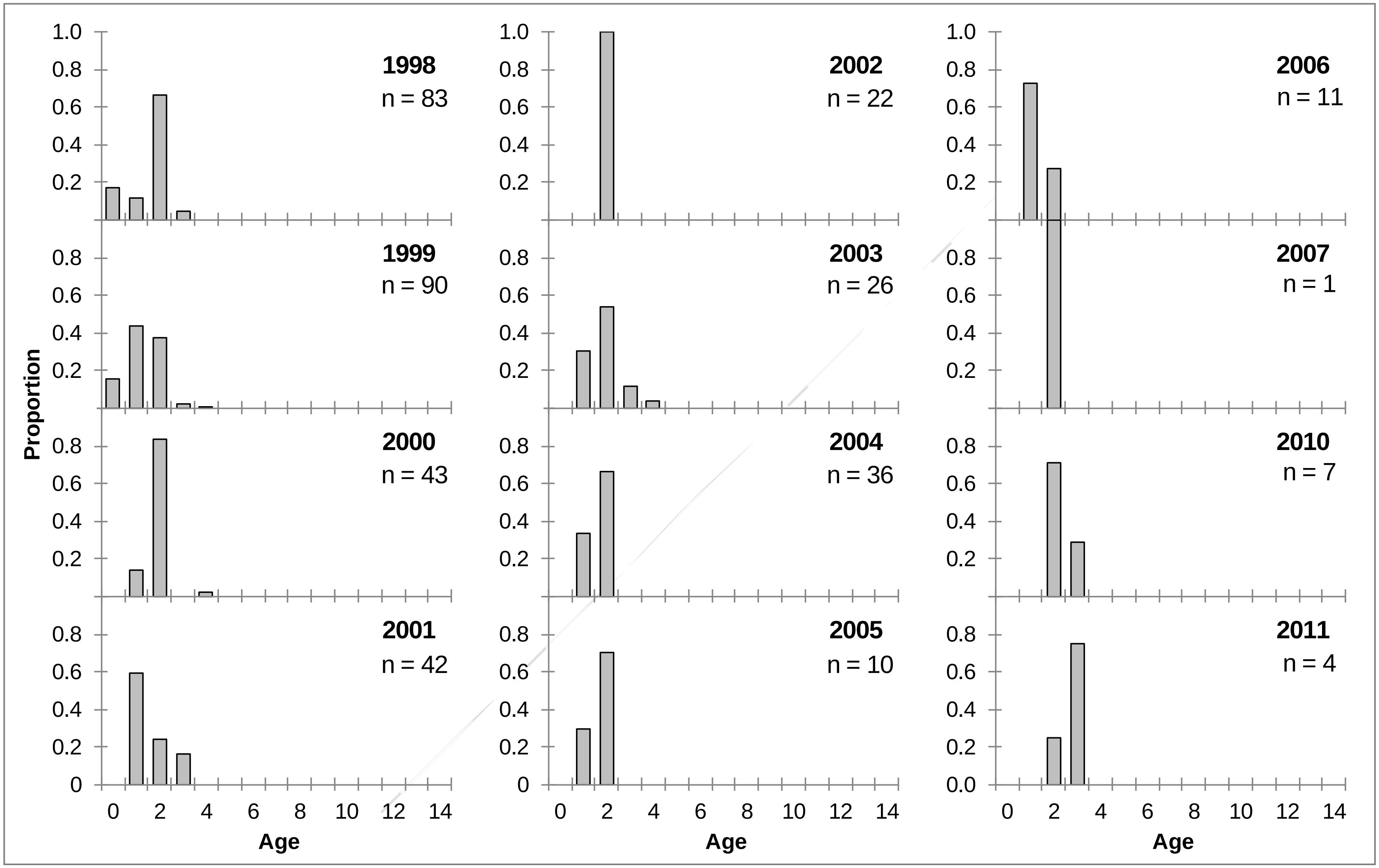

Figure 2.7. Annual age-frequency distributions of male striped mullet sampled from North Carolina commercial fisheries' landings, 1998–2011. There were no age data available for 2008 and 2009 from the commercial fishery.

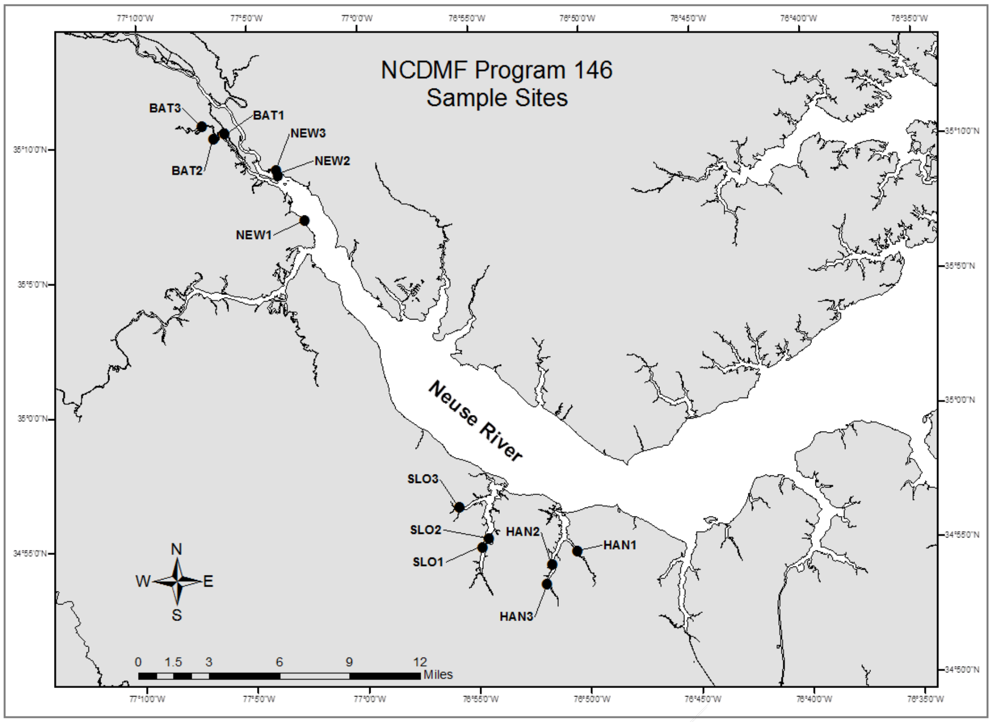

Figure 2.8. Map of sampling locations for NCDMF Program 146.

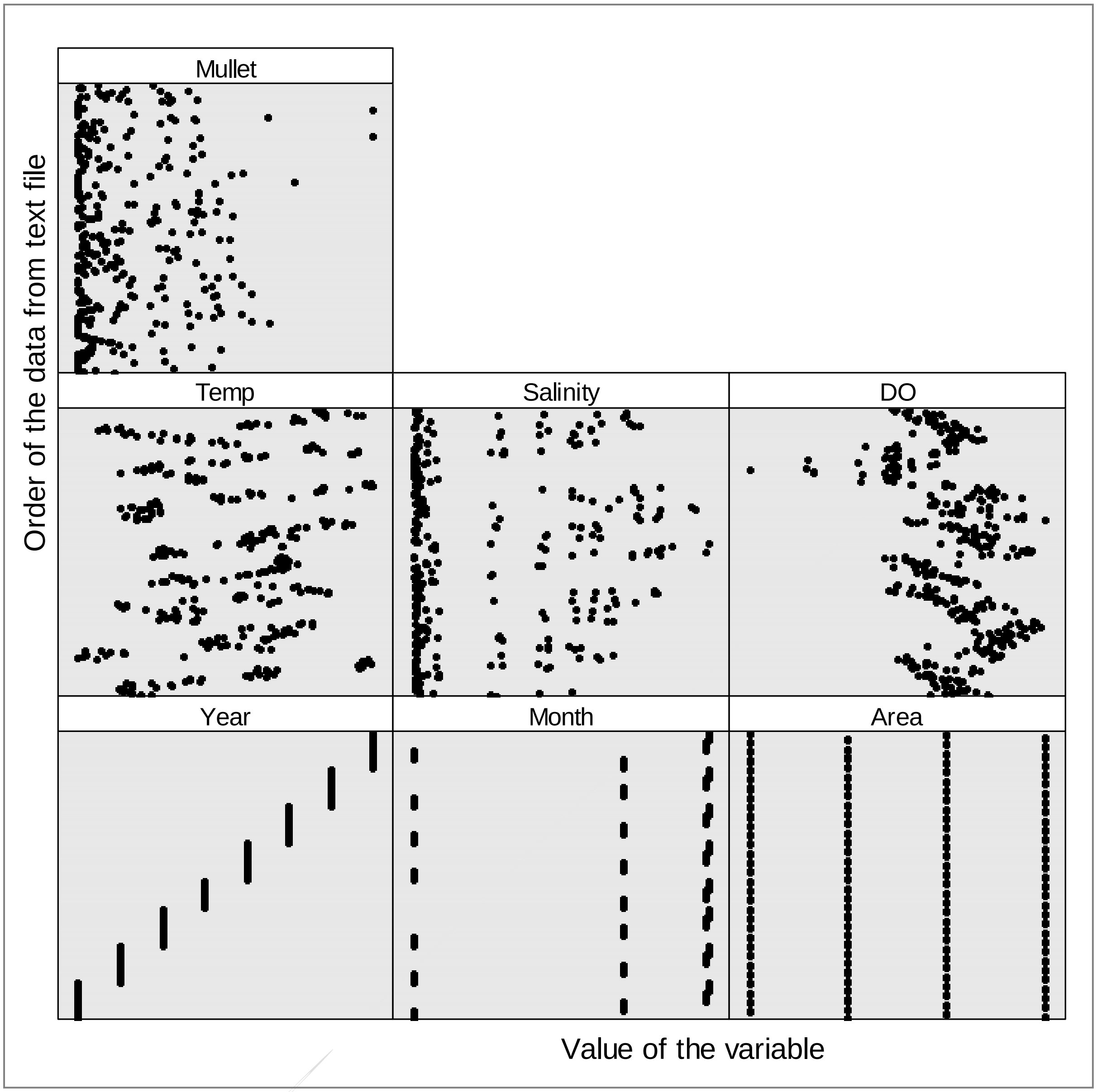

Figure 2.9. Cleveland dotplot for data collected from Program 146.

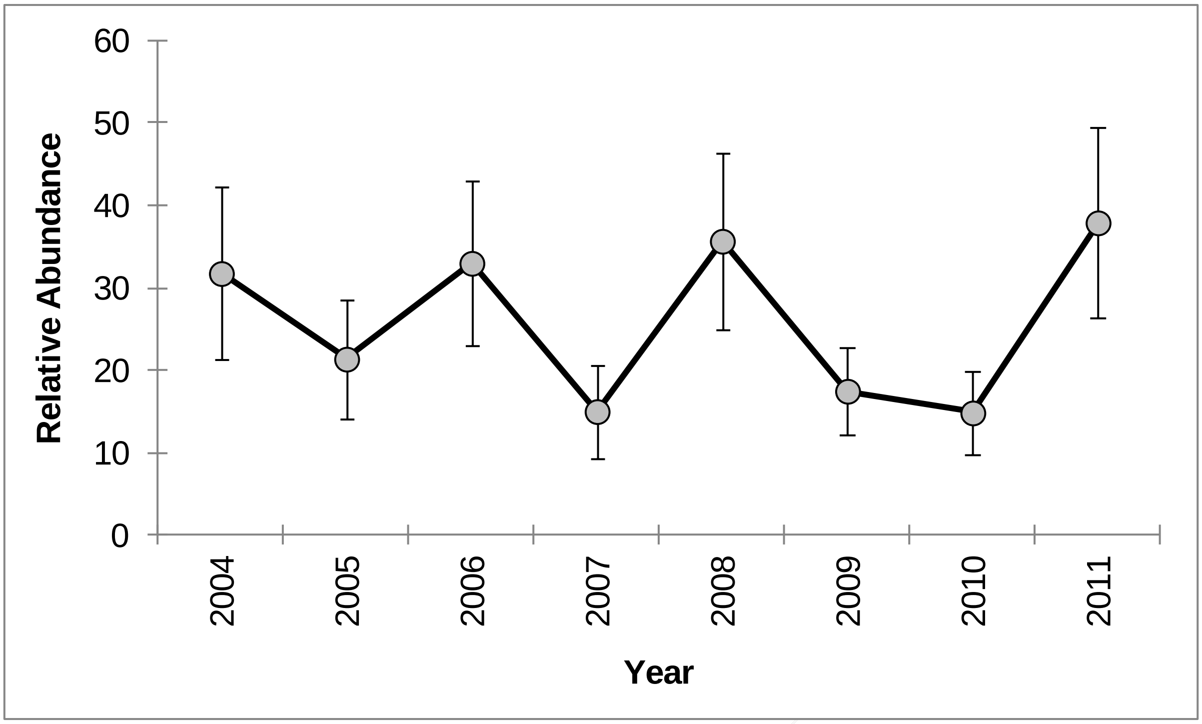

Figure 2.10. GLM-standardized index of relative abundance for adult striped mullet collected from Program 146 during January through April, 2004–2011. Error bars represent ± 1 standard error.

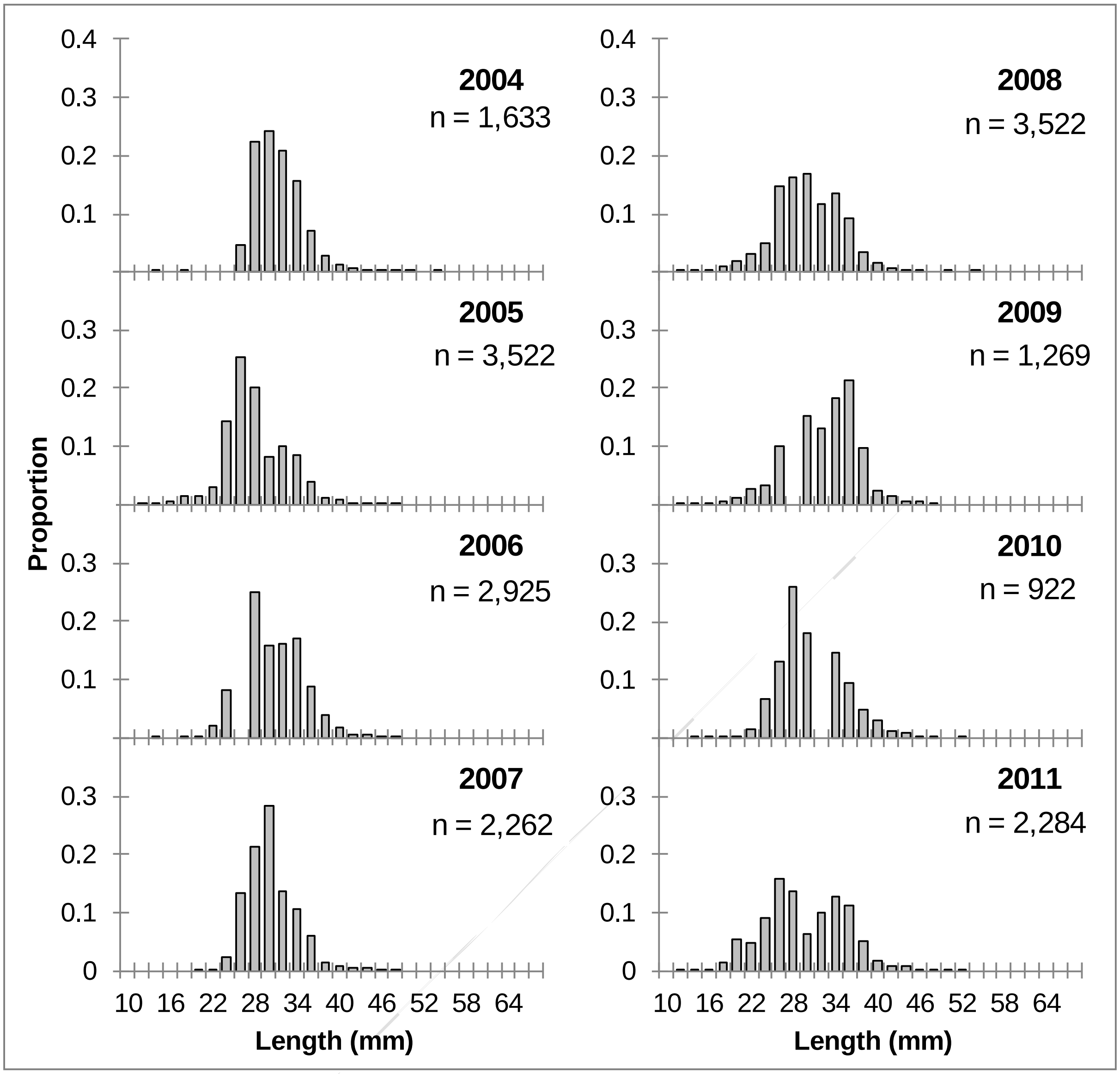

Figure 2.11. Annual length-frequency distributions of adult female striped mullet collected by NCDMF Program 146 during January through April, 2004–2011.

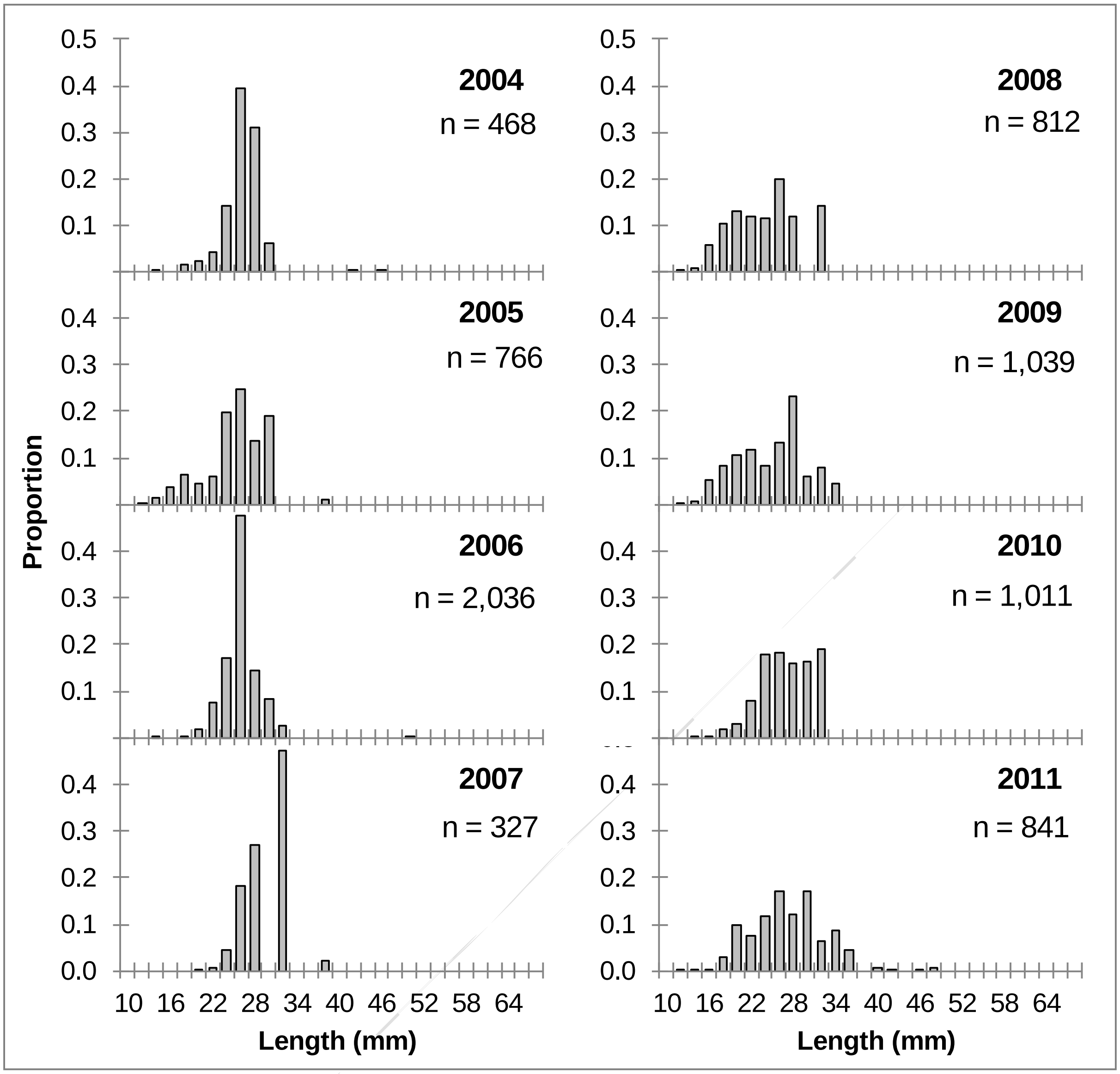

Figure 2.12. Annual length-frequency distributions of adult male striped mullet collected by NCDMF Program 146 during January through April, 2004–2011.

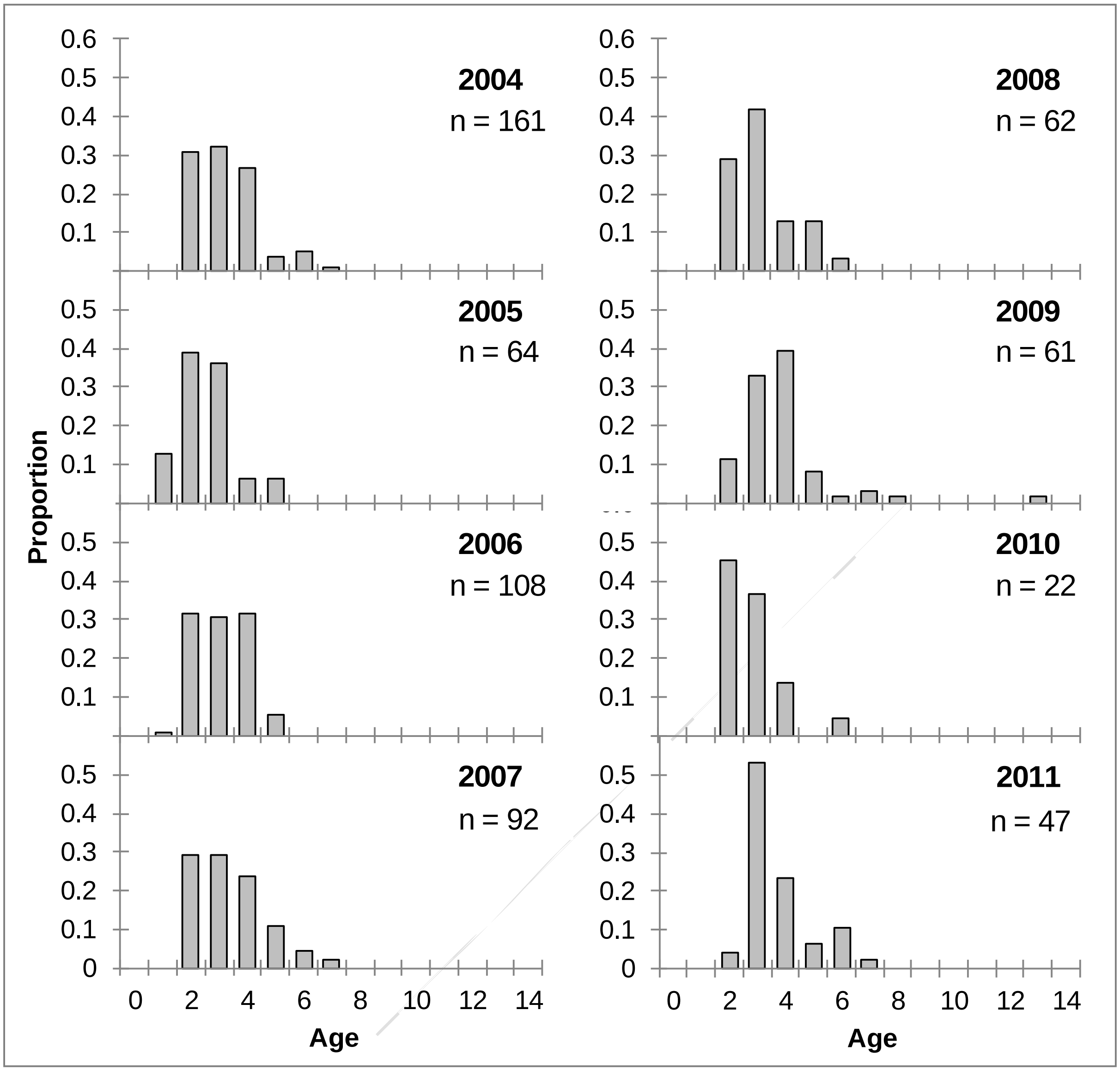

Figure 2.13. Annual age-frequency distributions of adult female striped mullet collected by NCDMF Program 146 during January through April, 2004–2011.

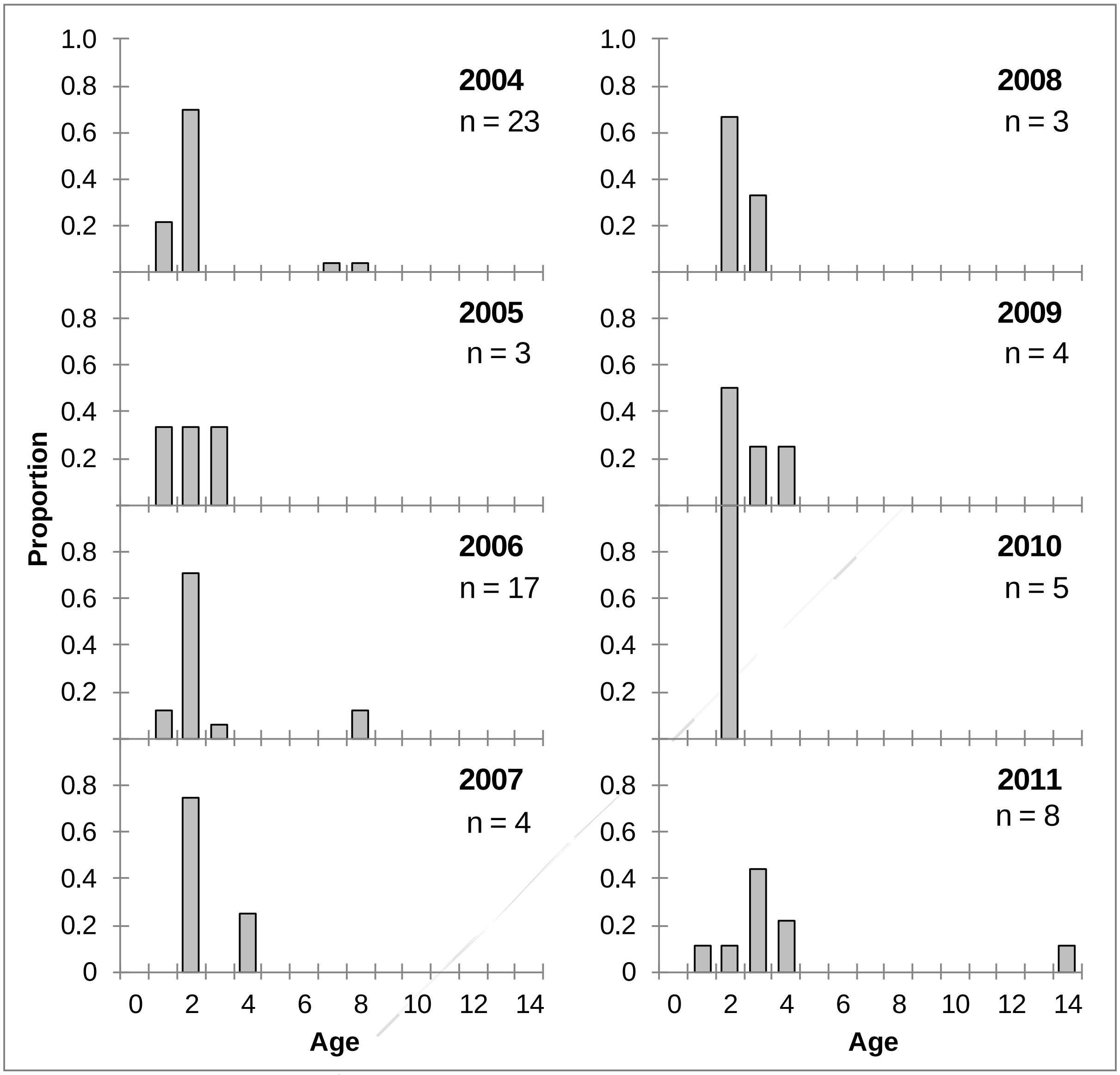

Figure 2.14. Annual age-frequency distributions of adult male striped mullet collected by NCDMF Program 146 during January through April, 2004–2011.

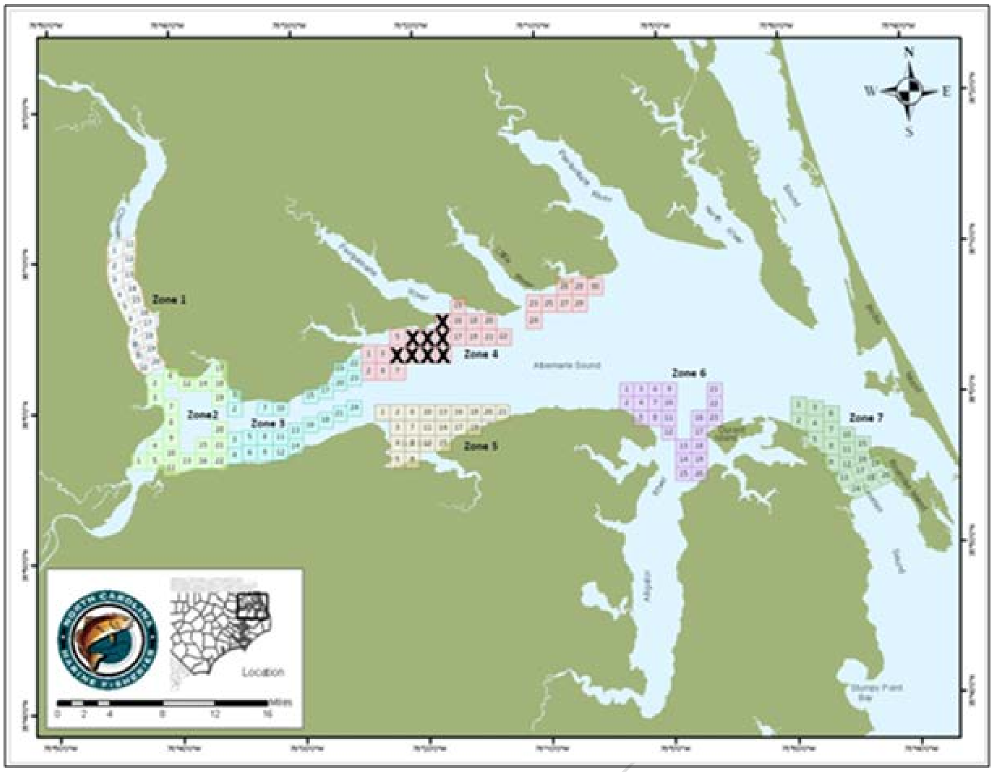

Figure 2.15. Locations of sampling zones and quadrants in Albemarle Sound sampled by NCDMF Program 135.

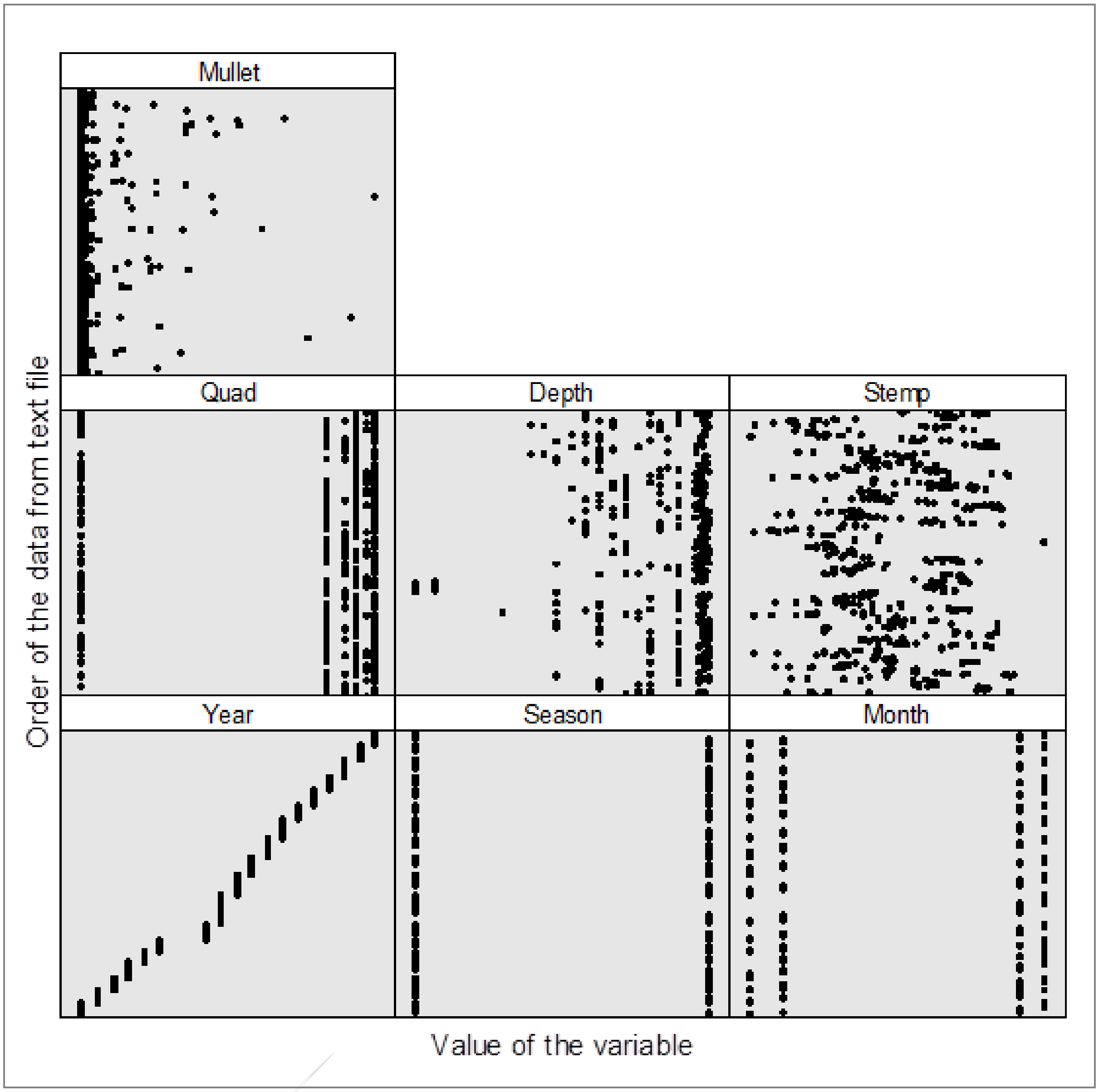

Figure 2.16. Cleveland dotplot for data collected from Program 135.

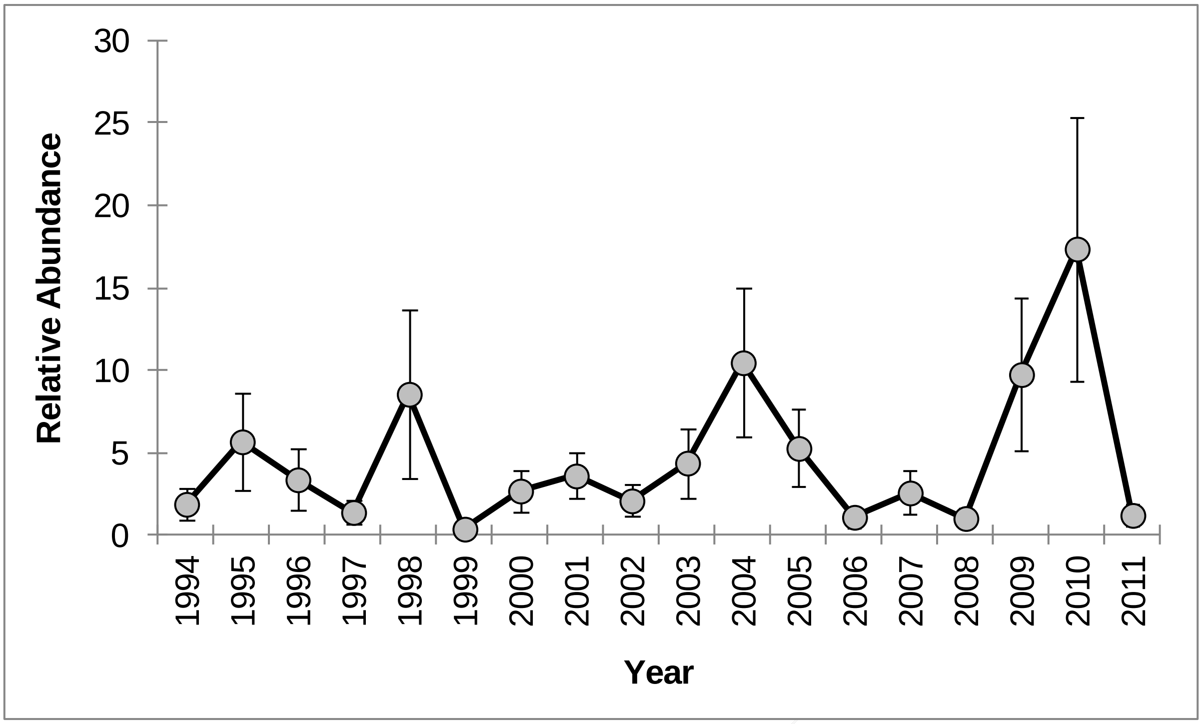

Figure 2.17. GLM-standardized index of relative abundance for adult striped mullet collected from Program 135 during November through February, 1994–2011. Error bars represent ± 1 standard error.

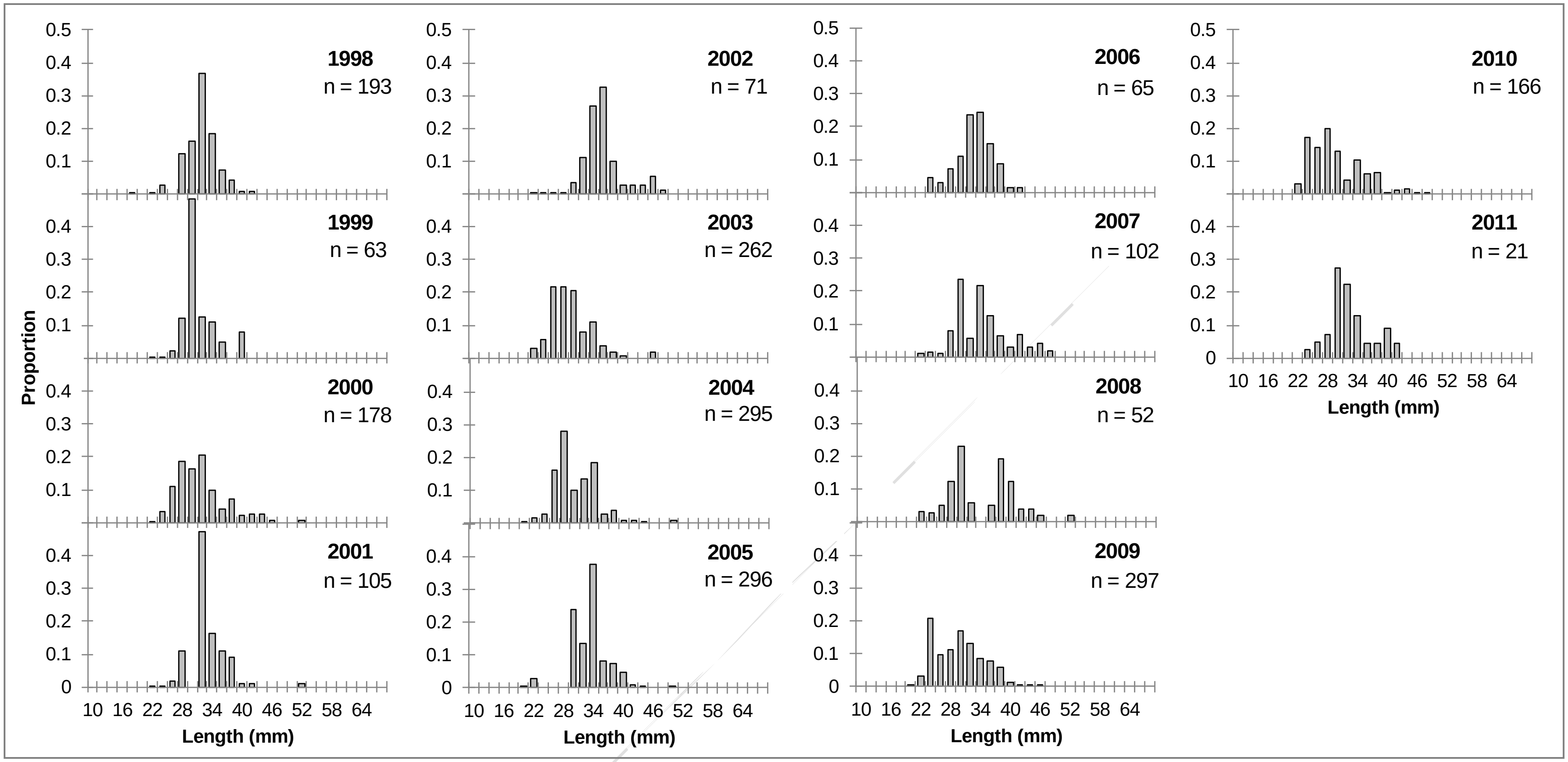

Figure 2.18. Annual length-frequency distributions of adult female striped mullet collected by NCDMF Program 135 during November through February, 1998–2011.

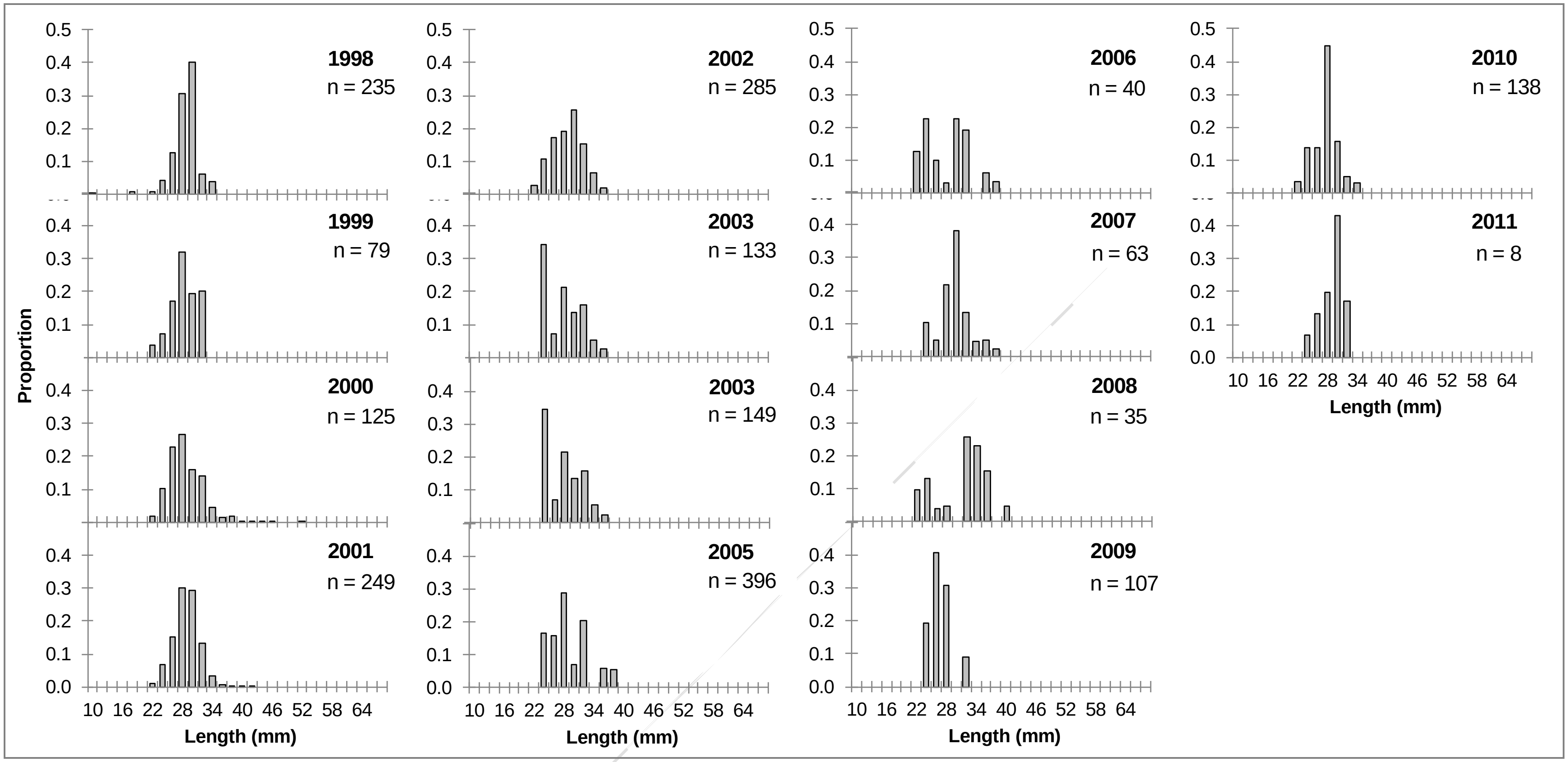

Figure 2.19. Annual length-frequency distributions of adult male striped mullet collected by NCDMF Program 135 during November through February, 1998–2011.

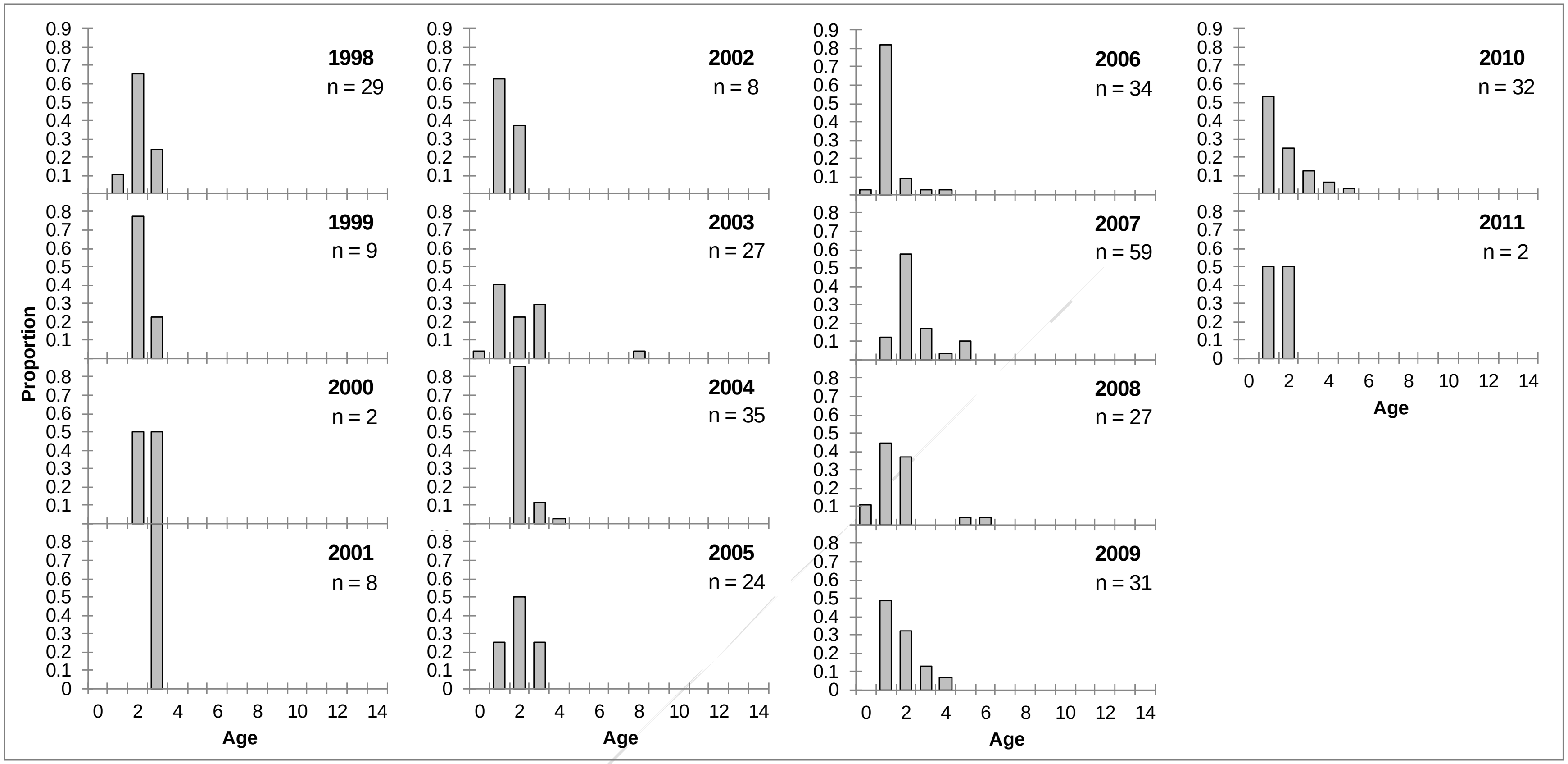

Figure 2.20. Annual age-frequency distributions of adult female striped mullet collected by NCDMF Program 135 during November through February, 1998–2011.

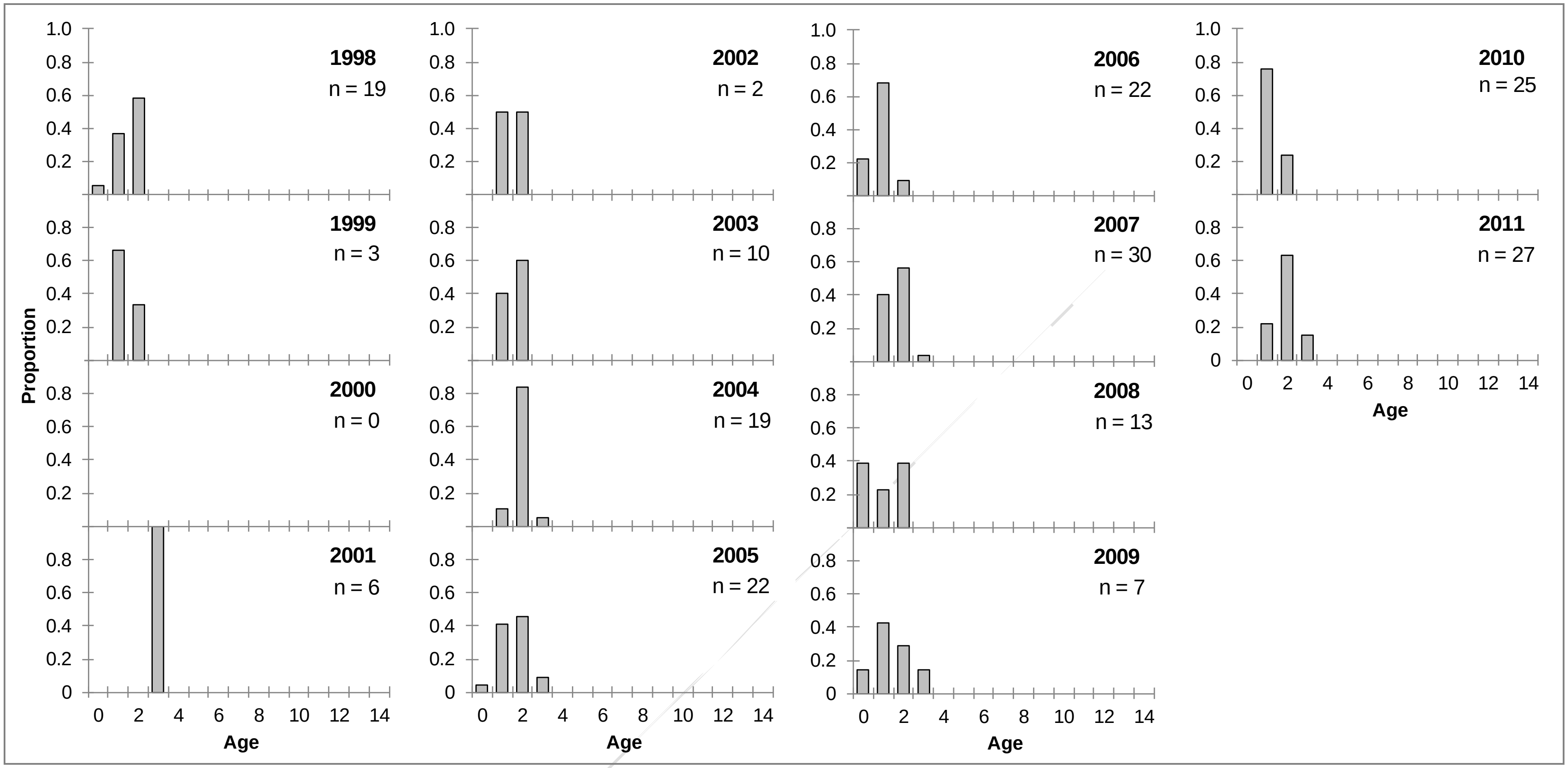

Figure 2.21. Annual age-frequency distributions of adult male striped mullet collected by NCDMF Program 135 during November through February, 1998–2011.

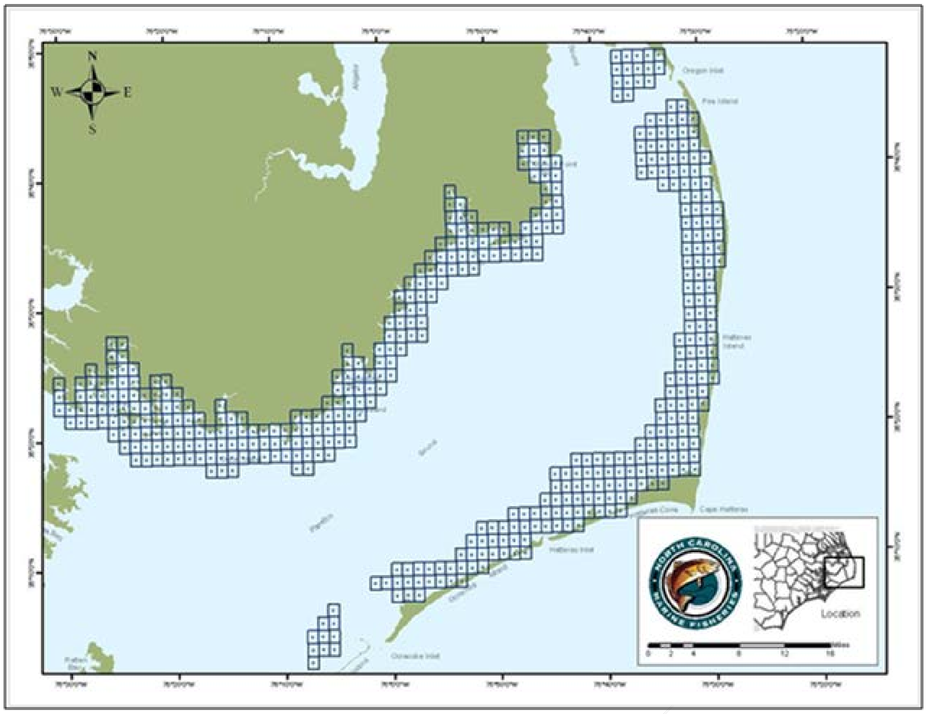

Figure 2.22. The sample regions and grid system for the Pamlico Sound portion of NCDMF Program 915.

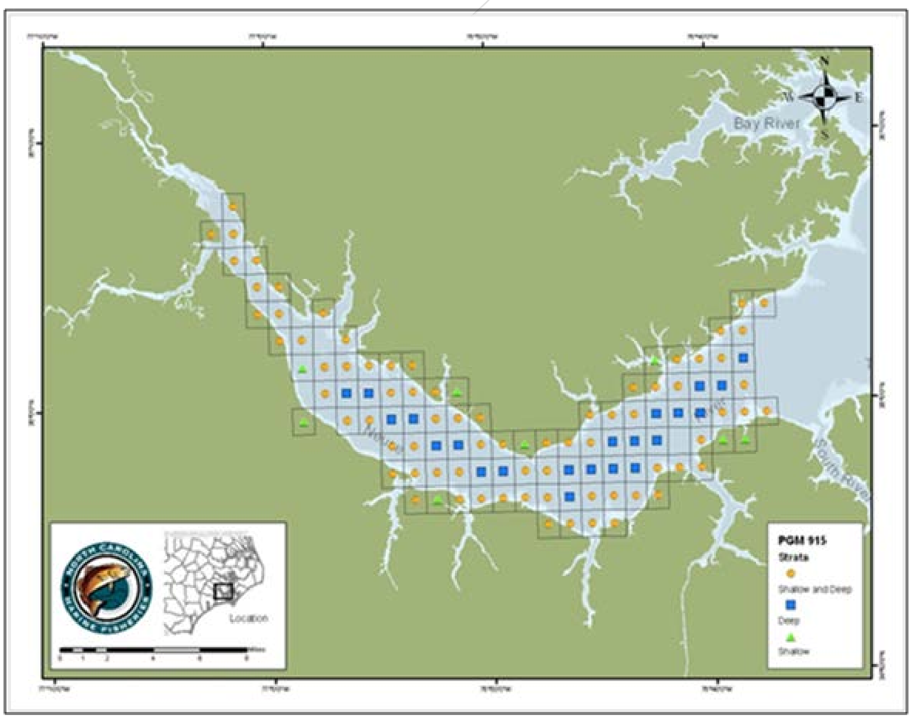

Figure 2.23. The sample regions and grid system for the Neuse River portion of NCDMF Program 915.

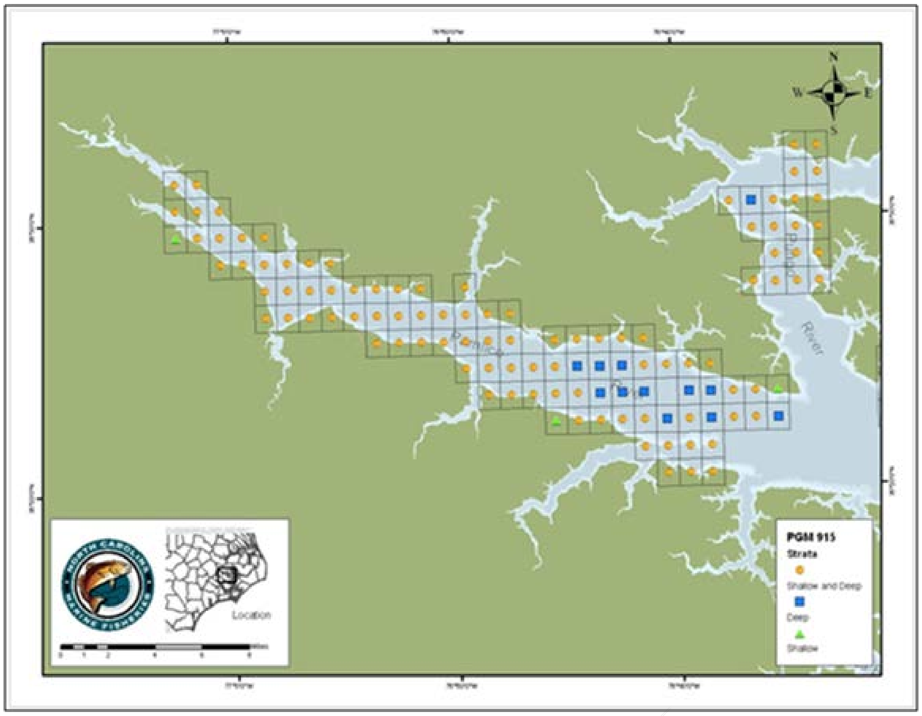

Figure 2.24. The sample regions and grid system for the Pamlico and Pungo river portions of NCDMF Program 915.

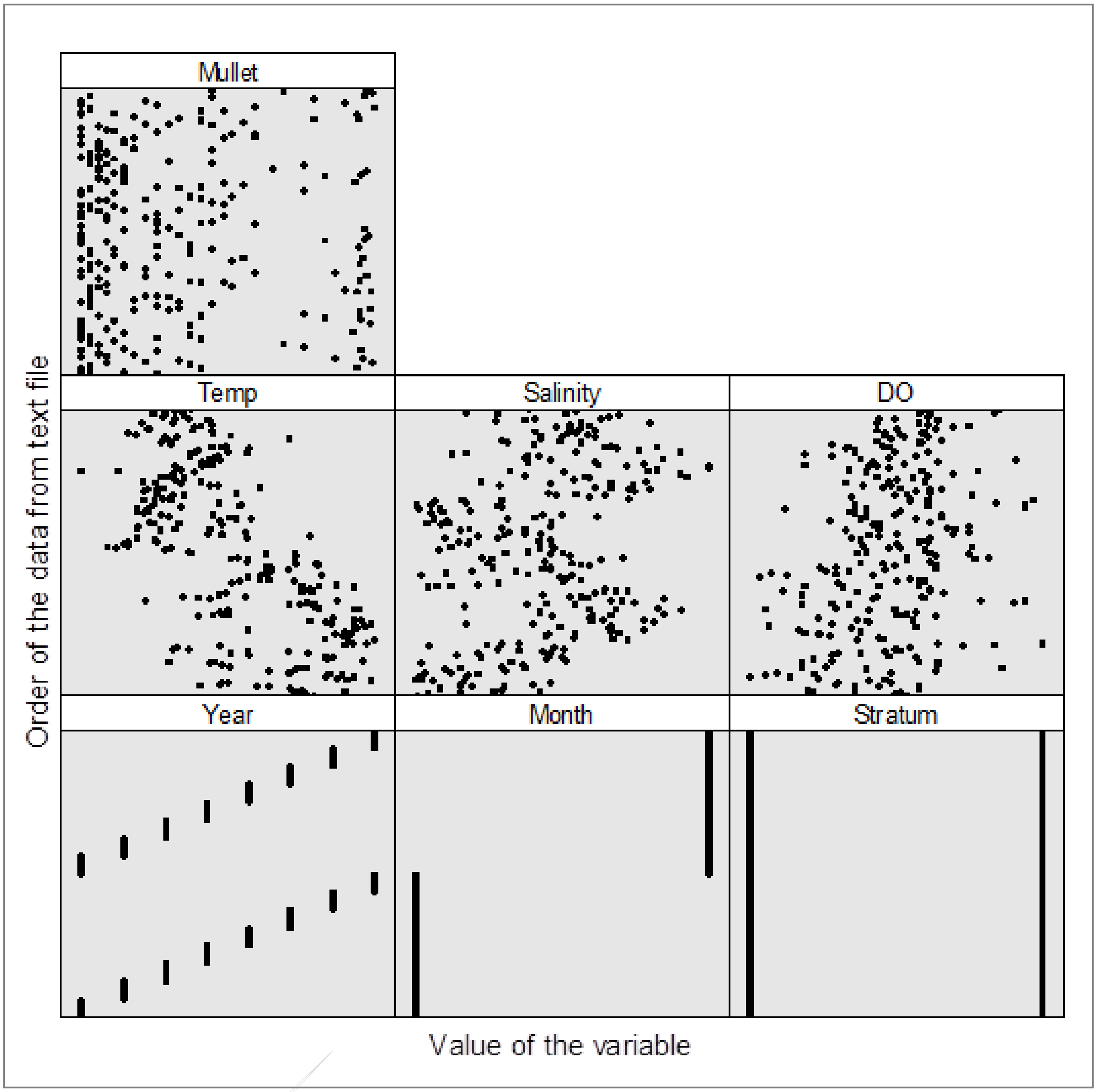

Figure 2.25. Cleveland dotplot for data collected from Program 915.

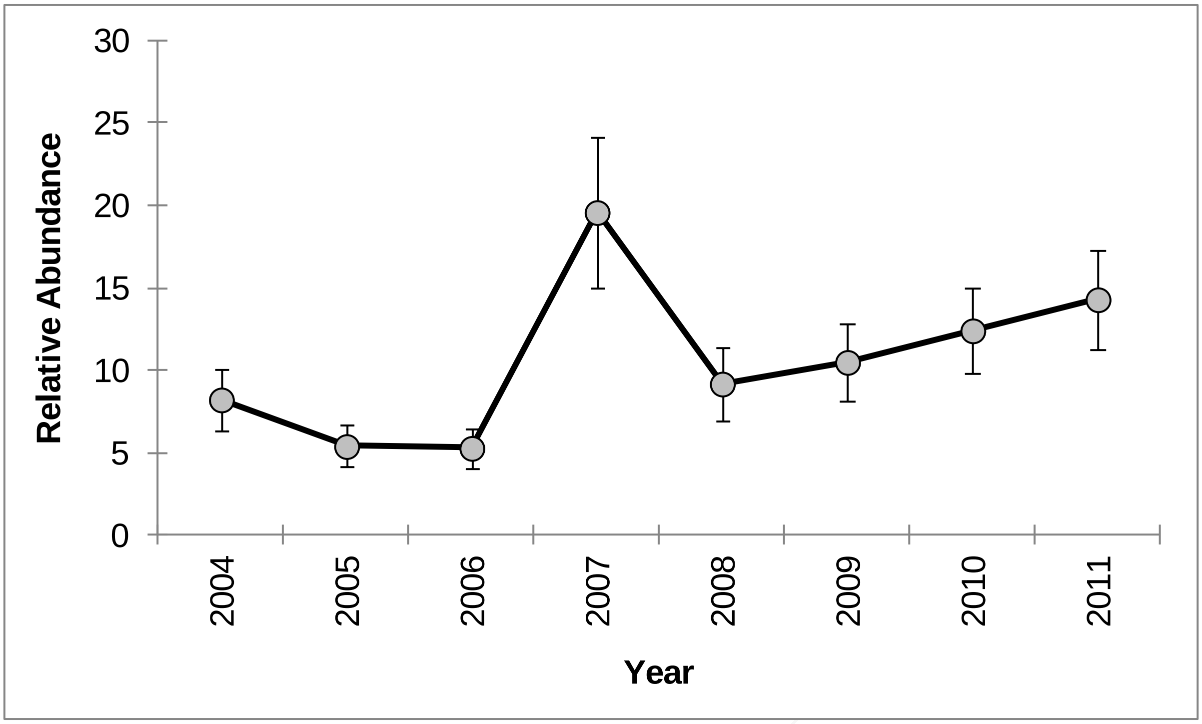

Figure 2.26. GLM-standardized index of relative abundance for adult striped mullet collected from Program 915 during October and November, 2004–2011. Error bars represent ± 1 standard error.

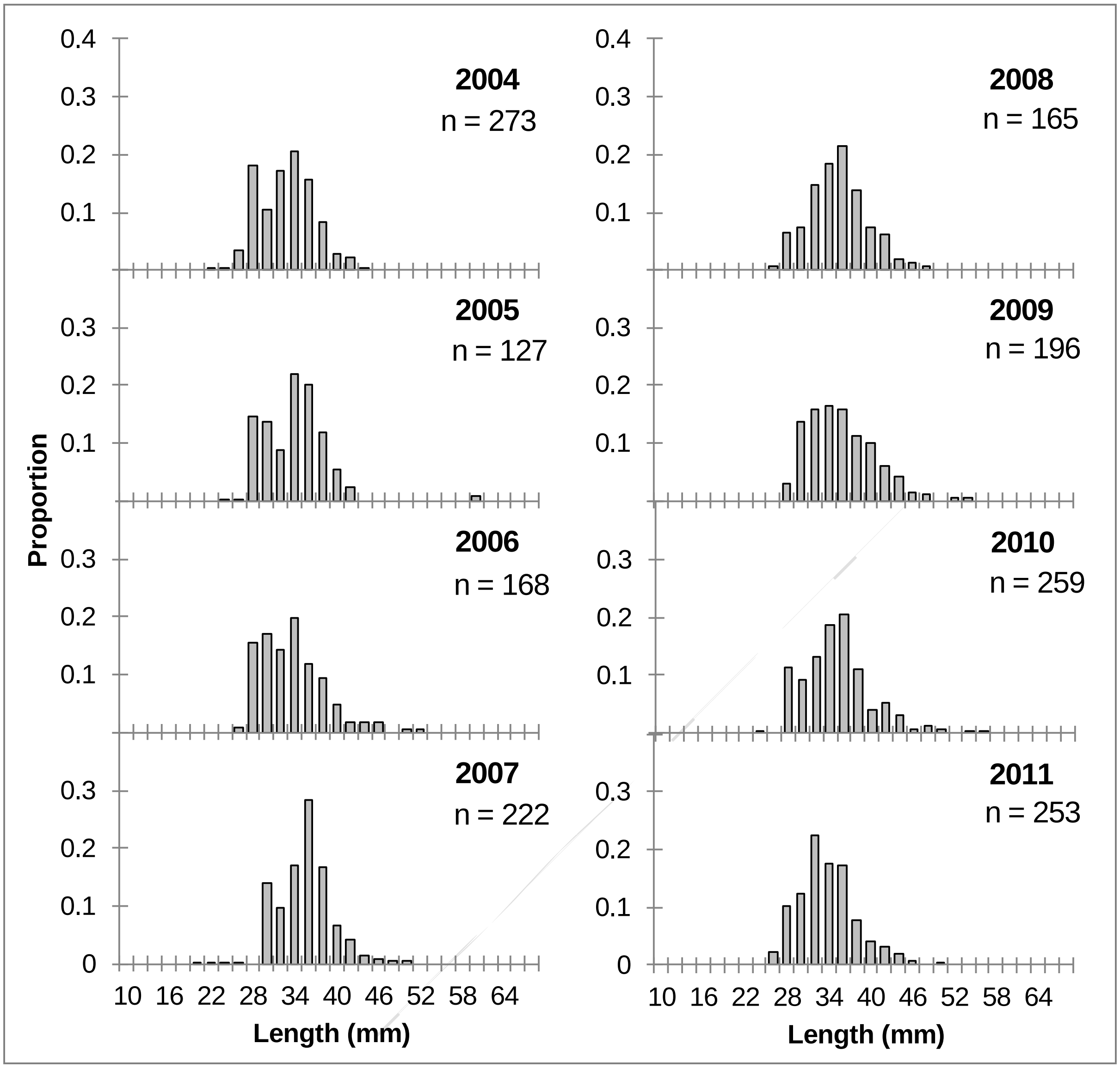

Figure 2.27. Annual length-frequency distributions of adult female striped mullet collected by NCDMF Program 915 during October and November, 2004–2011.

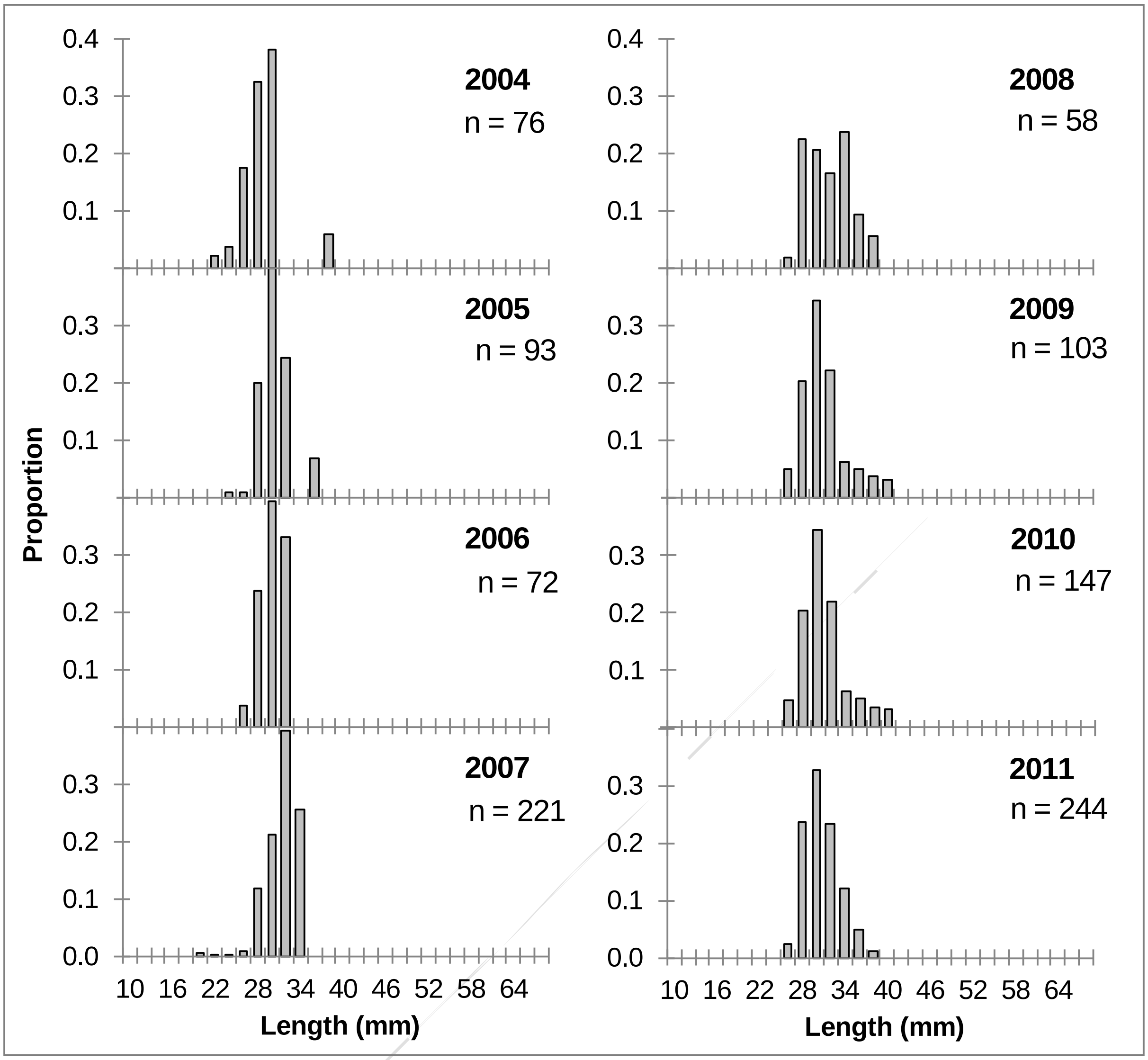

Figure 2.28. Annual length-frequency distributions of adult male striped mullet collected by NCDMF Program 915 during October and November, 2004–2011.

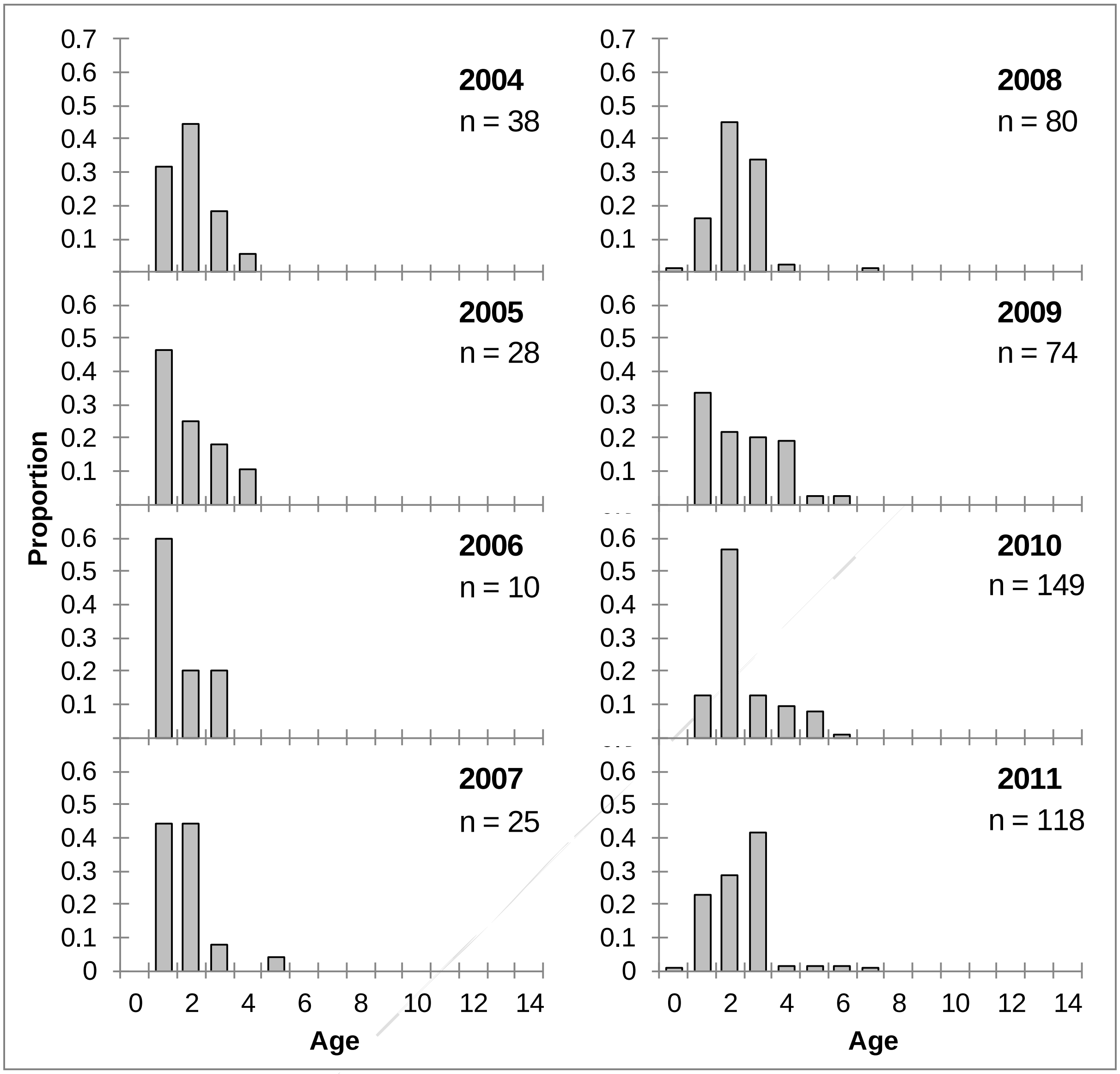

Figure 2.29. Annual age-frequency distributions of adult female striped mullet collected by NCDMF Program 915 during October and November, 2004–2011.

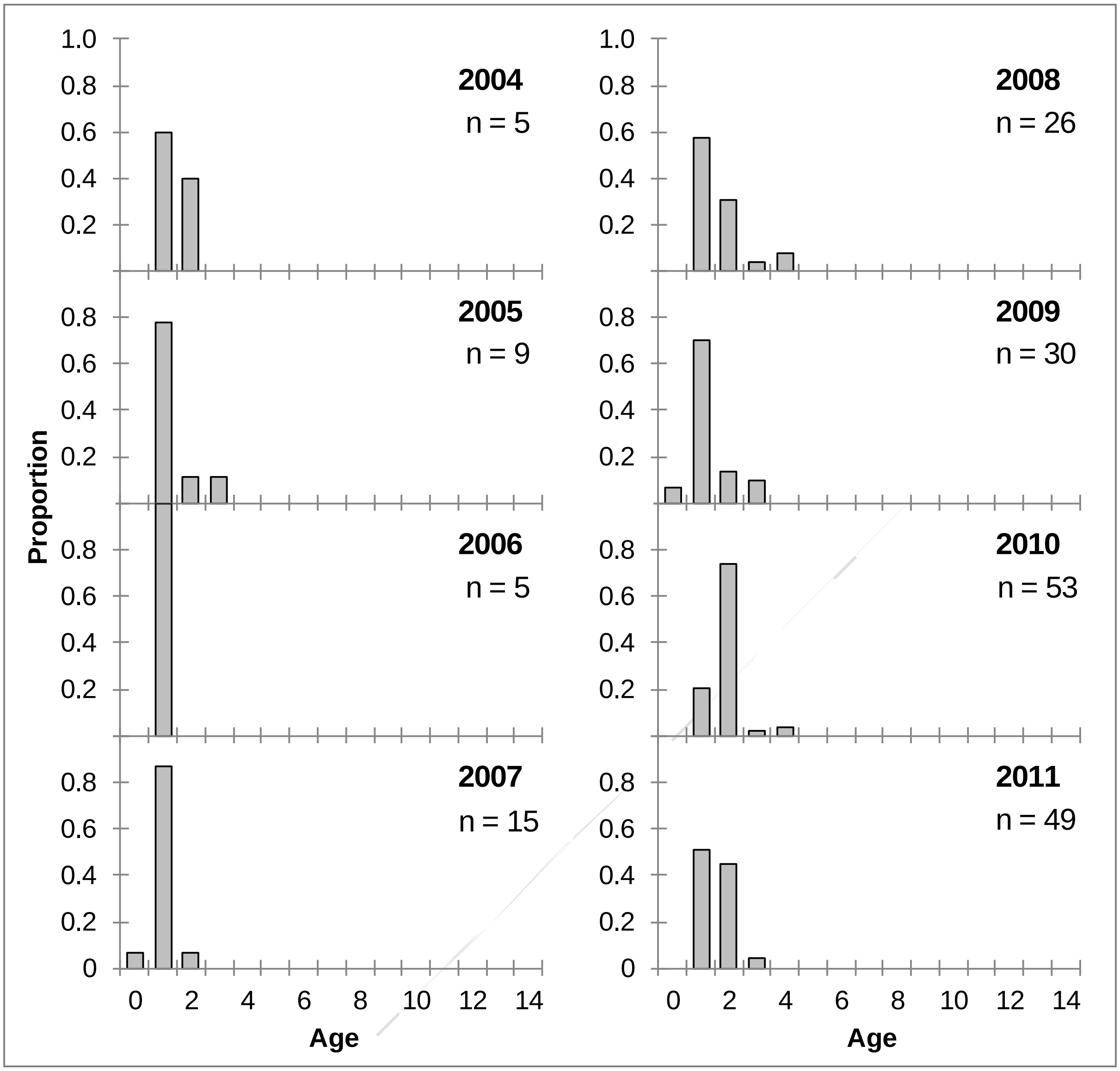

Figure 2.30. Annual age-frequency distributions of adult male striped mullet collected by NCDMF Program 915 during October and November, 2004–2011.

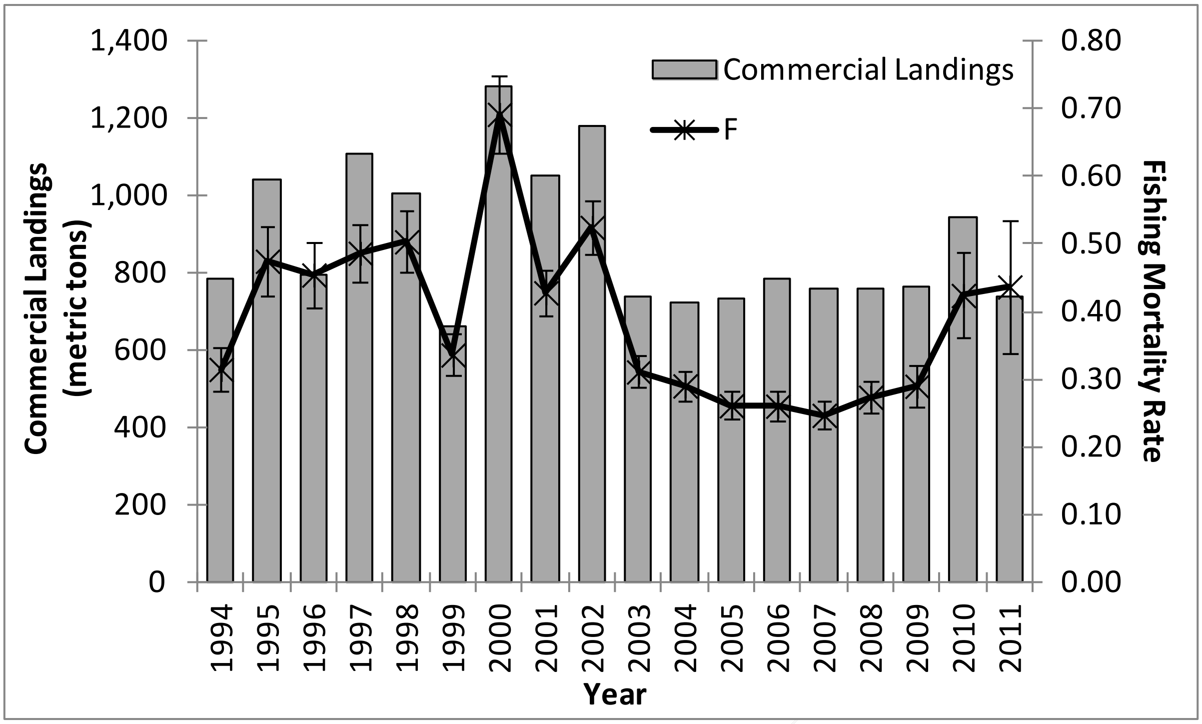

Figure 3.1. Annual observed commercial landings and predicted fishing mortality rates (numbers-weighted, ages 2–5) from the base run of the Stock Synthesis model. Error bars represent ± 1 standard deviation of fishing mortality rate.

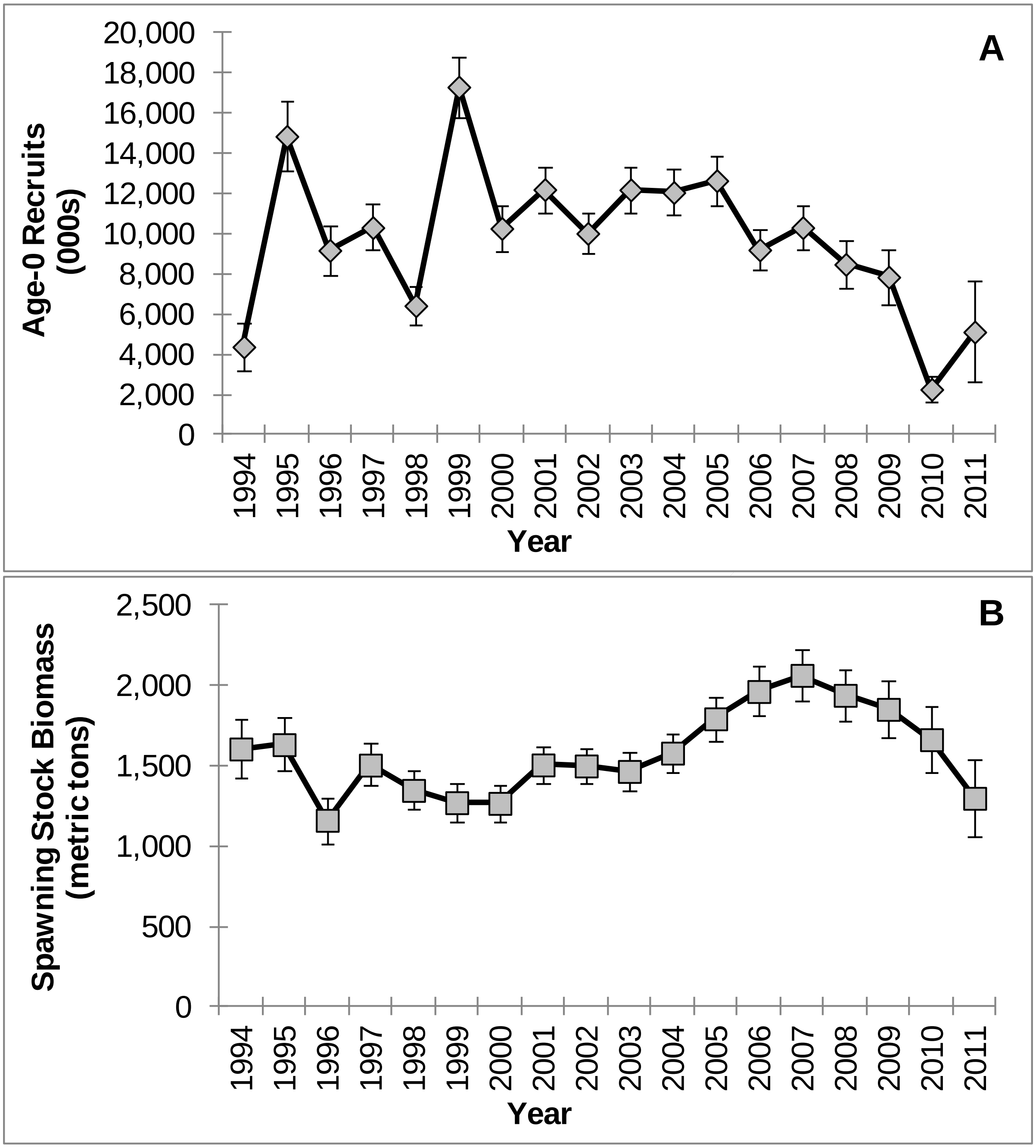

Figure 3.2. Predicted (A) age-0 recruitment and (B) spawning stock biomass from the base run of the Stock Synthesis model. Error bars represent ± 1 standard deviation of the estimate.

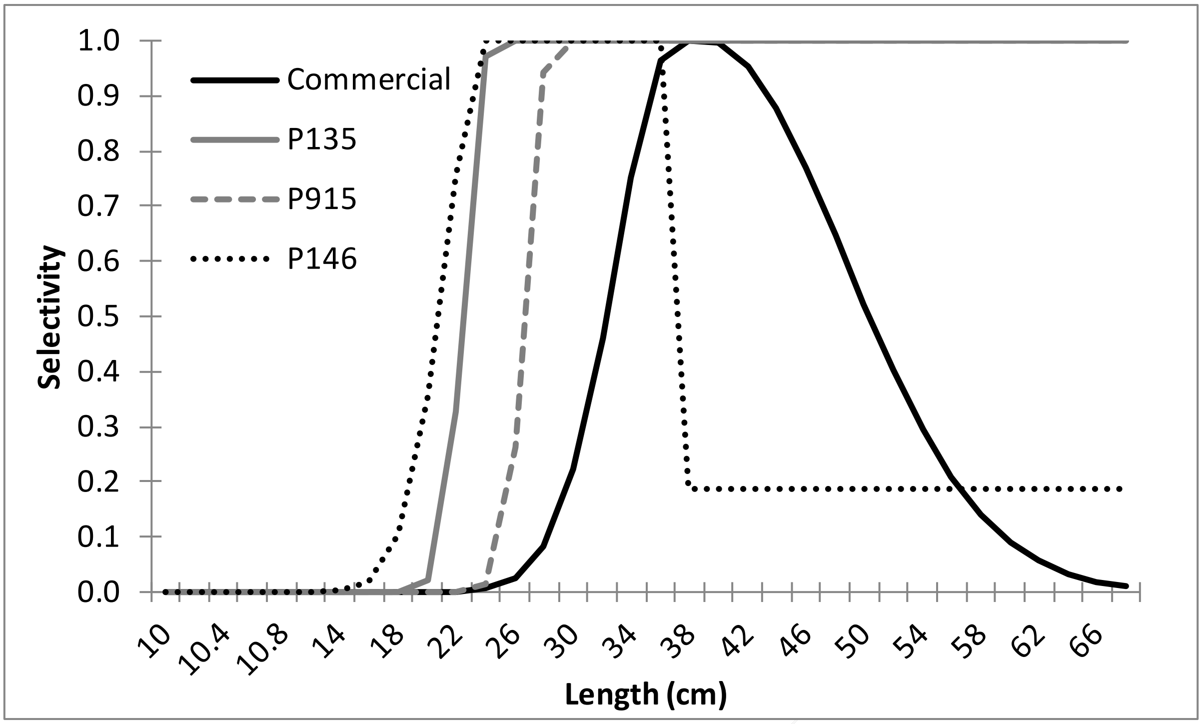

Figure 3.3. Predicted selectivity curves for the commercial fishery, Program 135, Program 915, and Program 146 from the base run of the Stock Synthesis model.

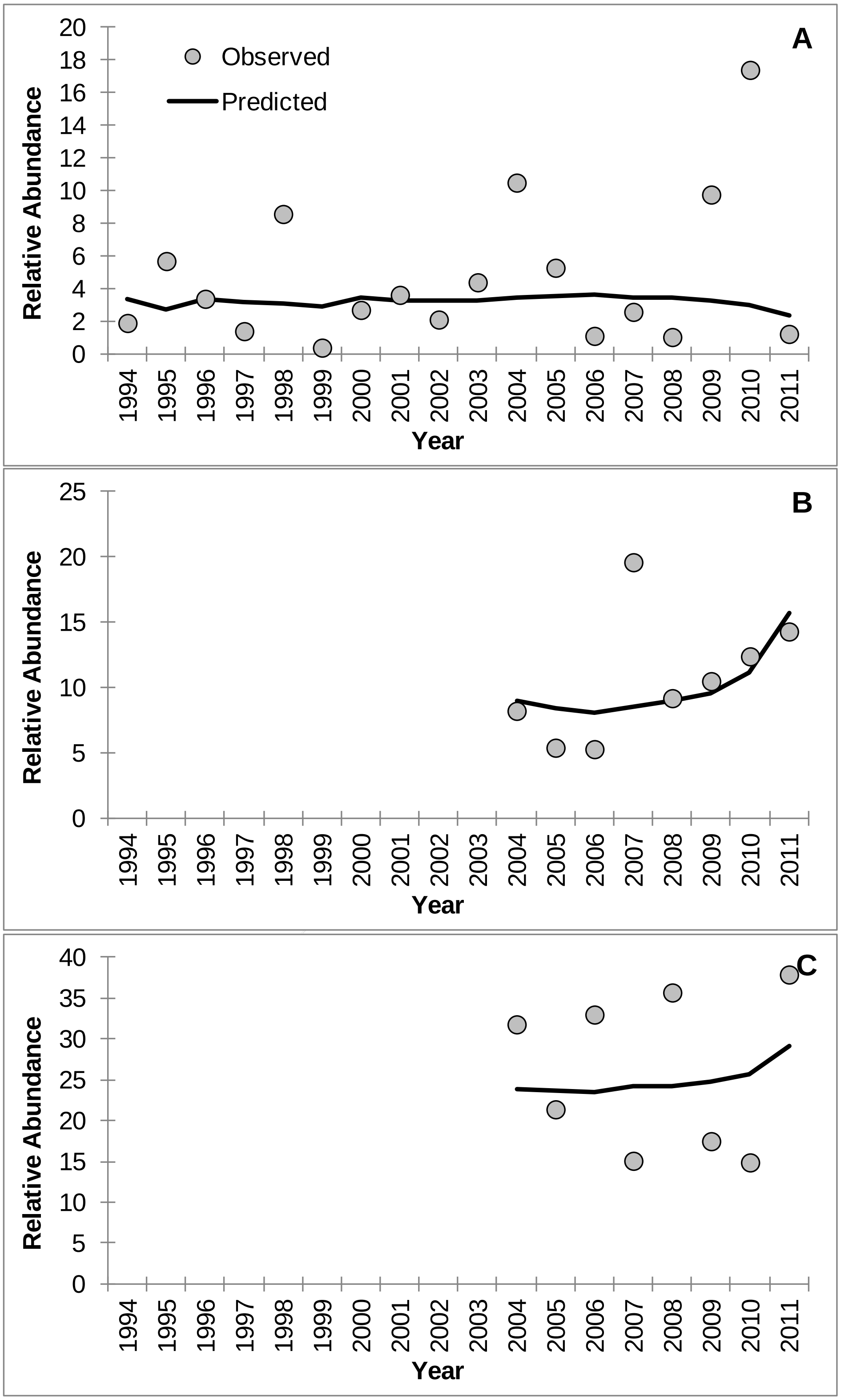

Figure 3.4. Observed and predicted values for the (A) Program 135, (B) Program 915, and (C) Program 146 indices of adult relative abundance from the base run of the Stock Synthesis model.

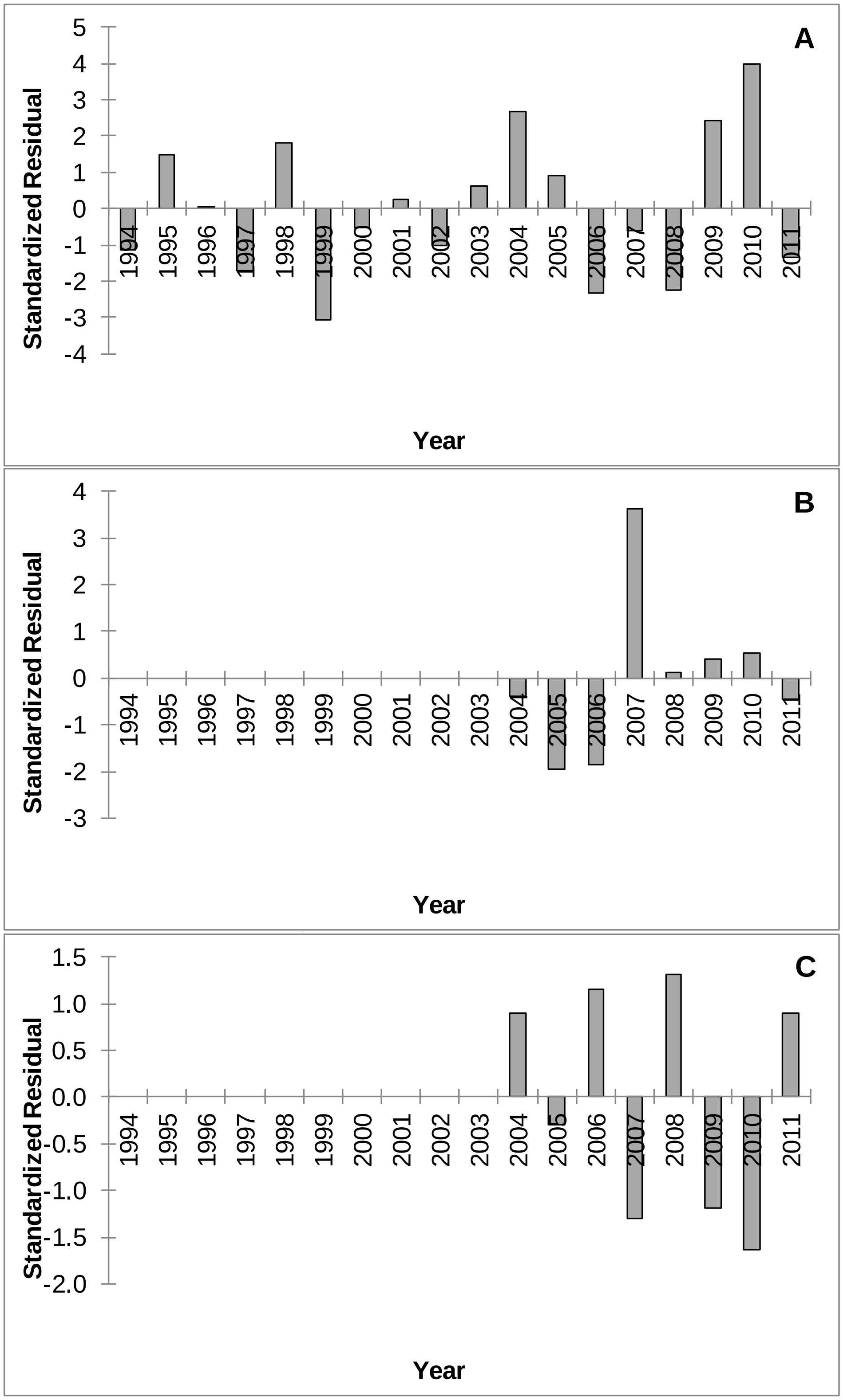

Figure 3.5. Standardized residuals for the (A) Program 135, (B) Program 915, and (C) Program 146 indices of adult relative abundance from the base run of the Stock Synthesis model.

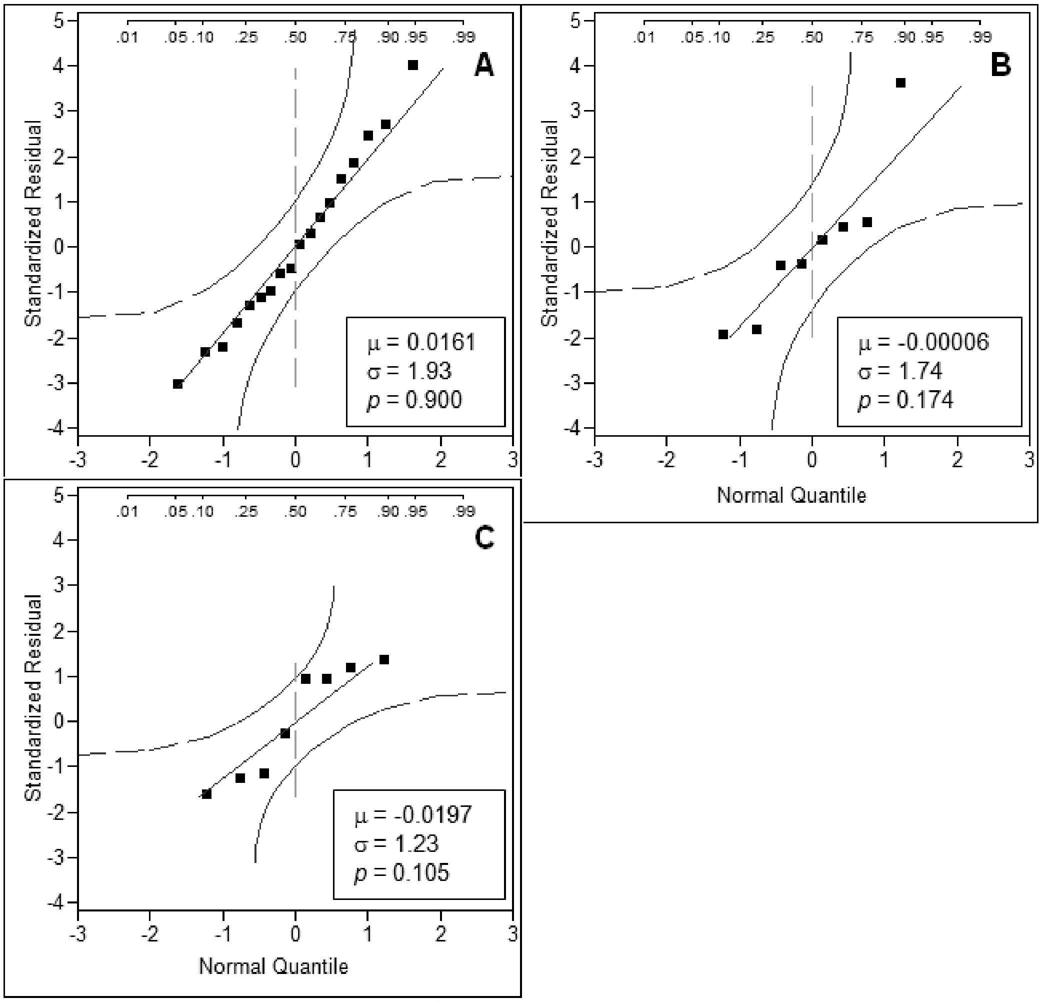

Figure 3.6. Normal quantile plots (Q-Q plots) of the standardized residuals for the (A) Program 135, (B) Program 915, and (C) Program 146 indices of adult relative abundance from the base run of the Stock Synthesis model. The mean (μ), standard deviation (σ), and test for normality (*p*-value) of the standardized residuals is also given.

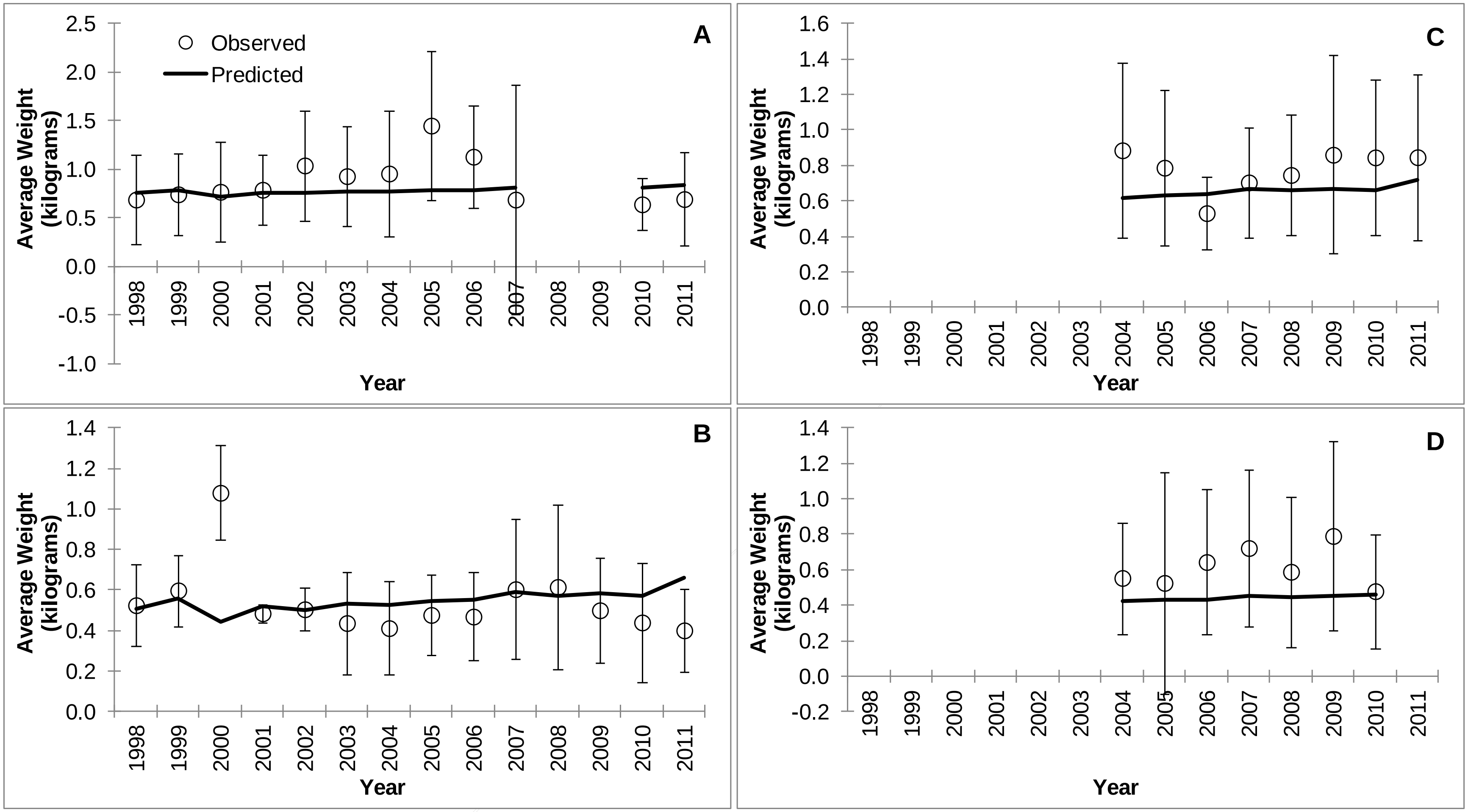

Figure 3.7. Observed and predicted average individual body weights for the (A) commercial fishery, (B) Program 135, (C) Program 915, and (D) Program 146 from the base run of the Stock Synthesis model. Error bars represent ± 1 standard deviation of fishing mortality rate.

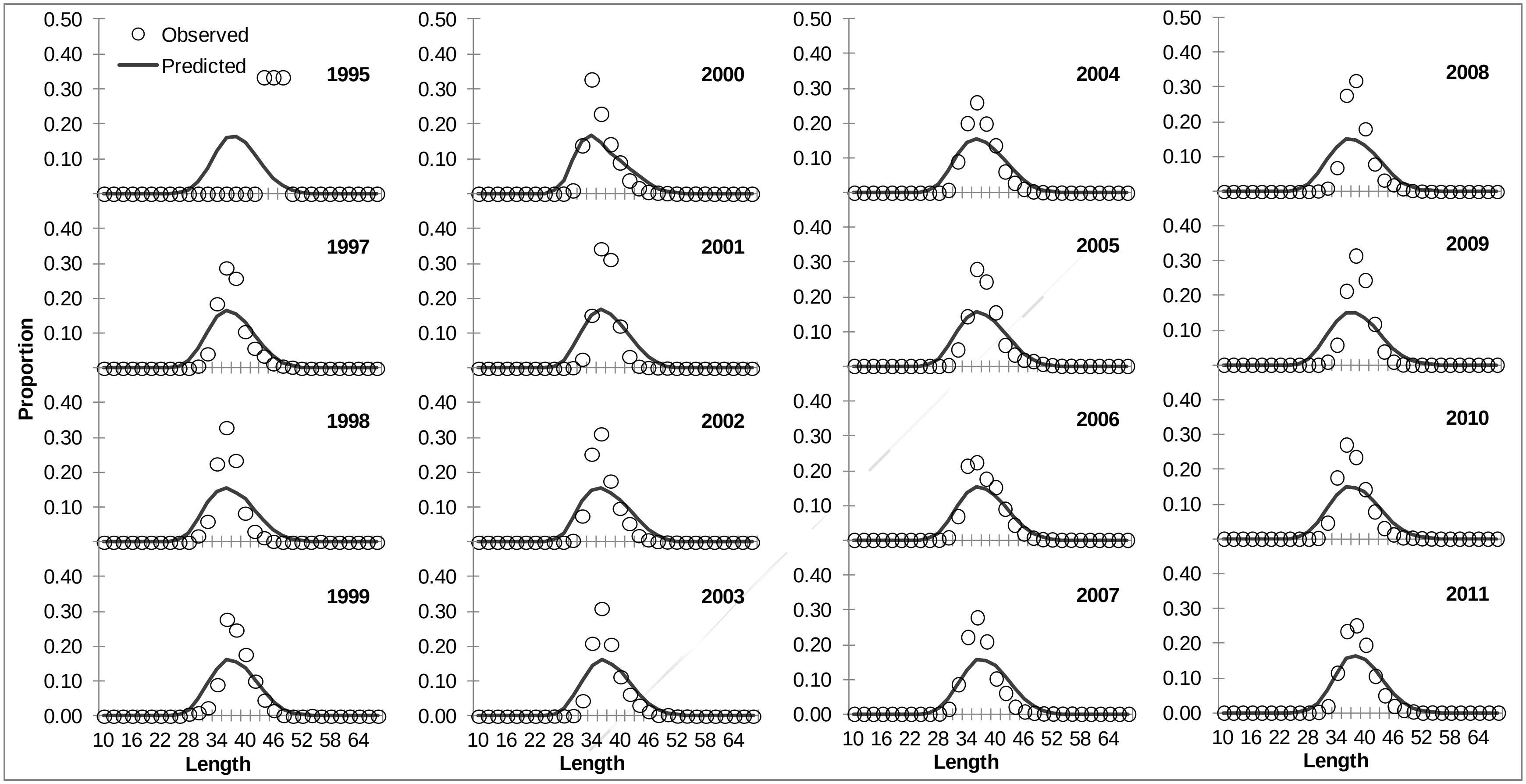

Figure 3.8. Observed and predicted annual female length-frequency distributions for the commercial fishery from the base run of the Stock Synthesis model.

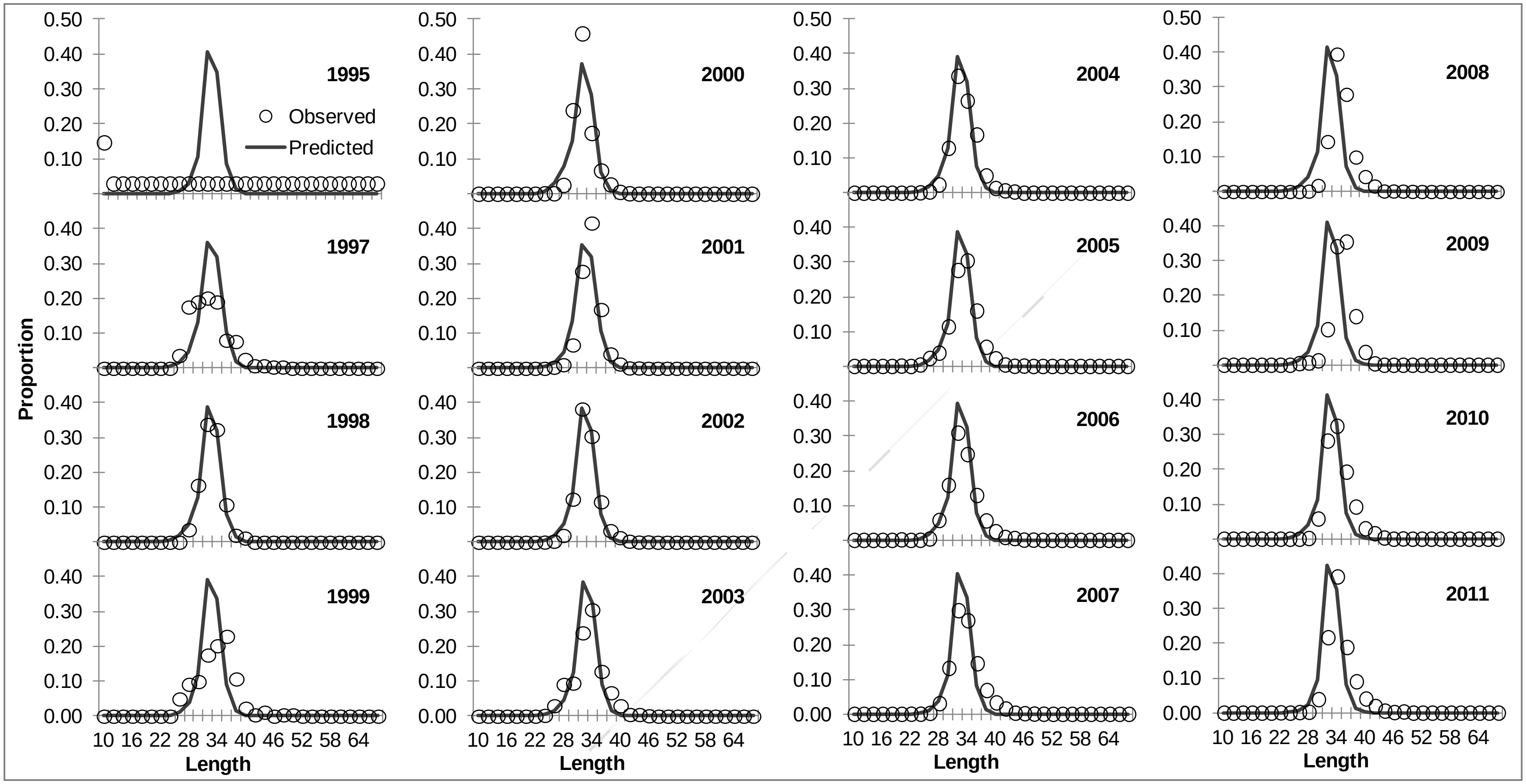

Figure 3.9. Observed and predicted annual male length-frequency distributions for the commercial fishery from the base run of the Stock Synthesis model.

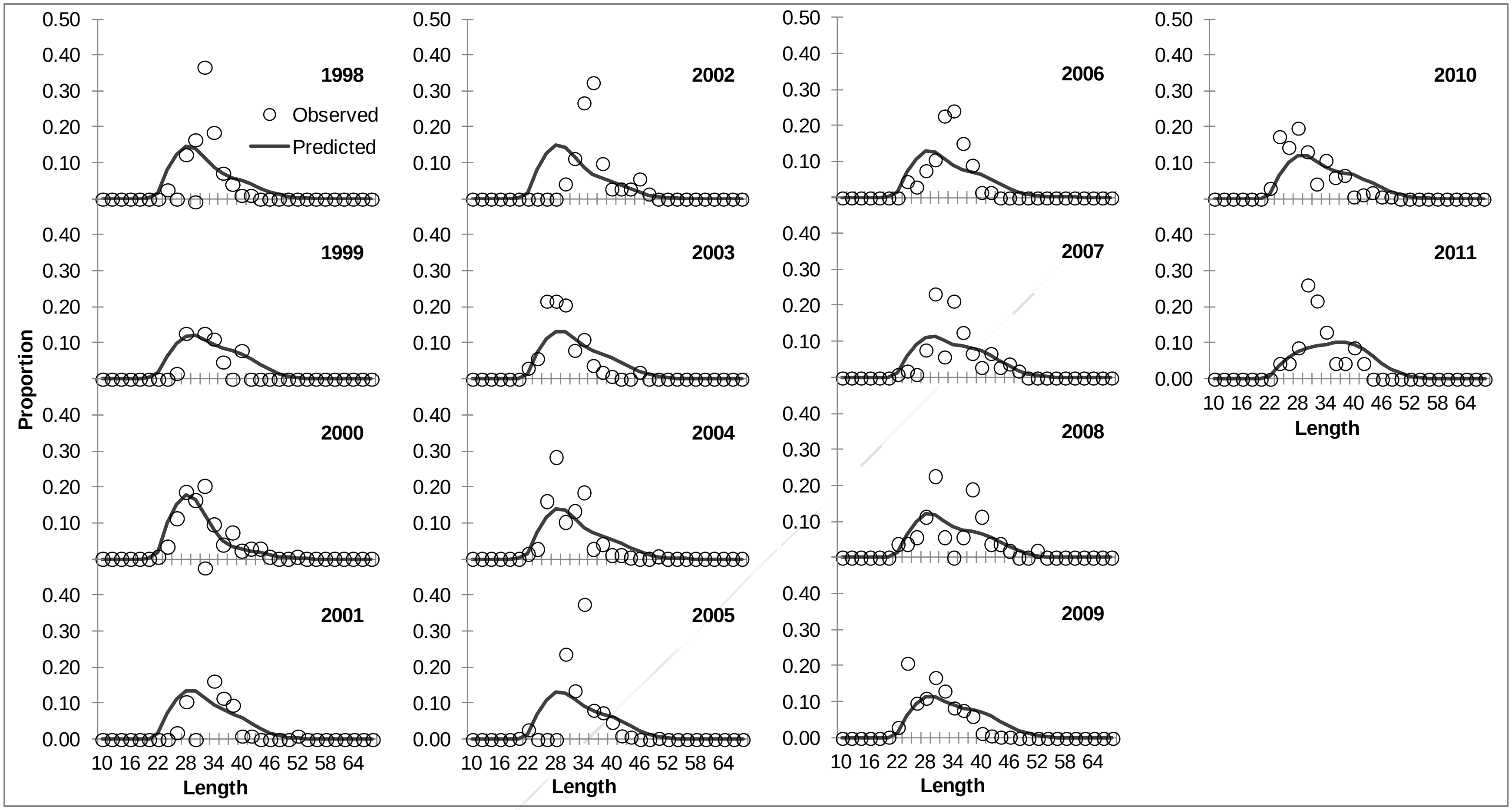

Figure 3.10. Observed and predicted annual female length-frequency distributions for Program 135 from the base run of the Stock Synthesis model.

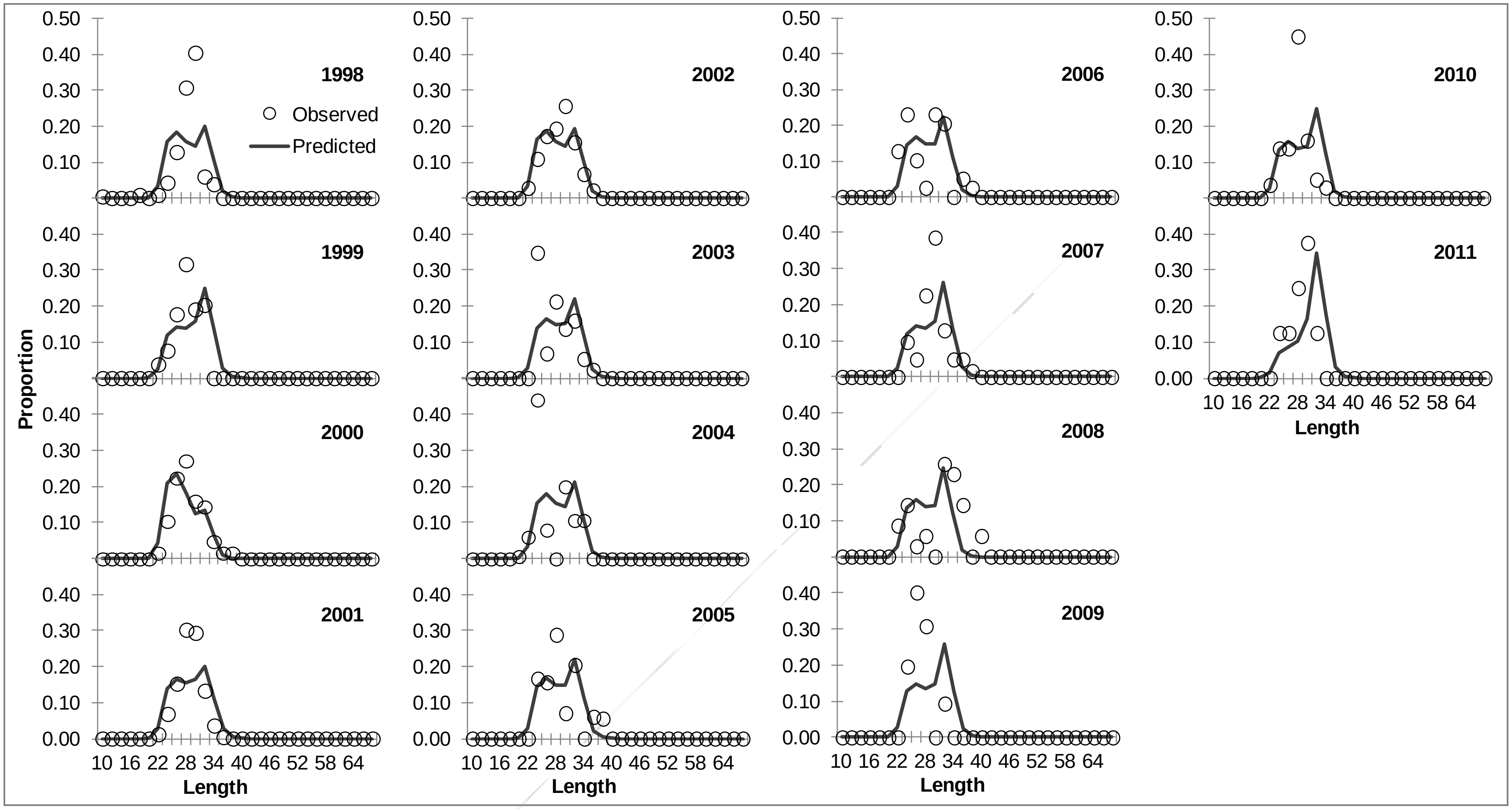

Figure 3.11. Observed and predicted annual male length-frequency distributions for Program 135 from the base run of the Stock Synthesis model.

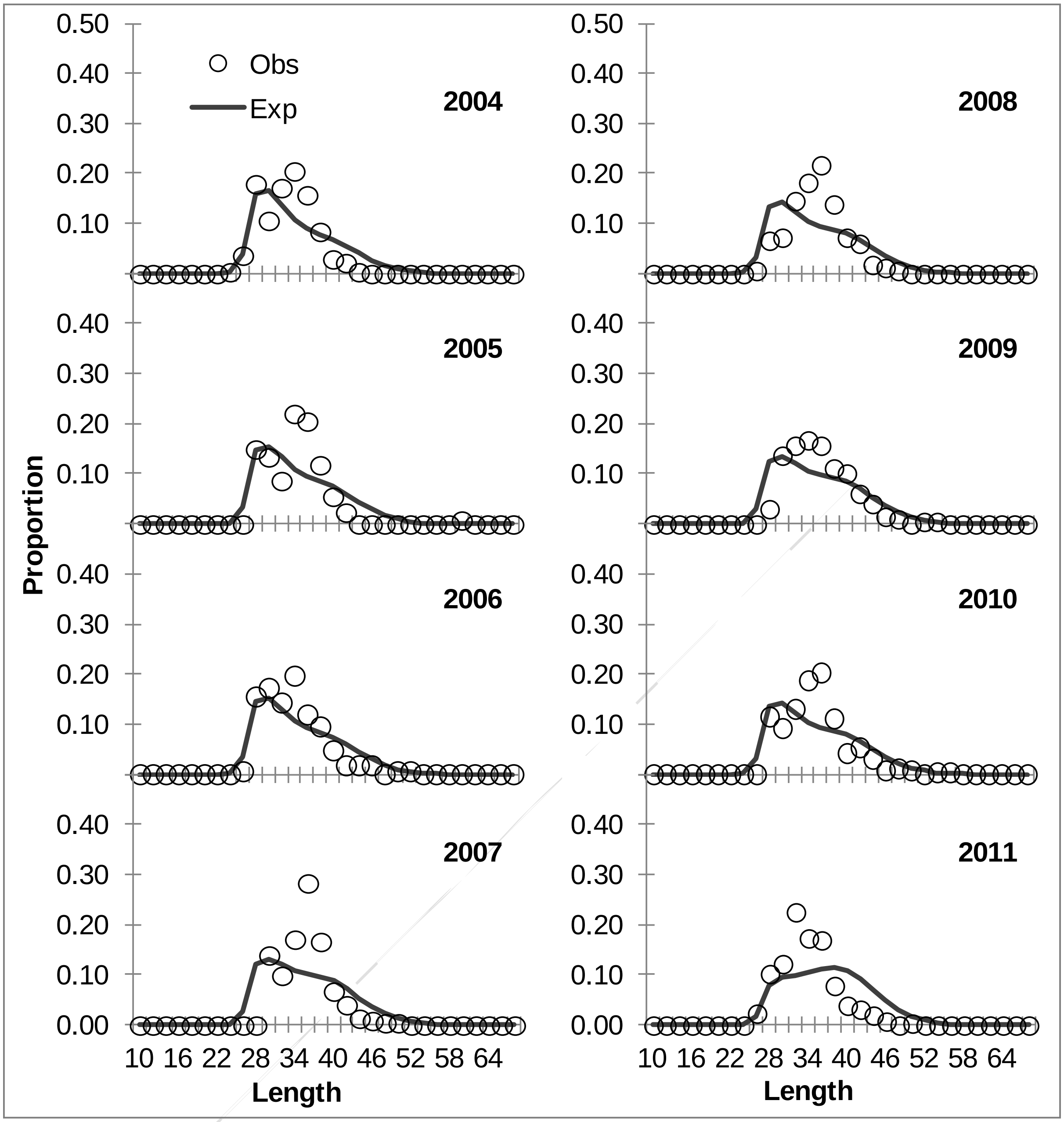

Figure 3.12. Observed and predicted annual female length-frequency distributions for Program 915 from the base run of the Stock Synthesis model.

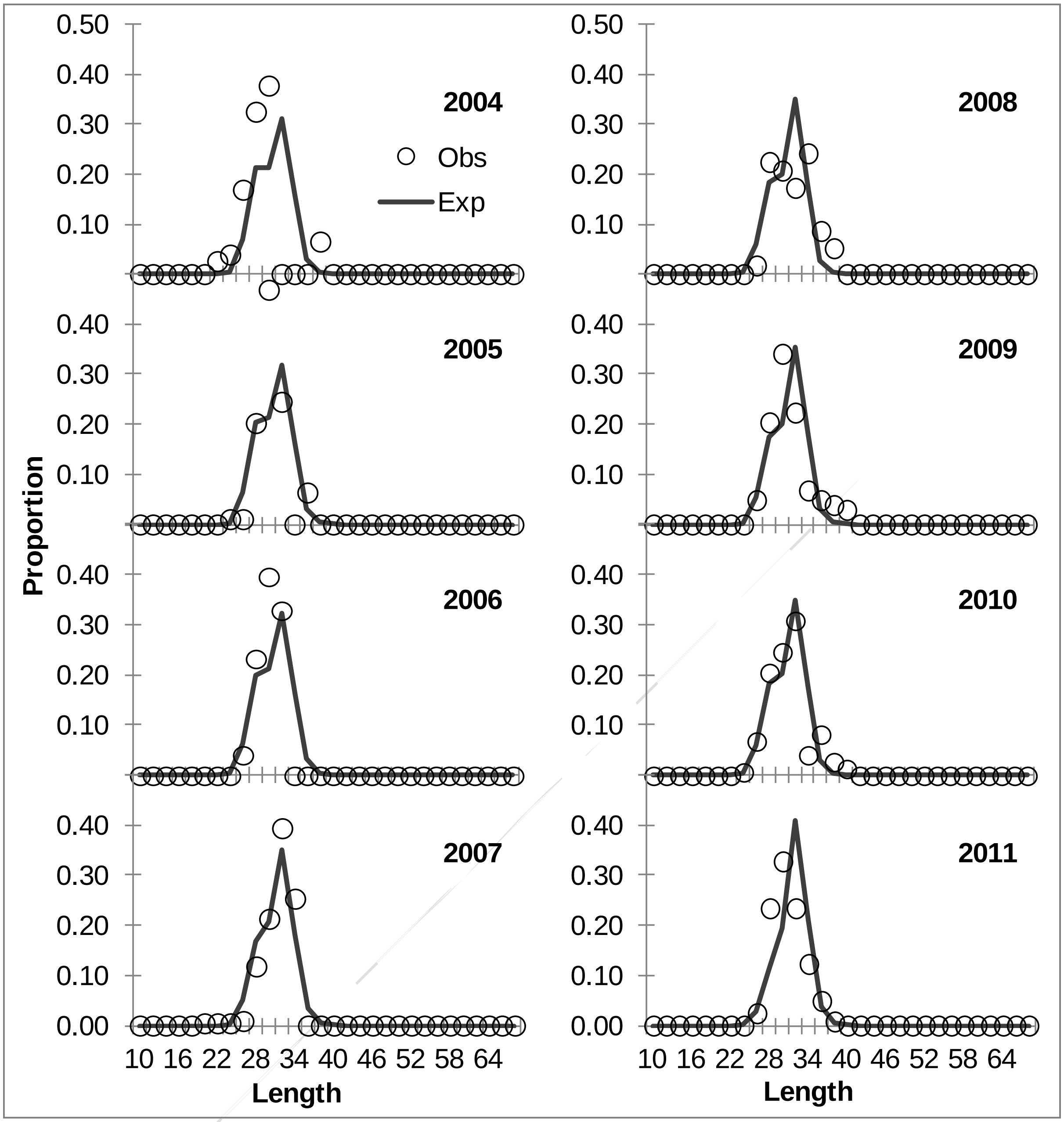

Figure 3.13. Observed and predicted annual male length-frequency distributions for Program 915 from the base run of the Stock Synthesis model.

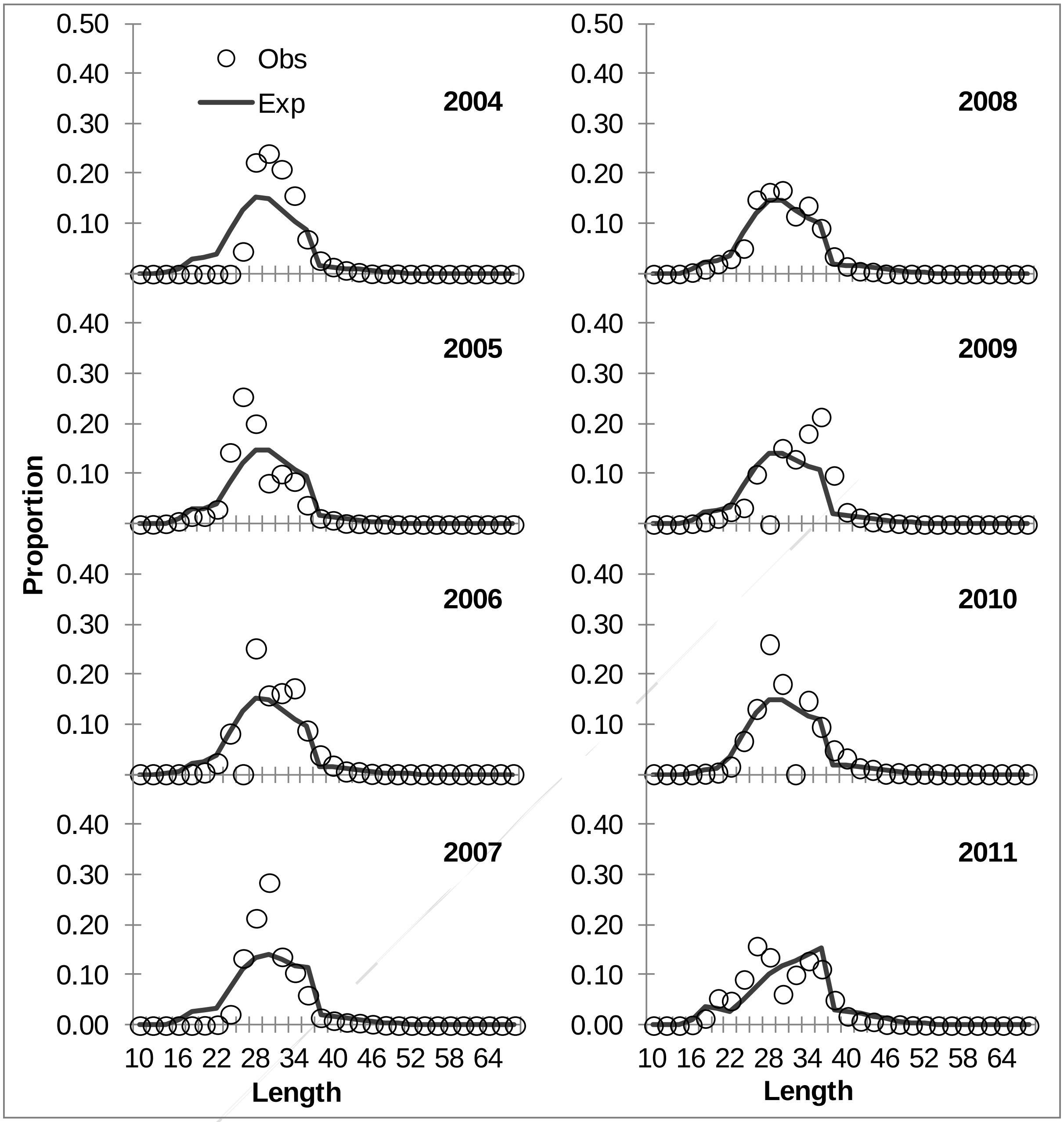

Figure 3.14. Observed and predicted annual female length-frequency distributions for Program 146 from the base run of the Stock Synthesis model.

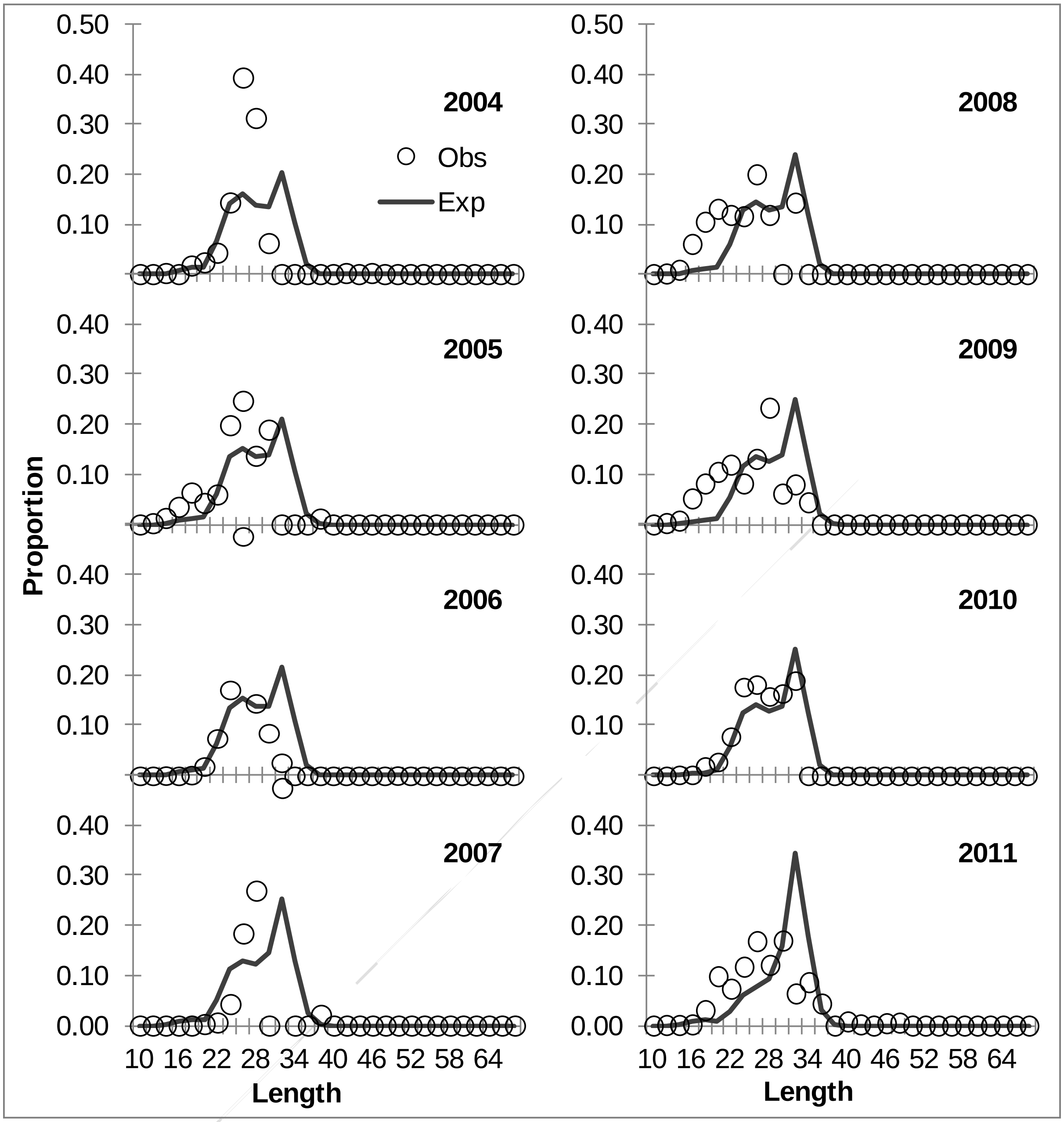

Figure 3.15. Observed and predicted annual male length-frequency distributions for Program 146 from the base run of the Stock Synthesis model.

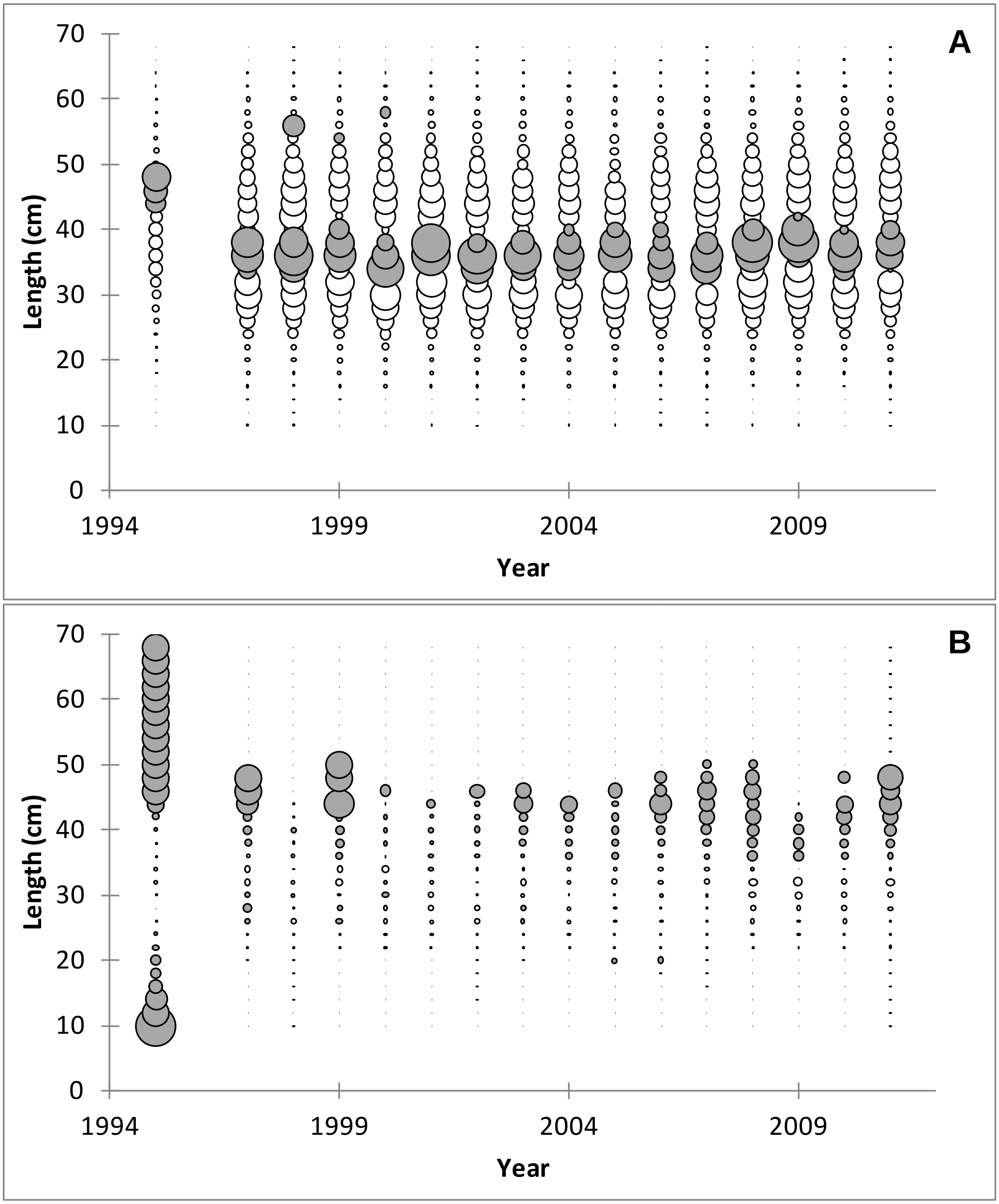

Figure 3.16. Standardized residuals for the commercial fishery length composition data for (A) female and (B) male striped mullet from the base run of the Stock Synthesis model. Gray circles represent positive residuals while white circles represent negative residuals. The area of the circles is proportional to the size of the residuals.

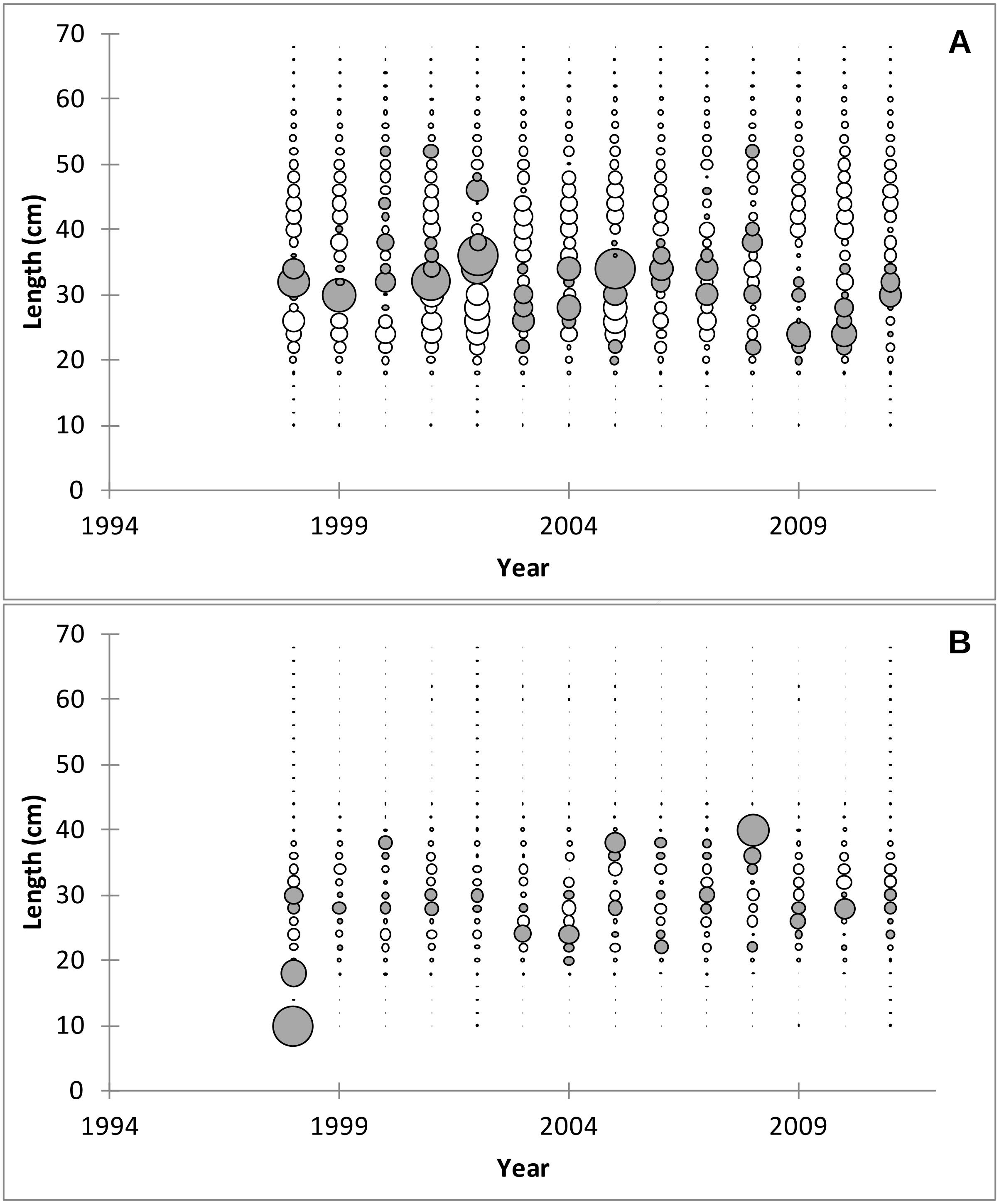

Figure 3.17. Standardized residuals for the Program 135 length composition data for (A) female and (B) male striped mullet from the base run of the Stock Synthesis model. Gray circles represent positive residuals while white circles represent negative residuals. The area of the circles is proportional to the size of the residuals.

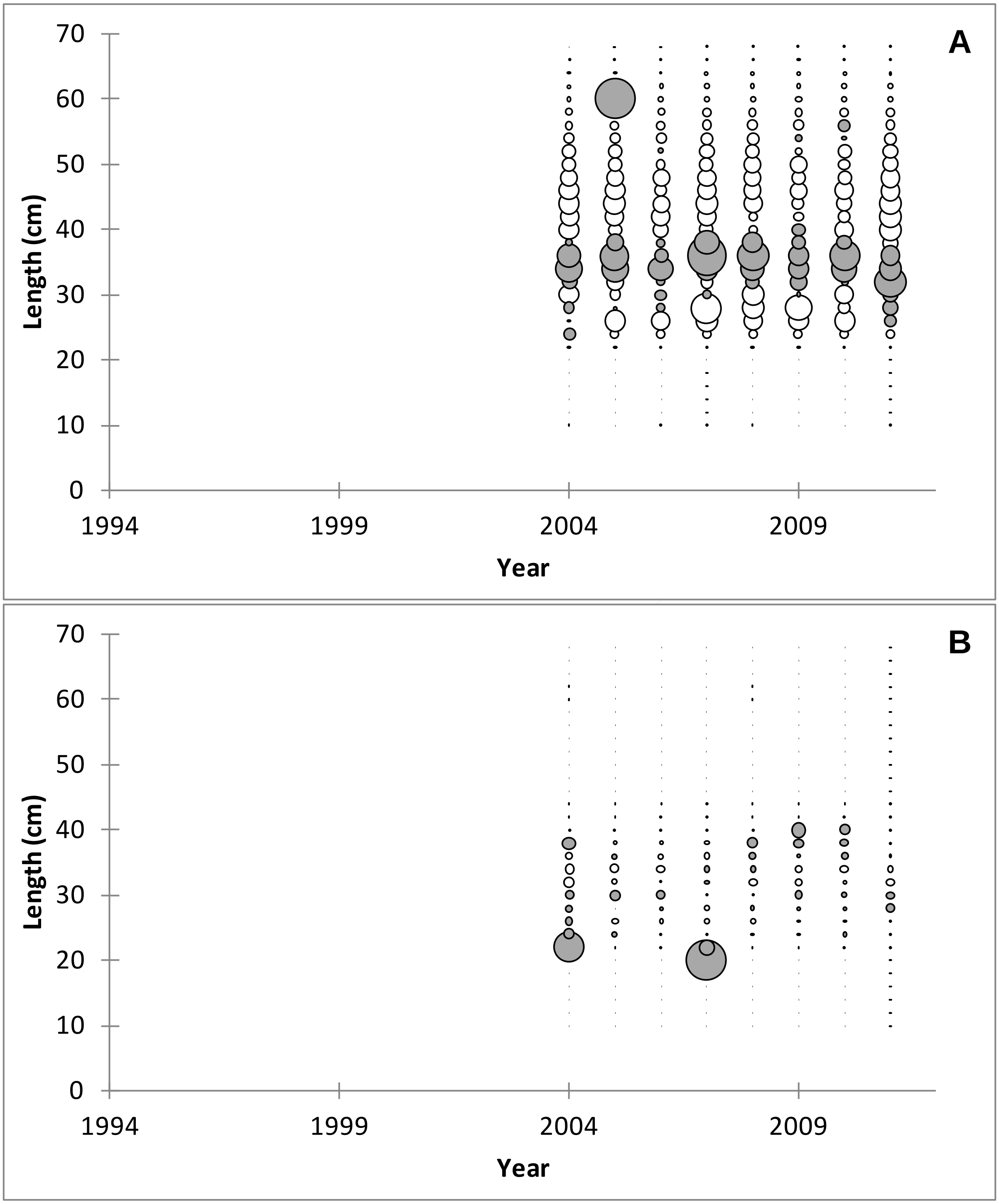

Figure 3.18. Standardized residuals for the Program 915 length composition data for (A) female and (B) male striped mullet from the base run of the Stock Synthesis model. Gray circles represent positive residuals while white circles represent negative residuals. The area of the circles is proportional to the size of the residuals.

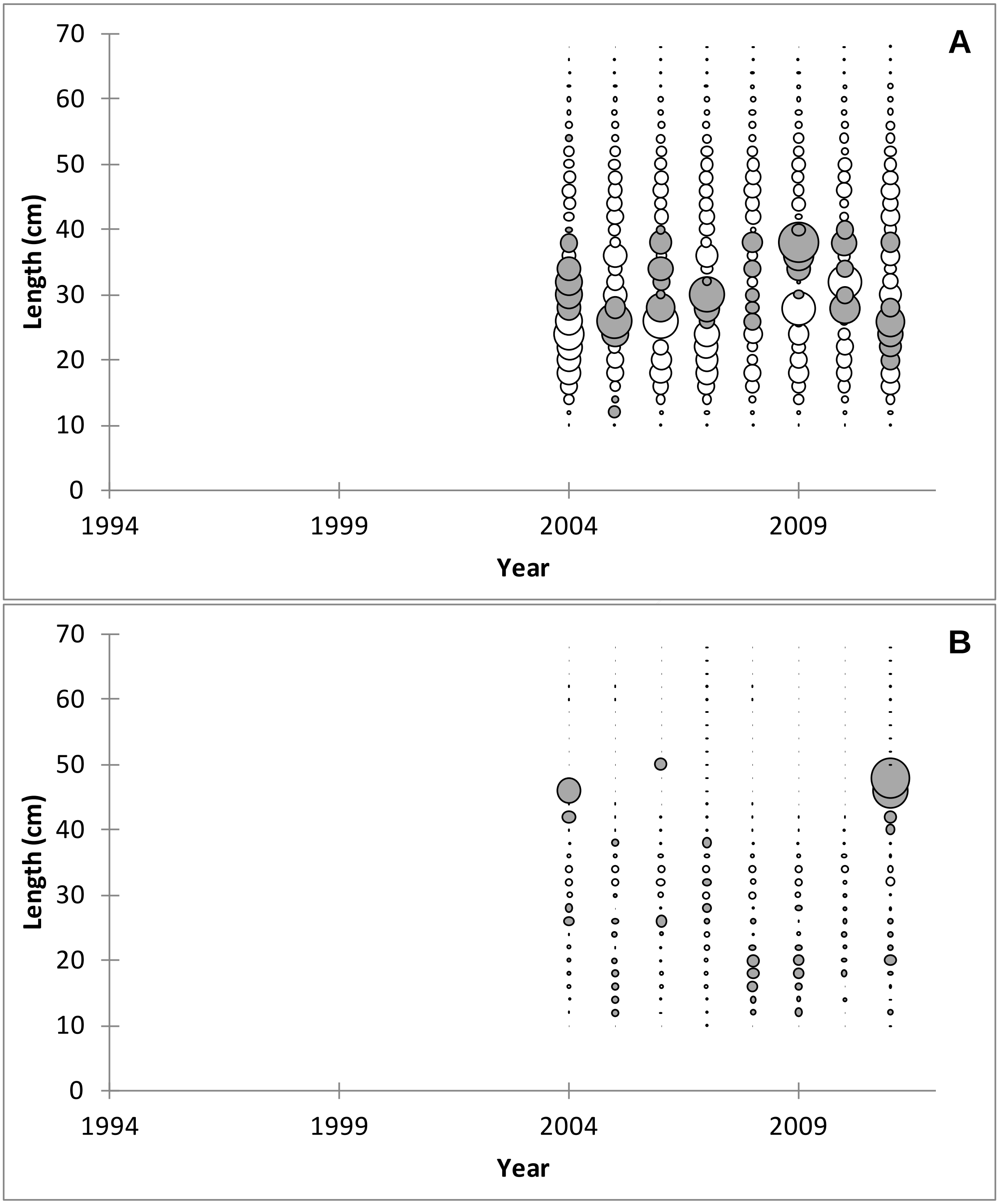

Figure 3.19. Standardized residuals for the Program 146 length composition data for (A) female and (B) male striped mullet from the base run of the Stock Synthesis model. Gray circles represent positive residuals while white circles represent negative residuals. The area of the circles is proportional to the size of the residuals.

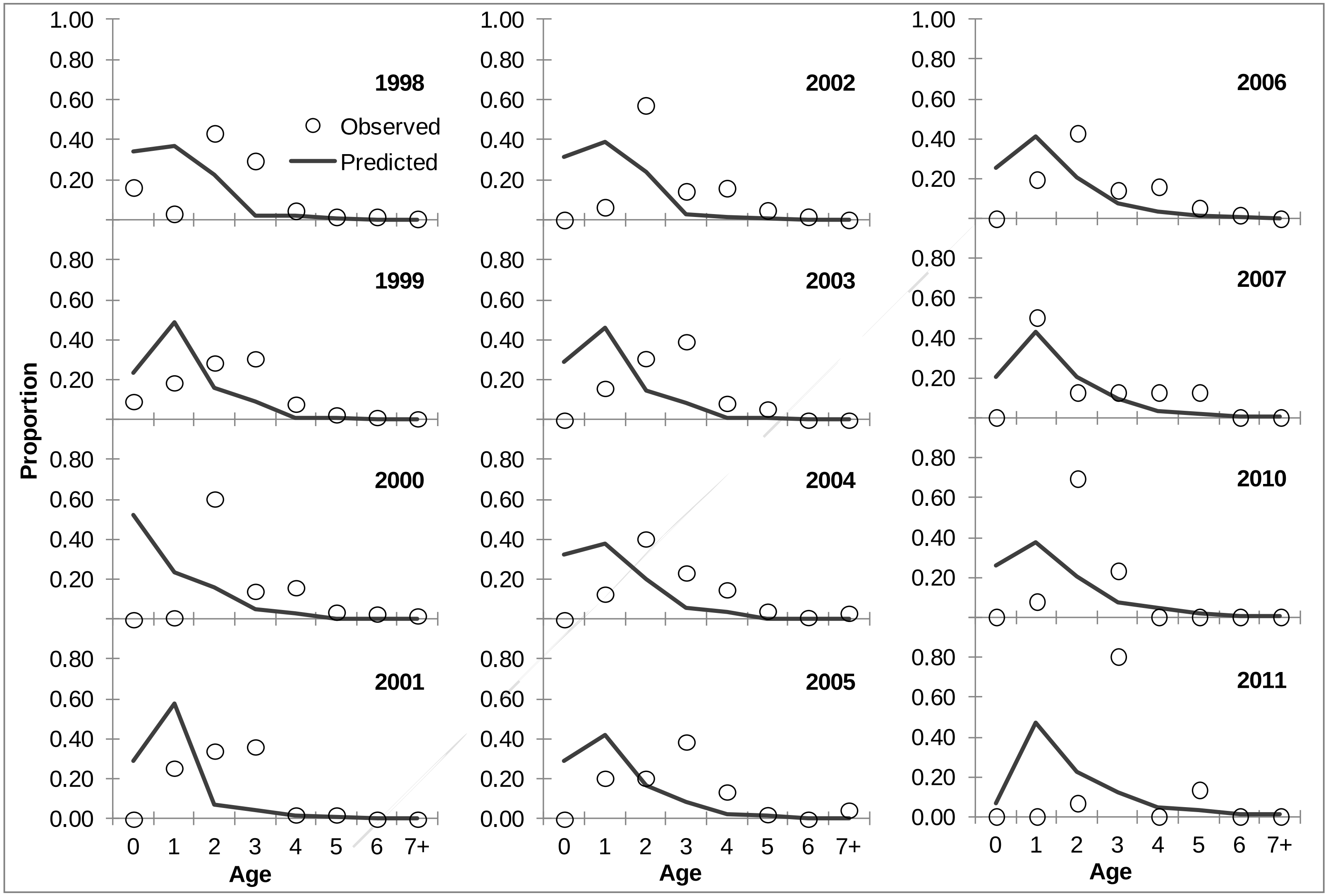

Figure 3.20. Observed and predicted annual female age-frequency distributions for the commercial fishery from the base run of the Stock Synthesis model.

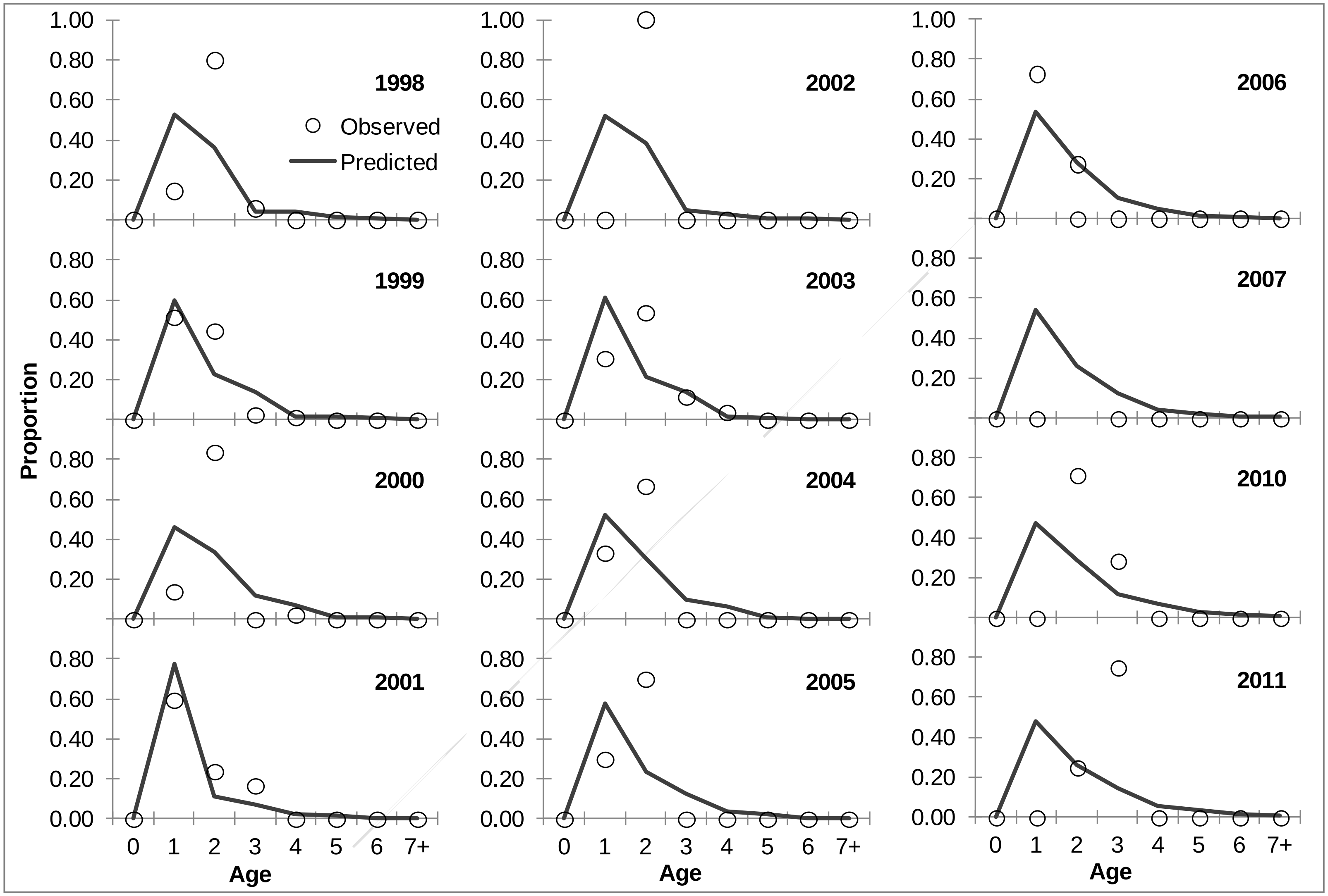

Figure 3.21. Observed and predicted annual male age-frequency distributions for the commercial fishery from the base run of the Stock Synthesis model.

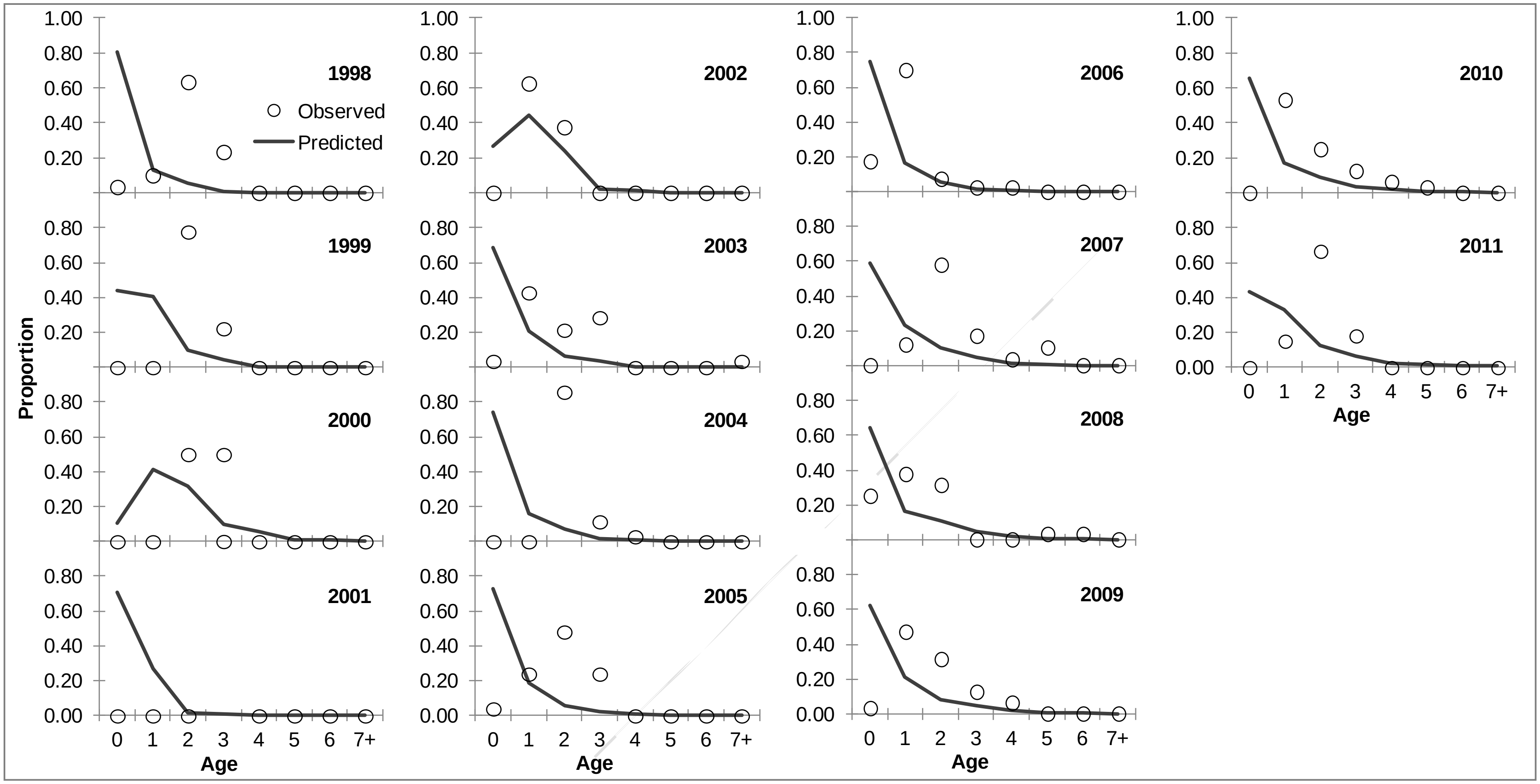

Figure 3.22. Observed and predicted annual female age-frequency distributions for Program 135 from the base run of the Stock Synthesis model.

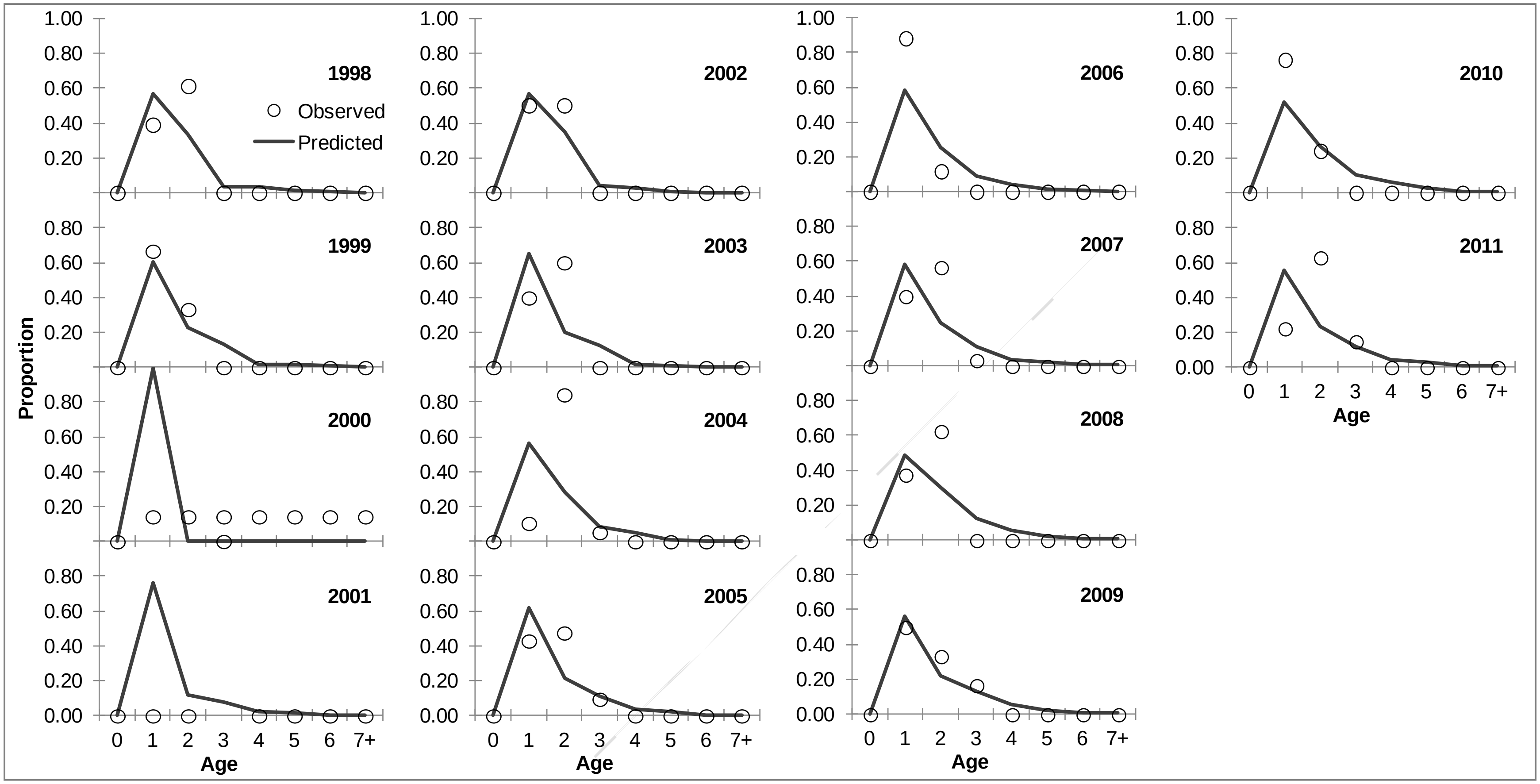

Figure 3.23. Observed and predicted annual male age-frequency distributions for Program 135 from the base run of the Stock Synthesis model.

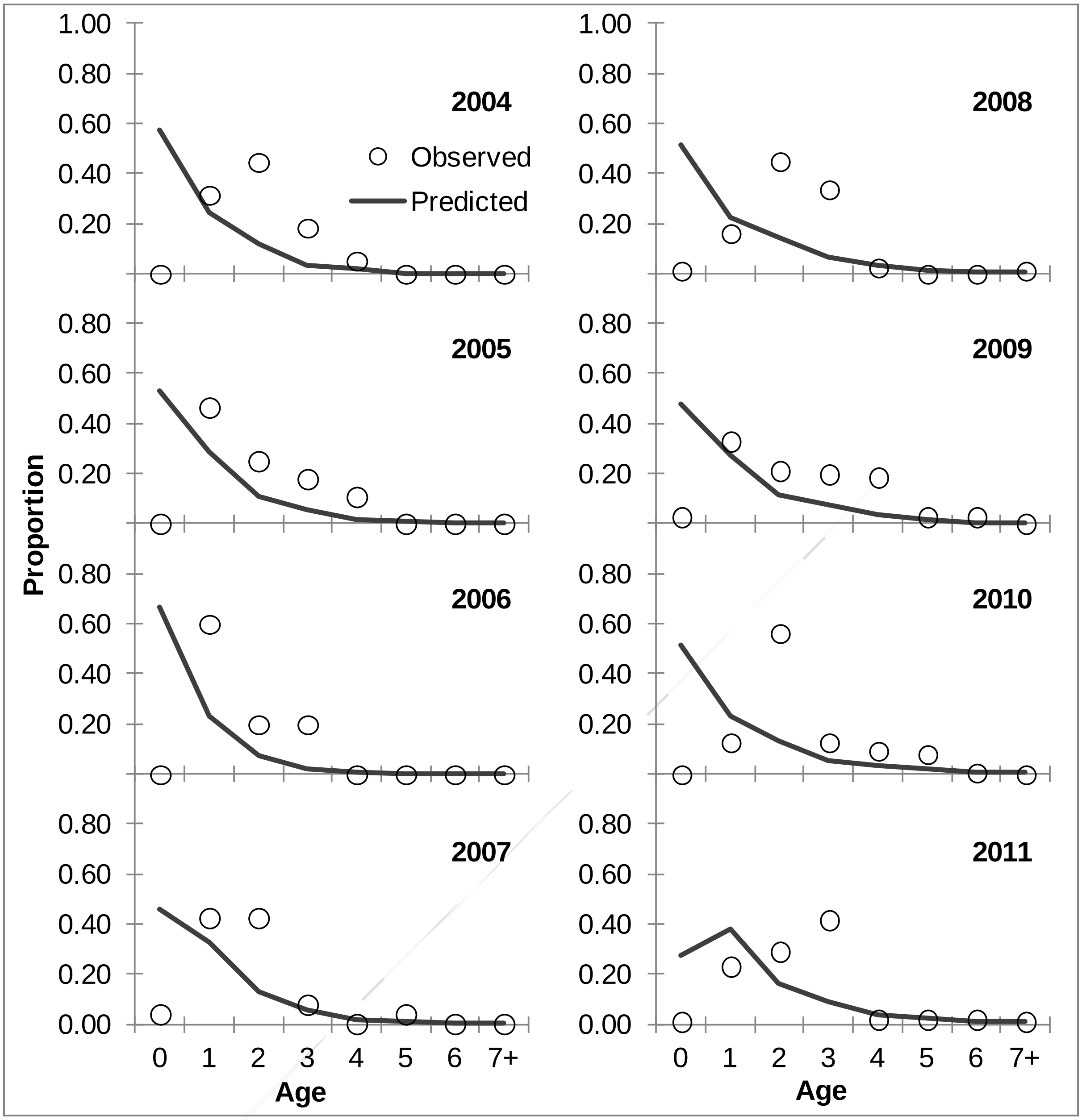

Figure 3.24. Observed and predicted annual female age-frequency distributions for Program 915 from the base run of the Stock Synthesis model.

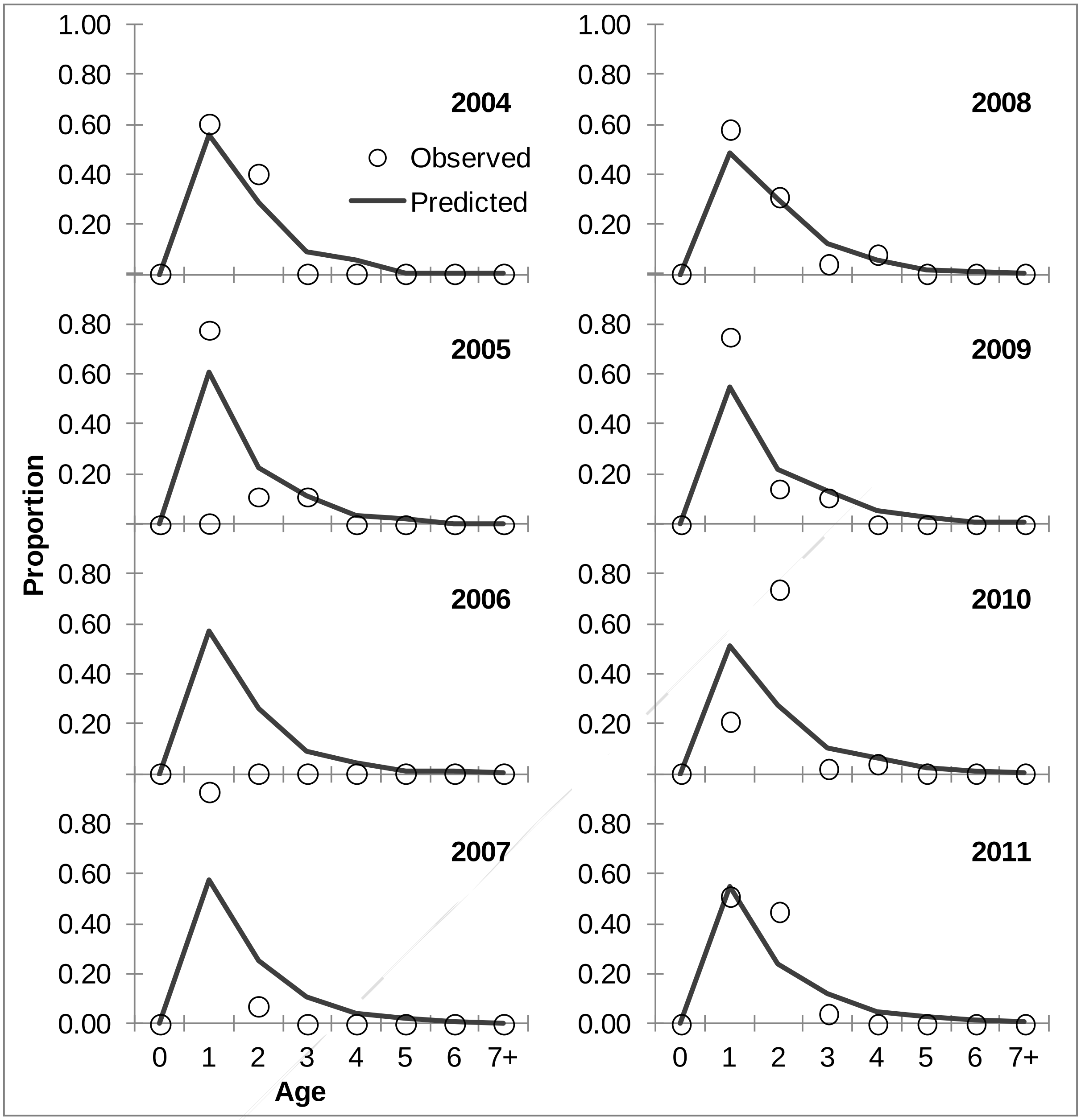

Figure 3.25. Observed and predicted annual male age-frequency distributions for Program 915 from the base run of the Stock Synthesis model.

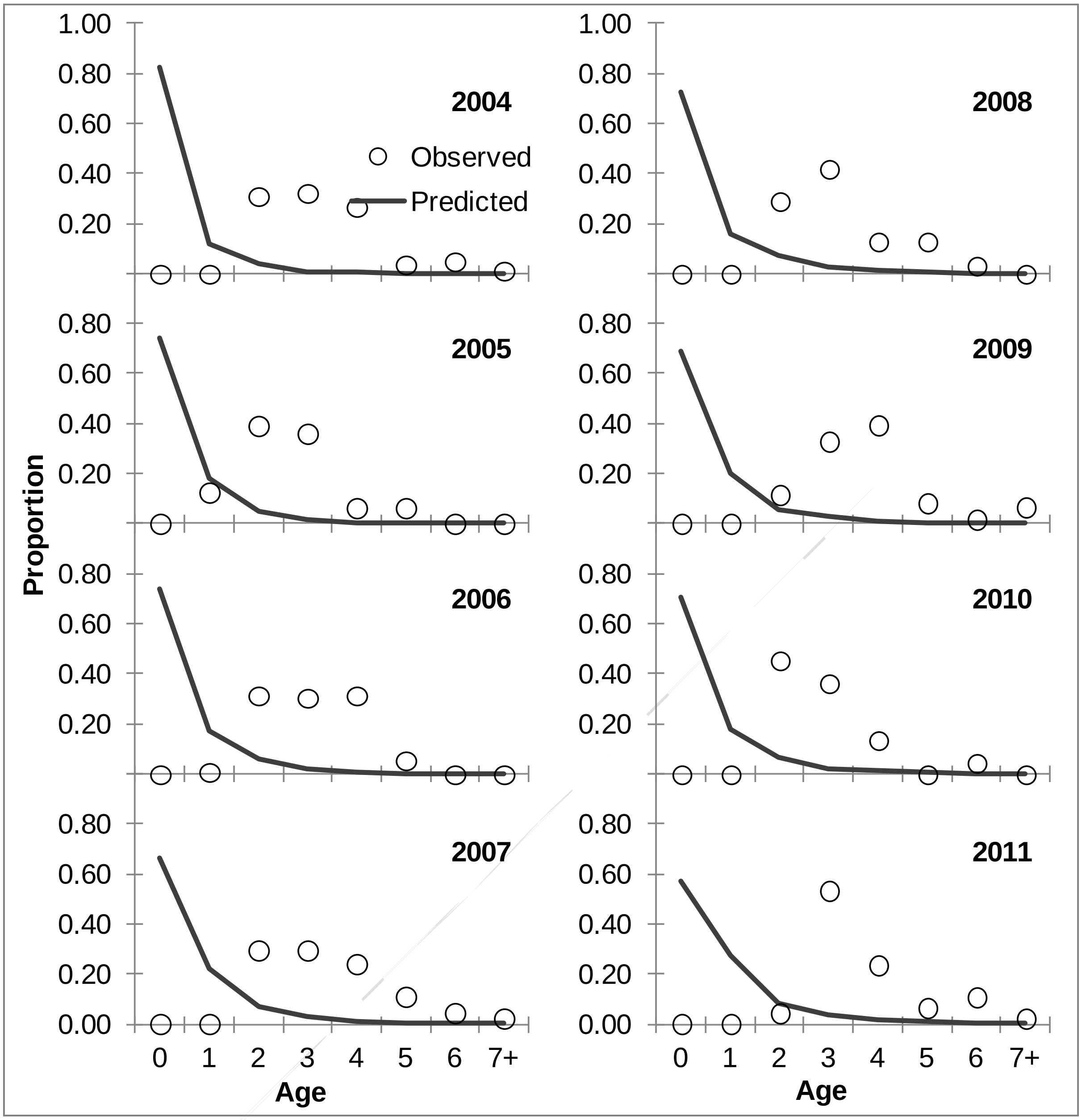

Figure 3.26. Observed and predicted annual female age-frequency distributions for Program 146 from the base run of the Stock Synthesis model.

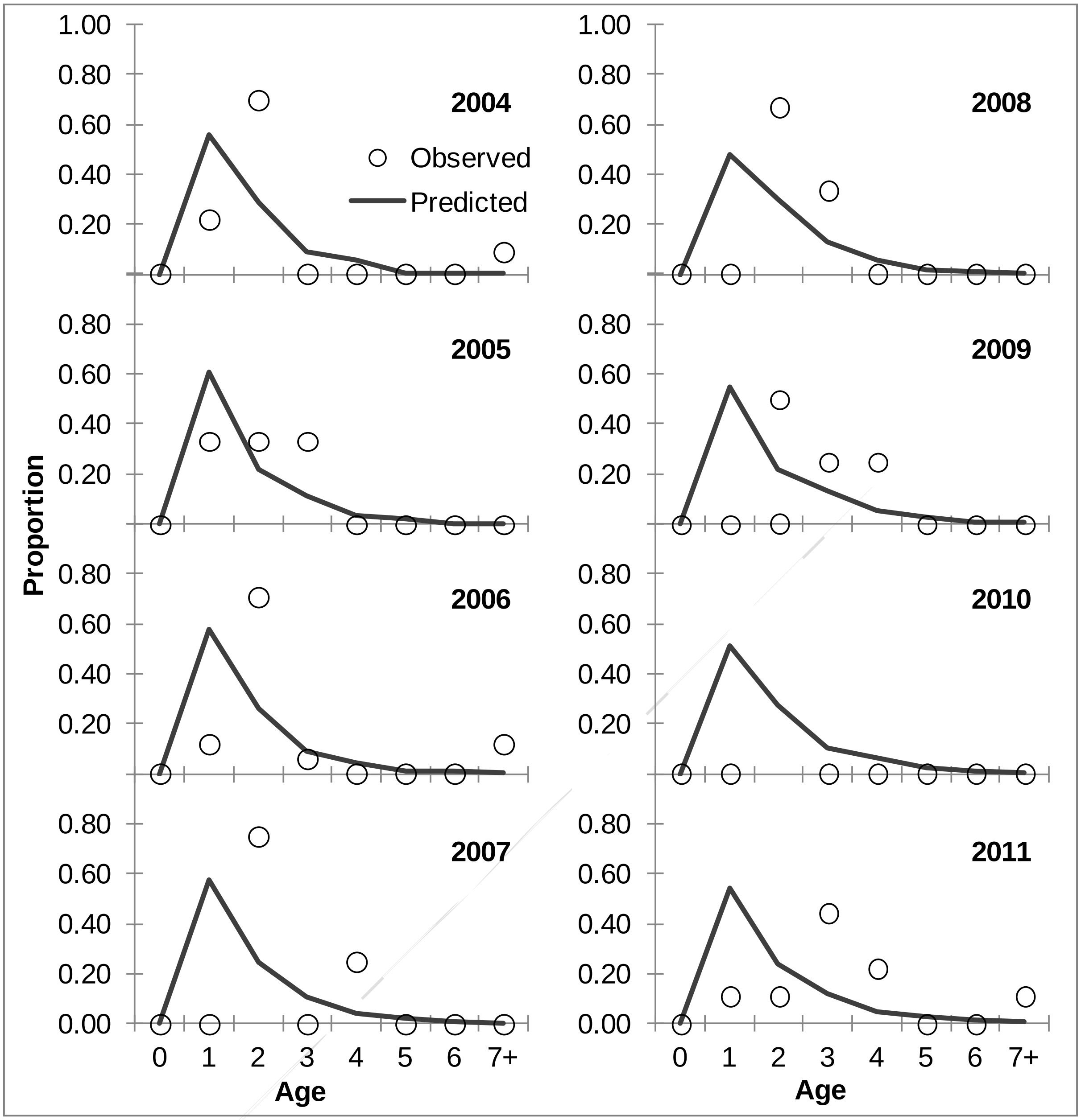

Figure 3.27. Observed and predicted annual male age-frequency distributions for Program 146 from the base run of the Stock Synthesis model.

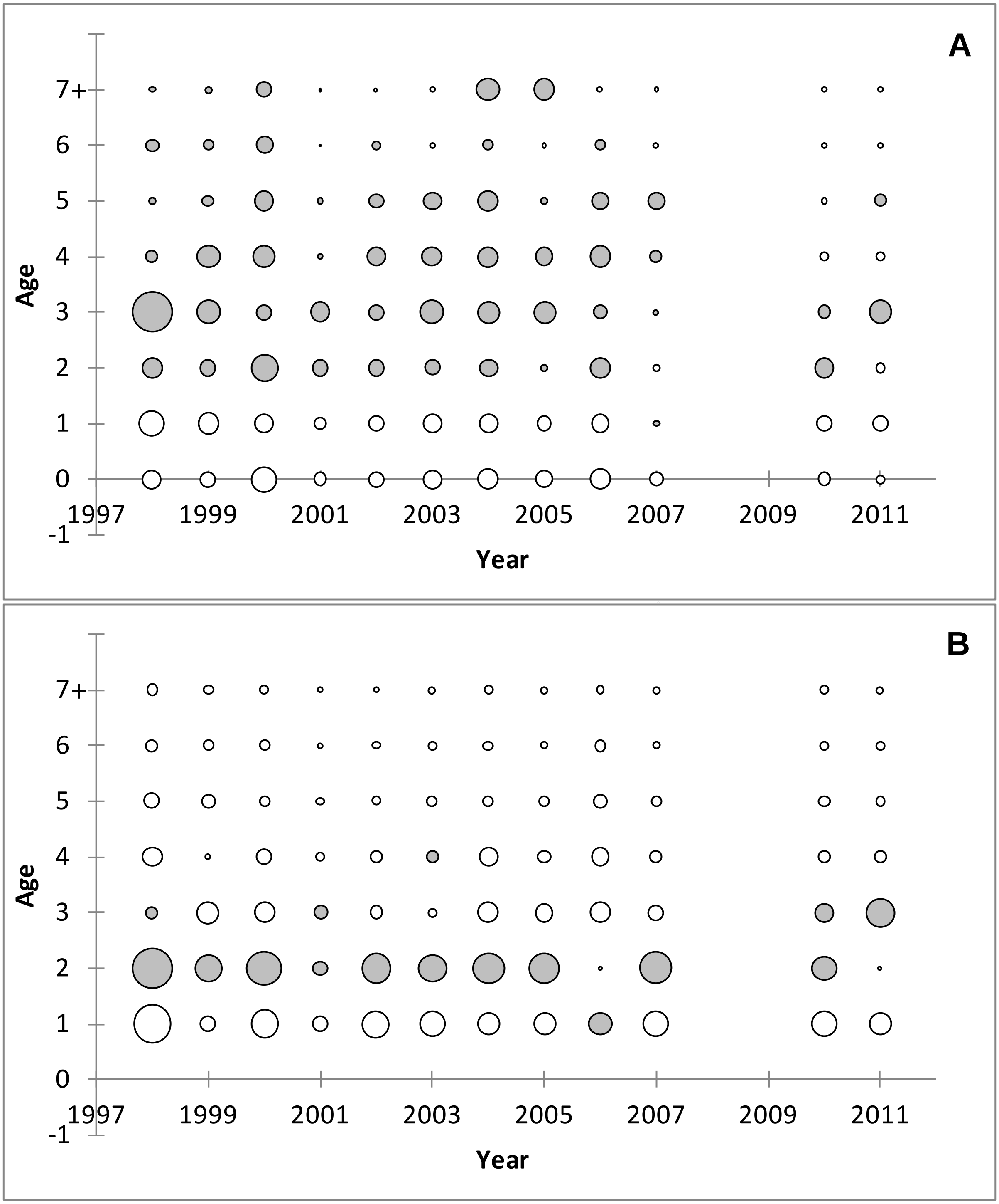

Figure 3.28. Standardized residuals for the commercial fishery age composition data for (A) female and (B) male striped mullet from the base run of the Stock Synthesis model. Gray circles represent positive residuals while white circles represent negative residuals. The area of the circles is proportional to the size of the residuals.

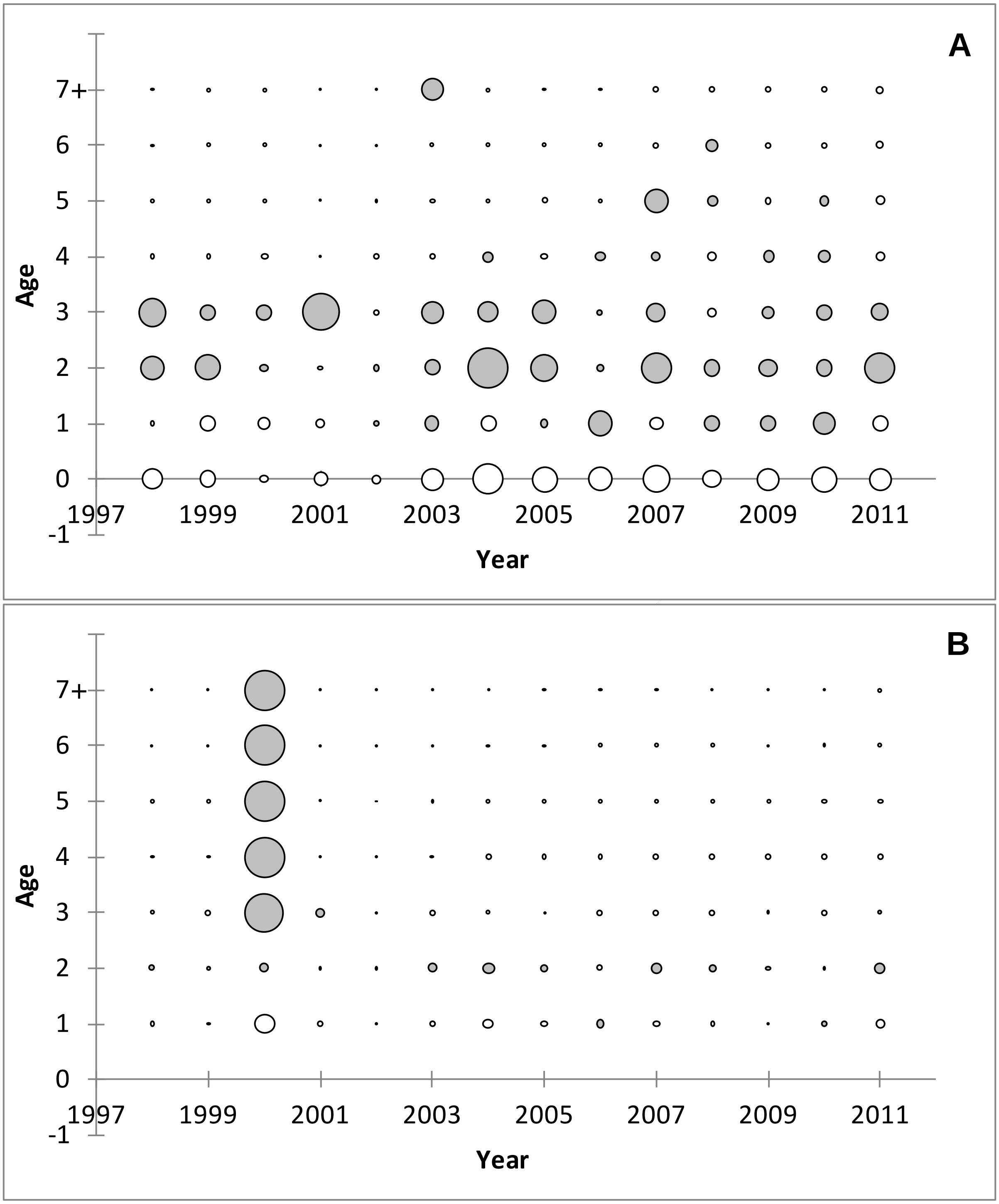

Figure 3.29. Standardized residuals for the Program 135 age composition data for (A) female and (B) male striped mullet from the base run of the Stock Synthesis model. Gray circles represent positive residuals while white circles represent negative residuals. The area of the circles is proportional to the size of the residuals.

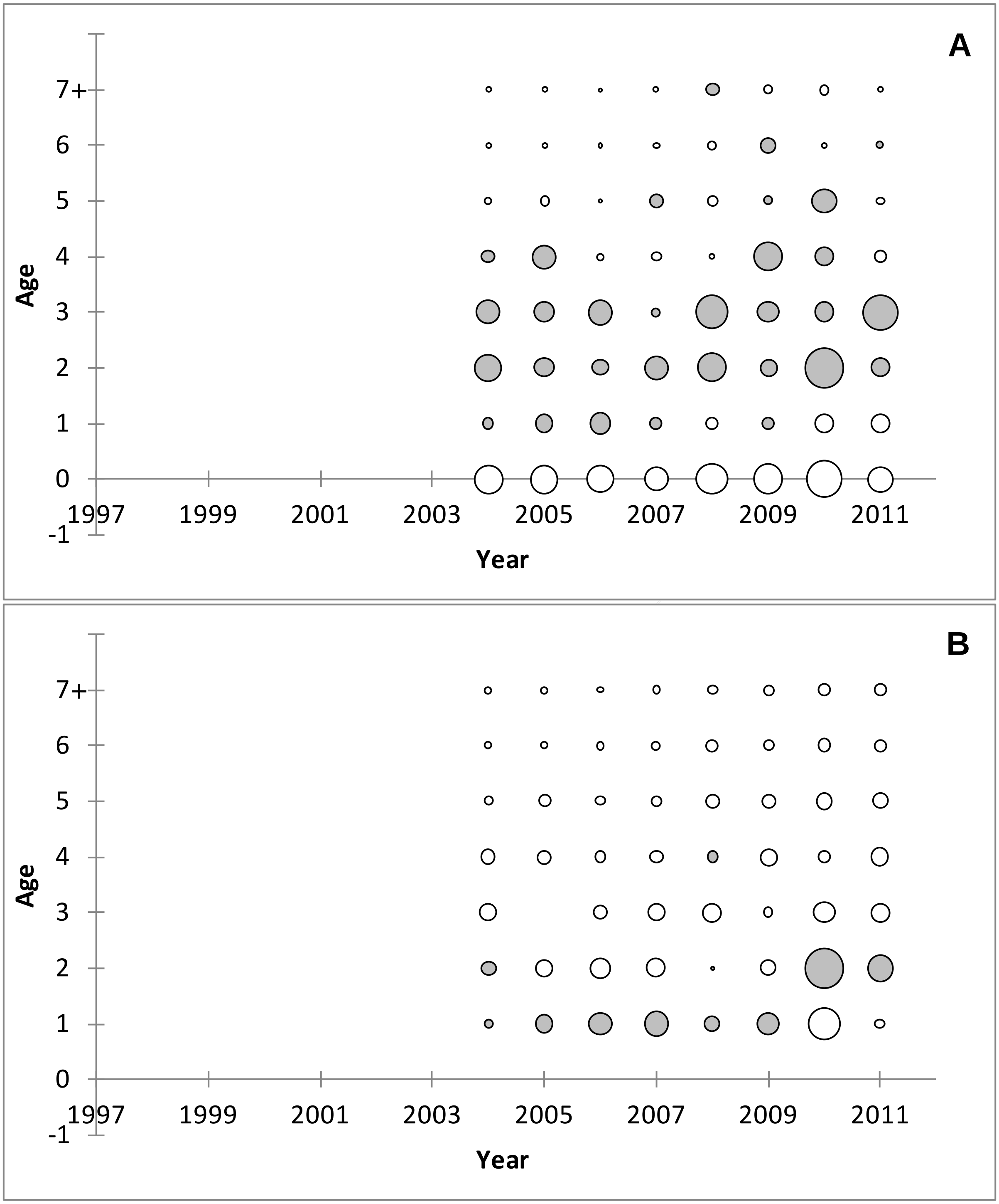

Figure 3.30. Standardized residuals for the Program 915 age composition data for (A) female and (B) male striped mullet from the base run of the Stock Synthesis model. Gray circles represent positive residuals while white circles represent negative residuals. The area of the circles is proportional to the size of the residuals.

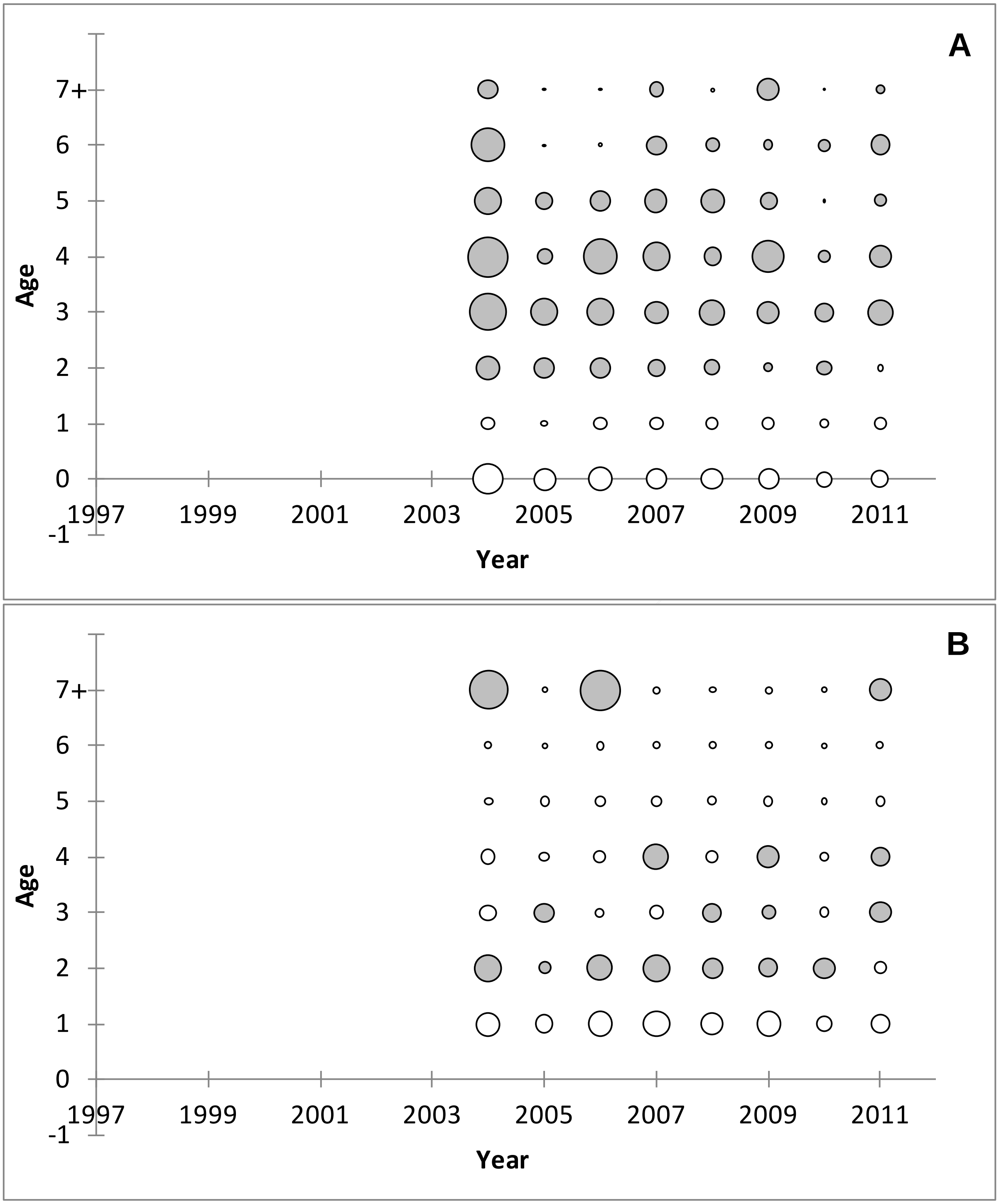

Figure 3.31. Standardized residuals for the Program 146 age composition data for (A) female and (B) male striped mullet from the base run of the Stock Synthesis model. Gray circles represent positive residuals while white circles represent negative residuals. The area of the circles is proportional to the size of the residuals.

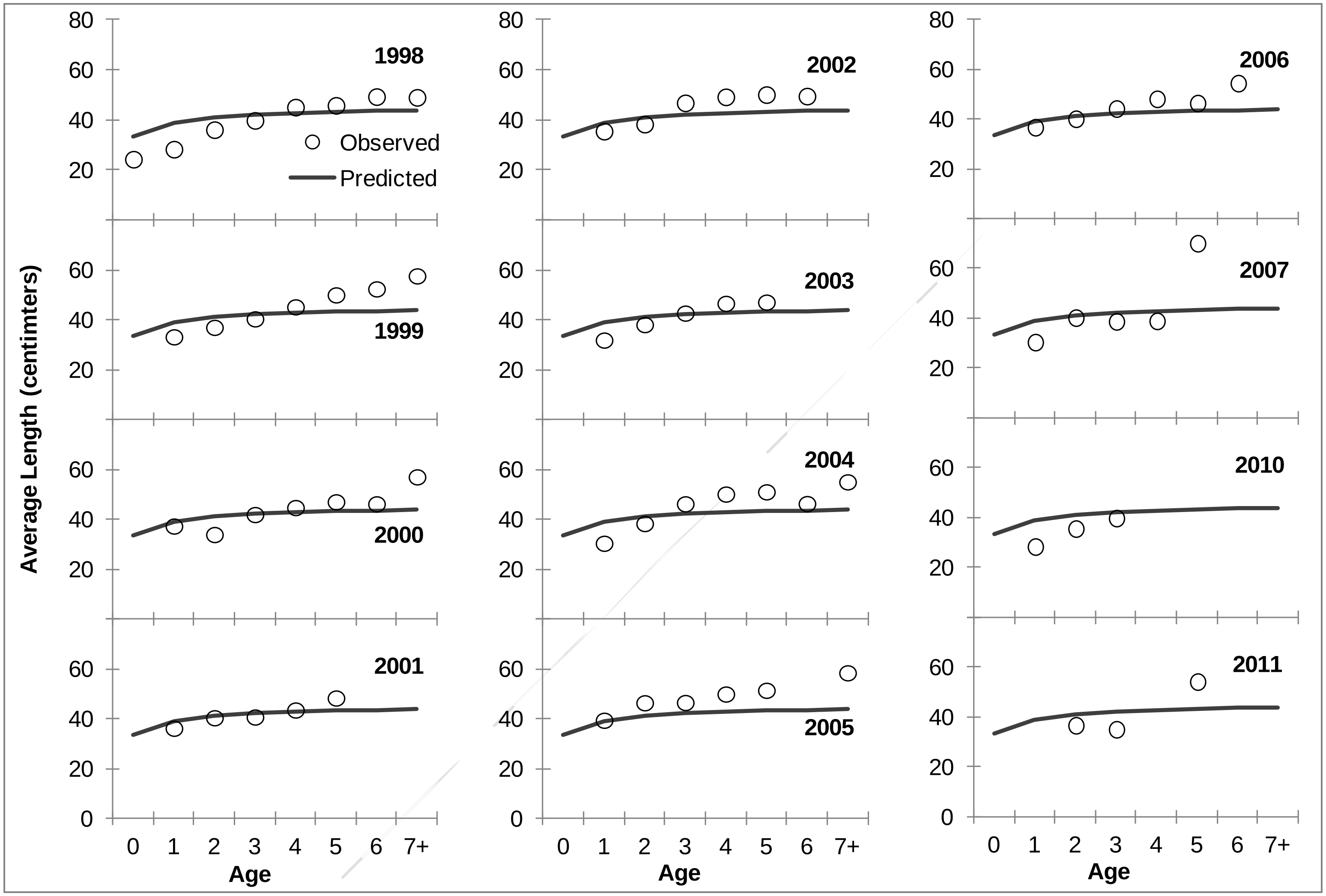

Figure 3.32. Observed and predicted annual female length at age for the commercial fishery from the base run of the Stock Synthesis model.

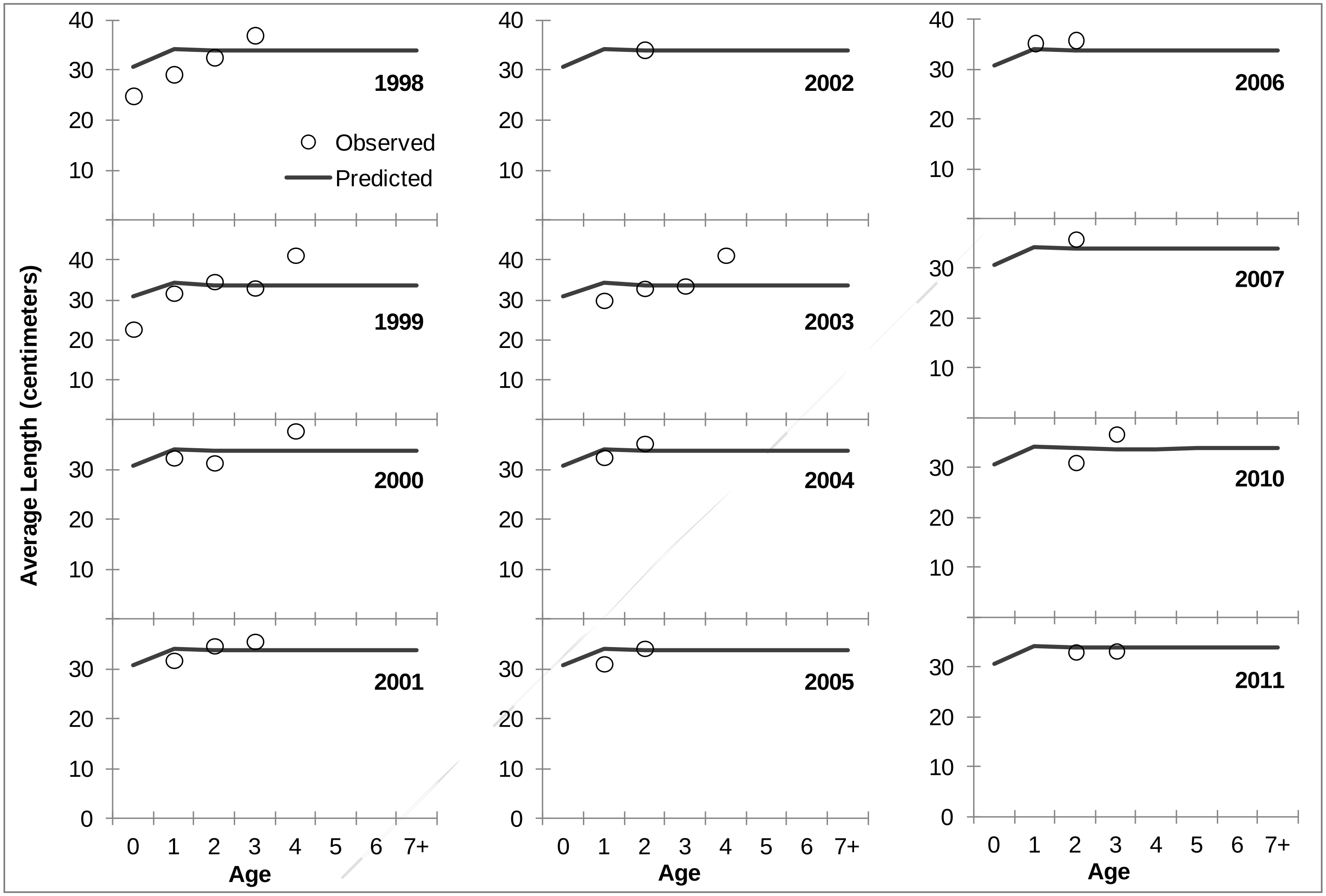

Figure 3.33. Observed and predicted annual male length at age for the commercial fishery from the base run of the Stock Synthesis model.

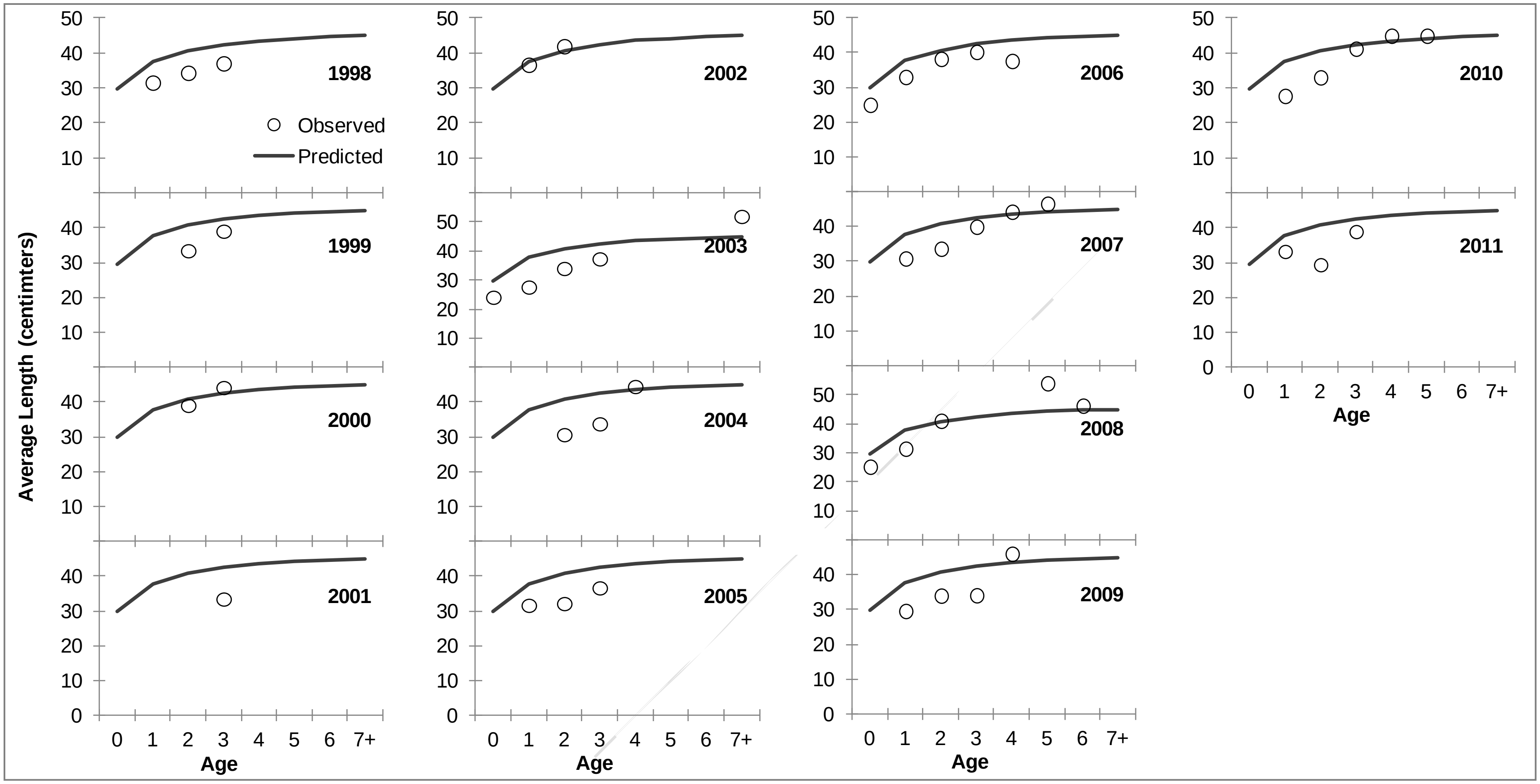

Figure 3.34. Observed and predicted annual female length at age for Program 135 from the base run of the Stock Synthesis model.

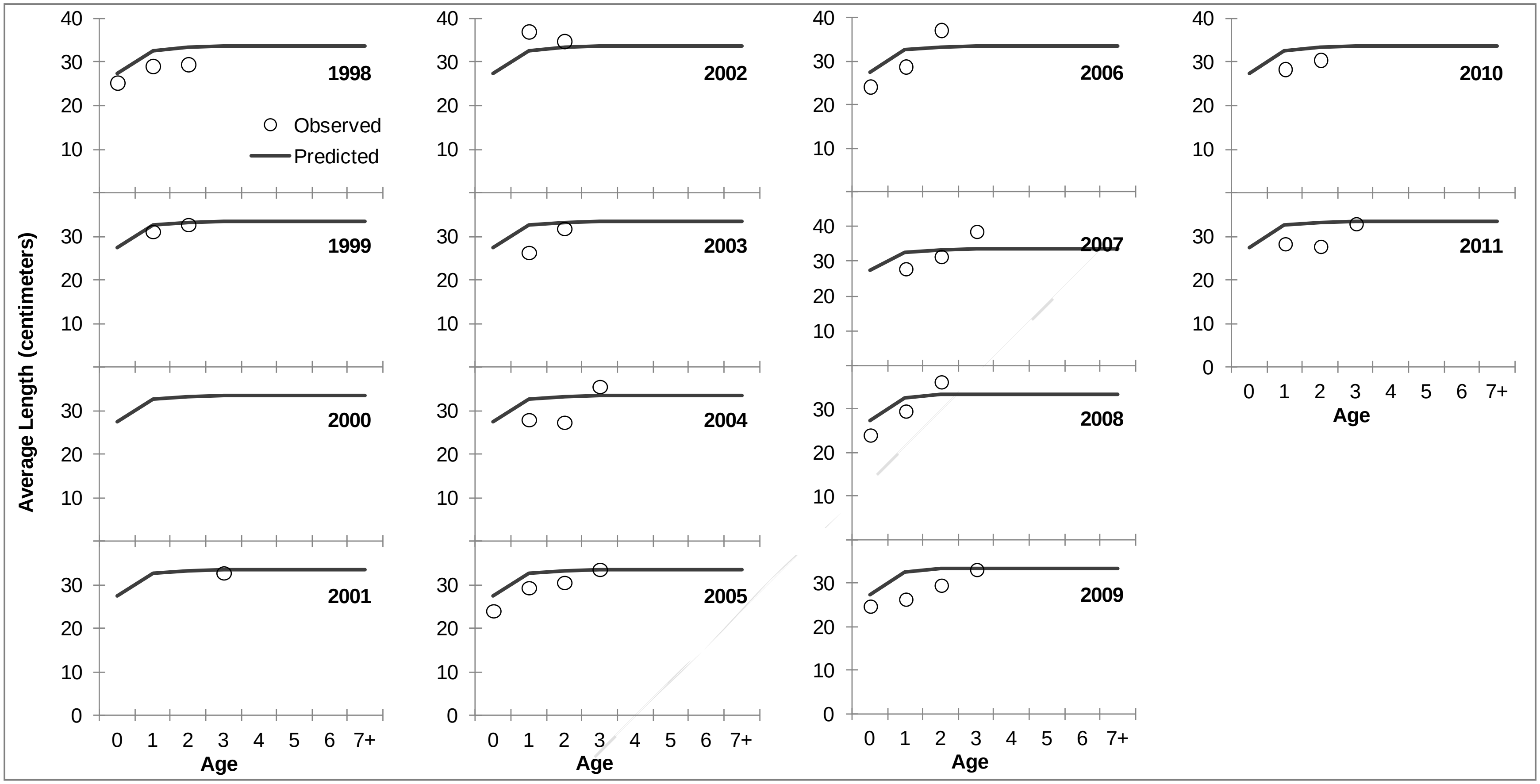

Figure 3.35. Observed and predicted annual male length at age for Program 135 from the base run of the Stock Synthesis model.

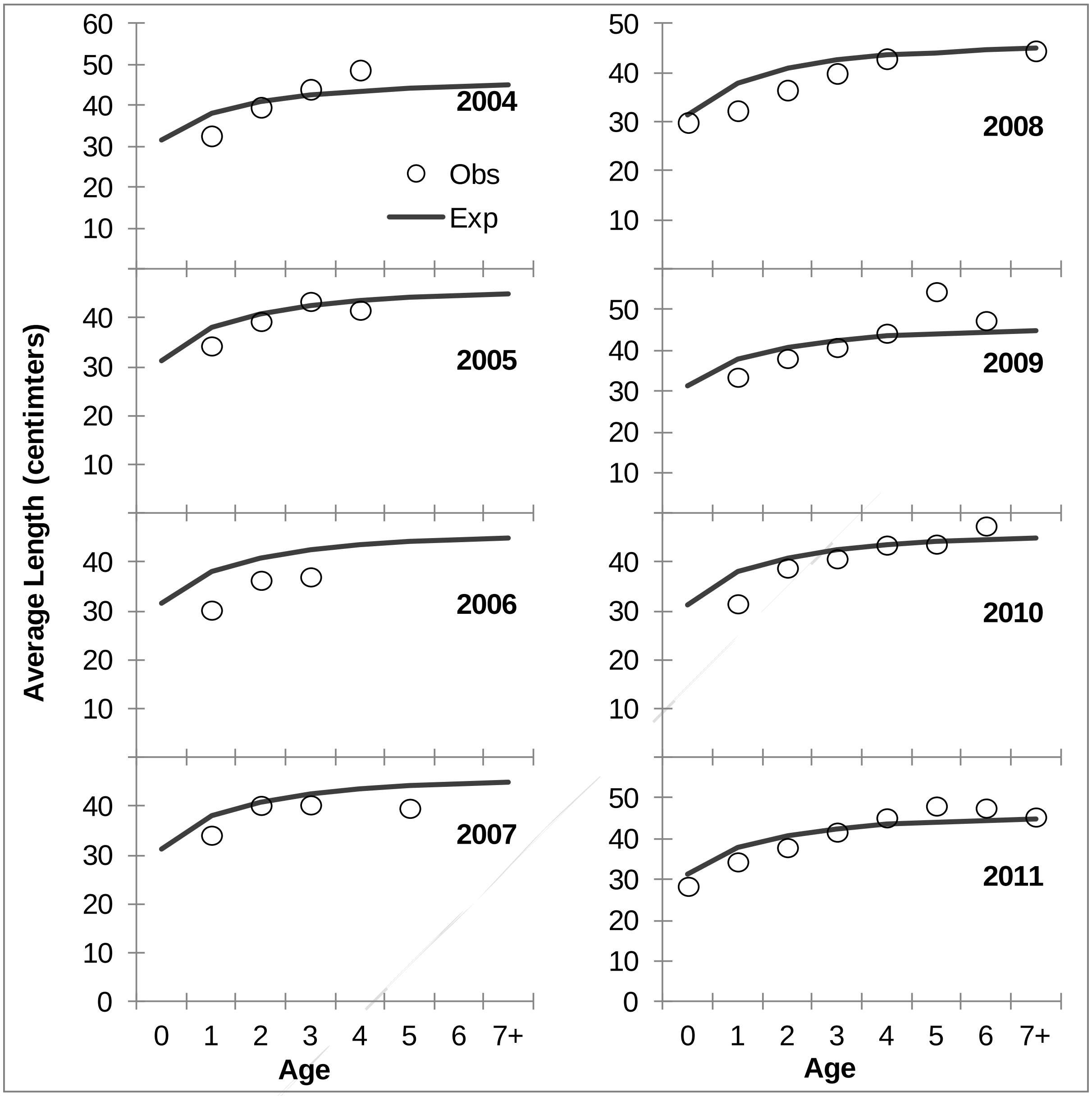

Figure 3.36. Observed and predicted annual female length at age for Program 915 from the base run of the Stock Synthesis model.

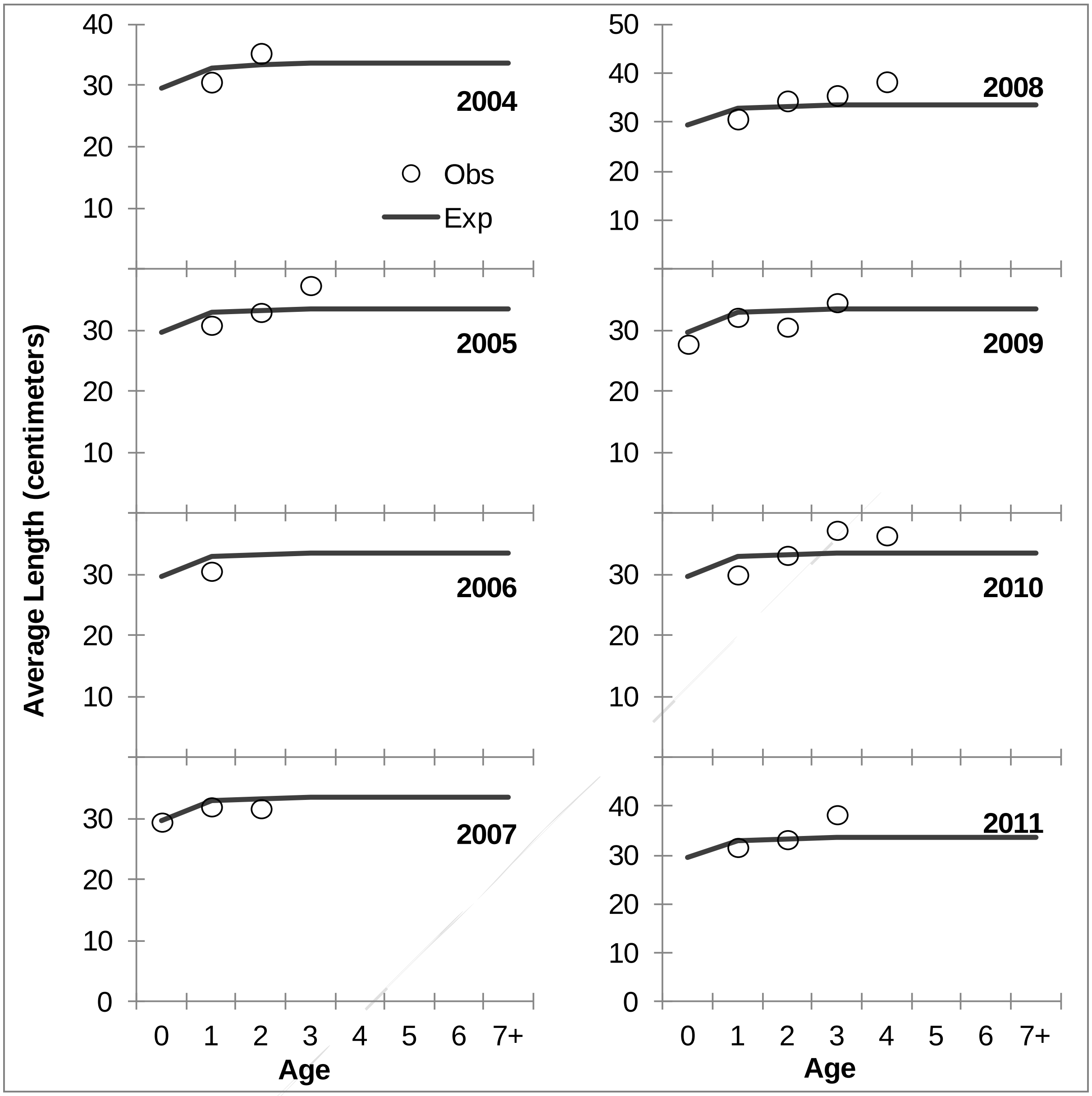

Figure 3.37. Observed and predicted annual male length at age for Program 915 from the base run of the Stock Synthesis model.

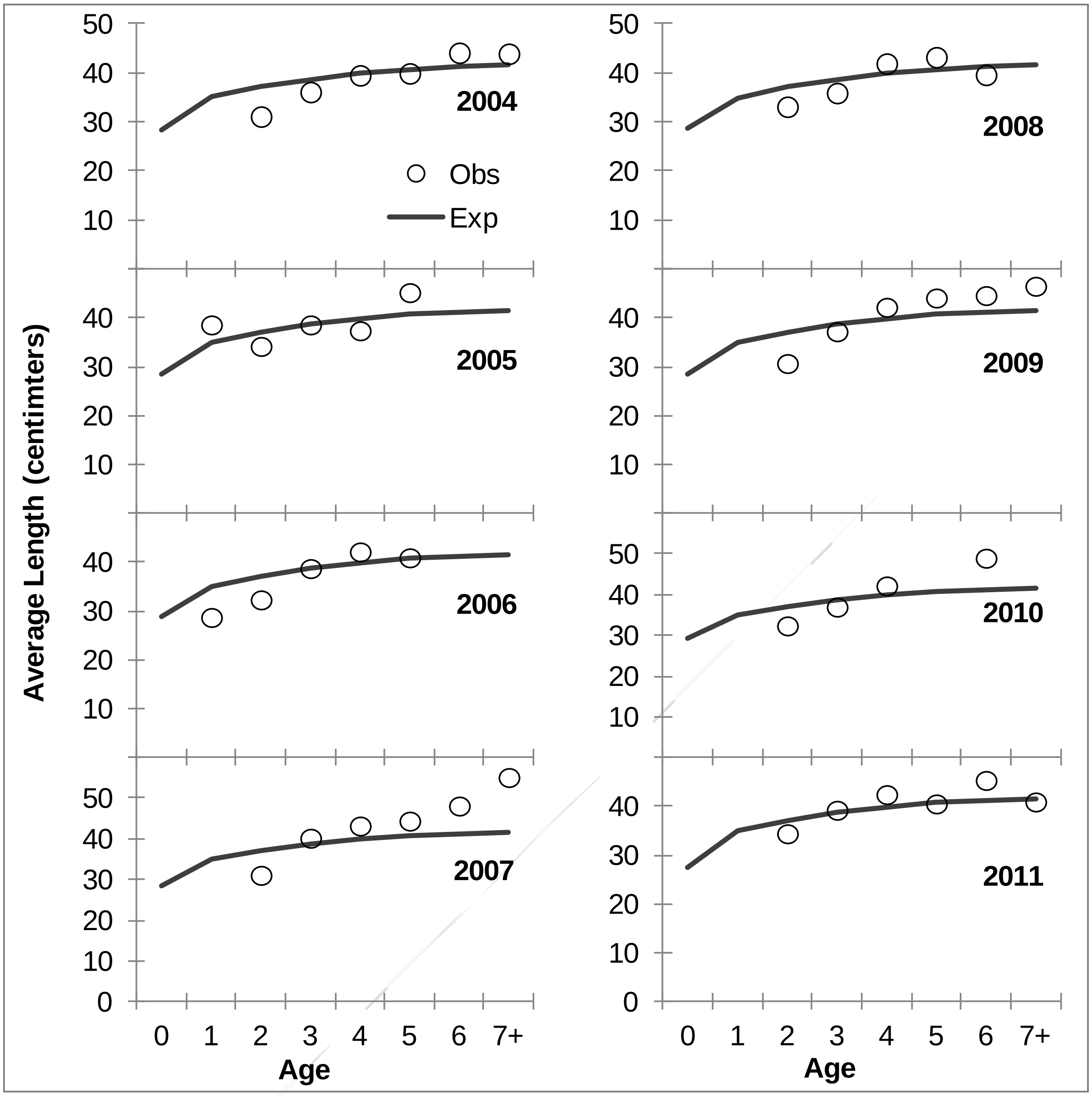

Figure 3.38. Observed and predicted annual female length at age for Program 146 from the base run of the Stock Synthesis model.

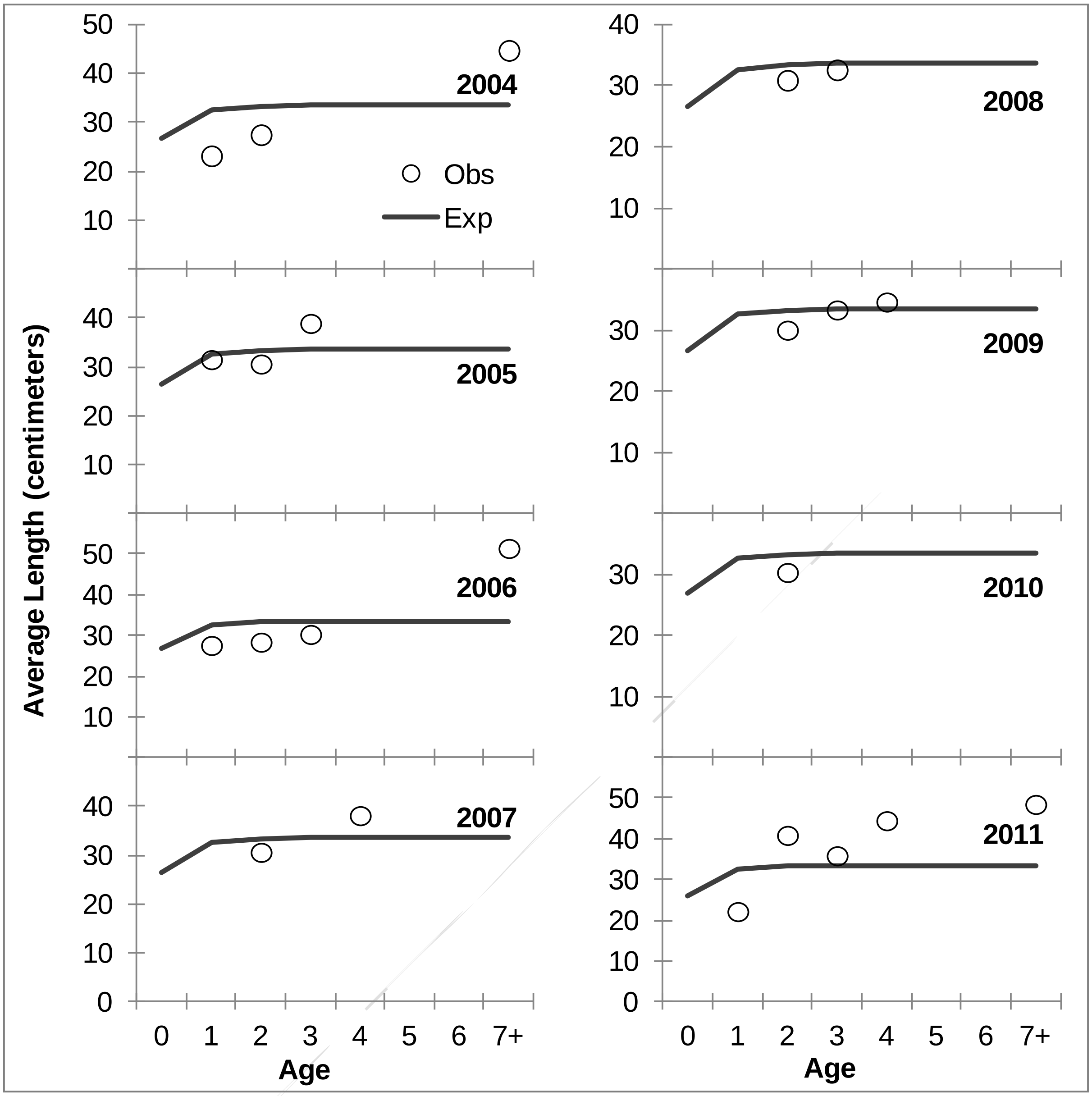

Figure 3.39. Observed and predicted annual male length at age for Program 146 from the base run of the Stock Synthesis model.

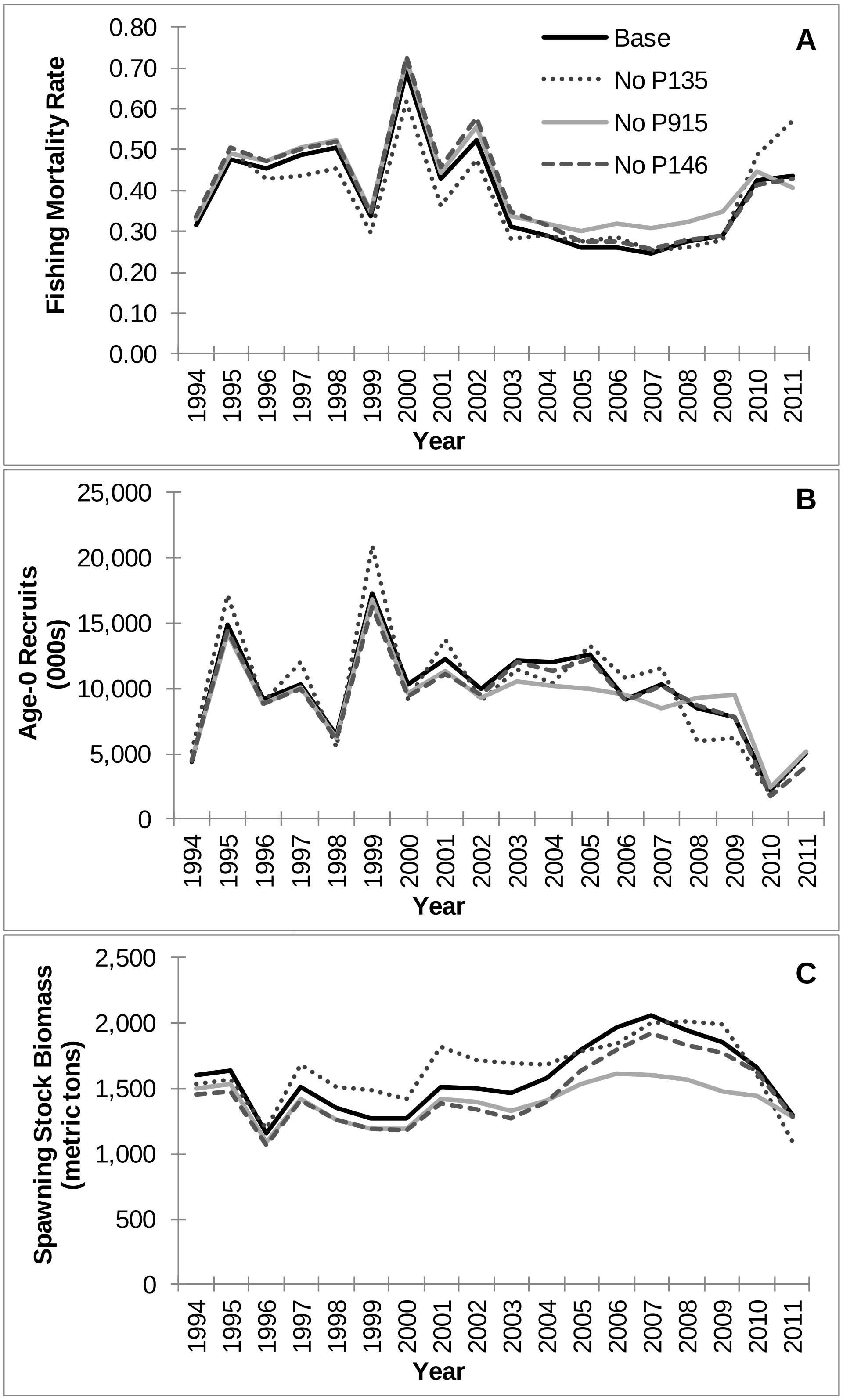

Figure 3.40. Sensitivity of model-predicted (A) *F*, (B) recruitment, and (C) SSB to removal of various fisheries-independent data sources.

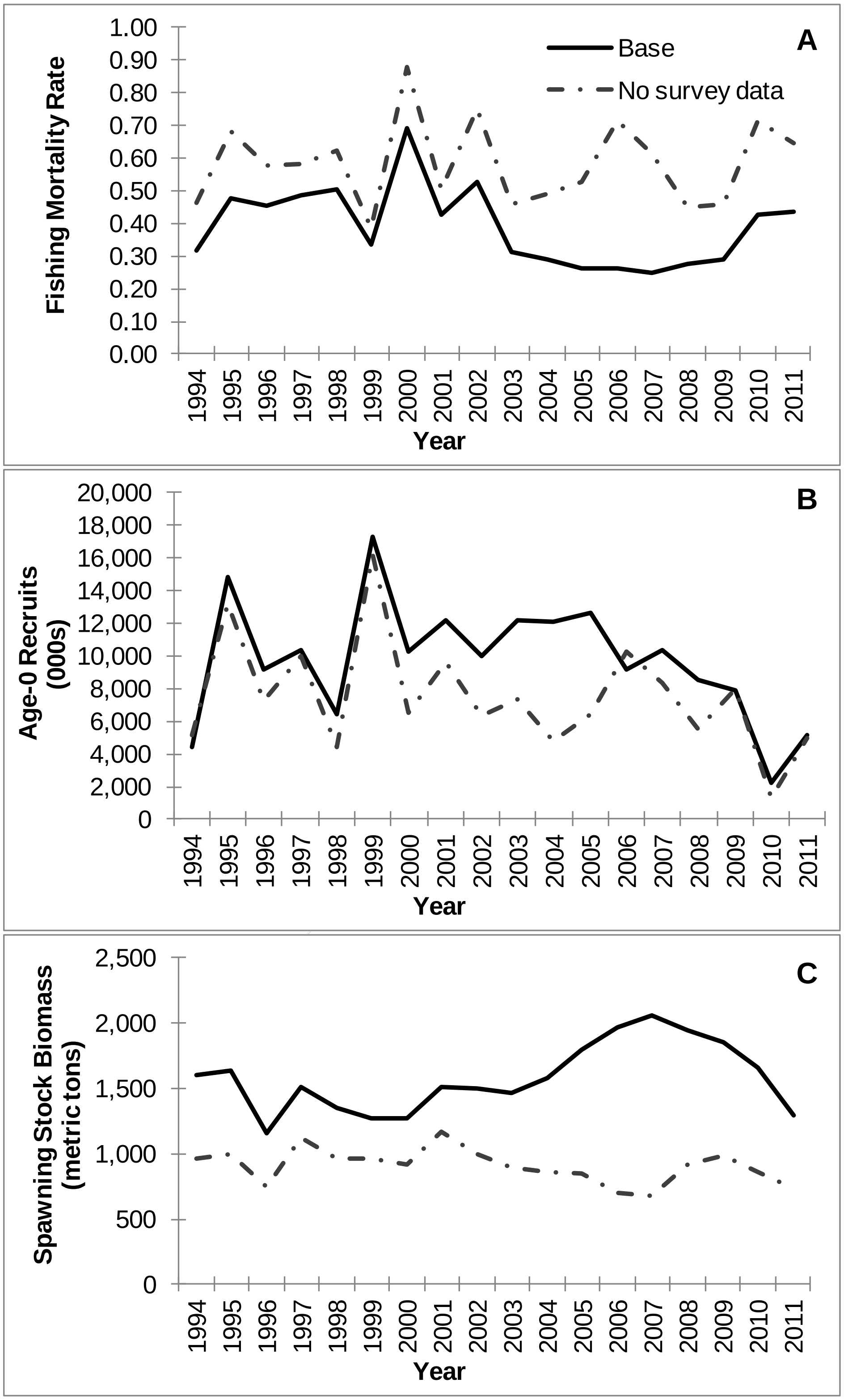

Figure 3.41. Sensitivity of model-predicted (A) *F*, (B) recruitment, and (C) SSB to removal of all survey data (indices and associated biological data).

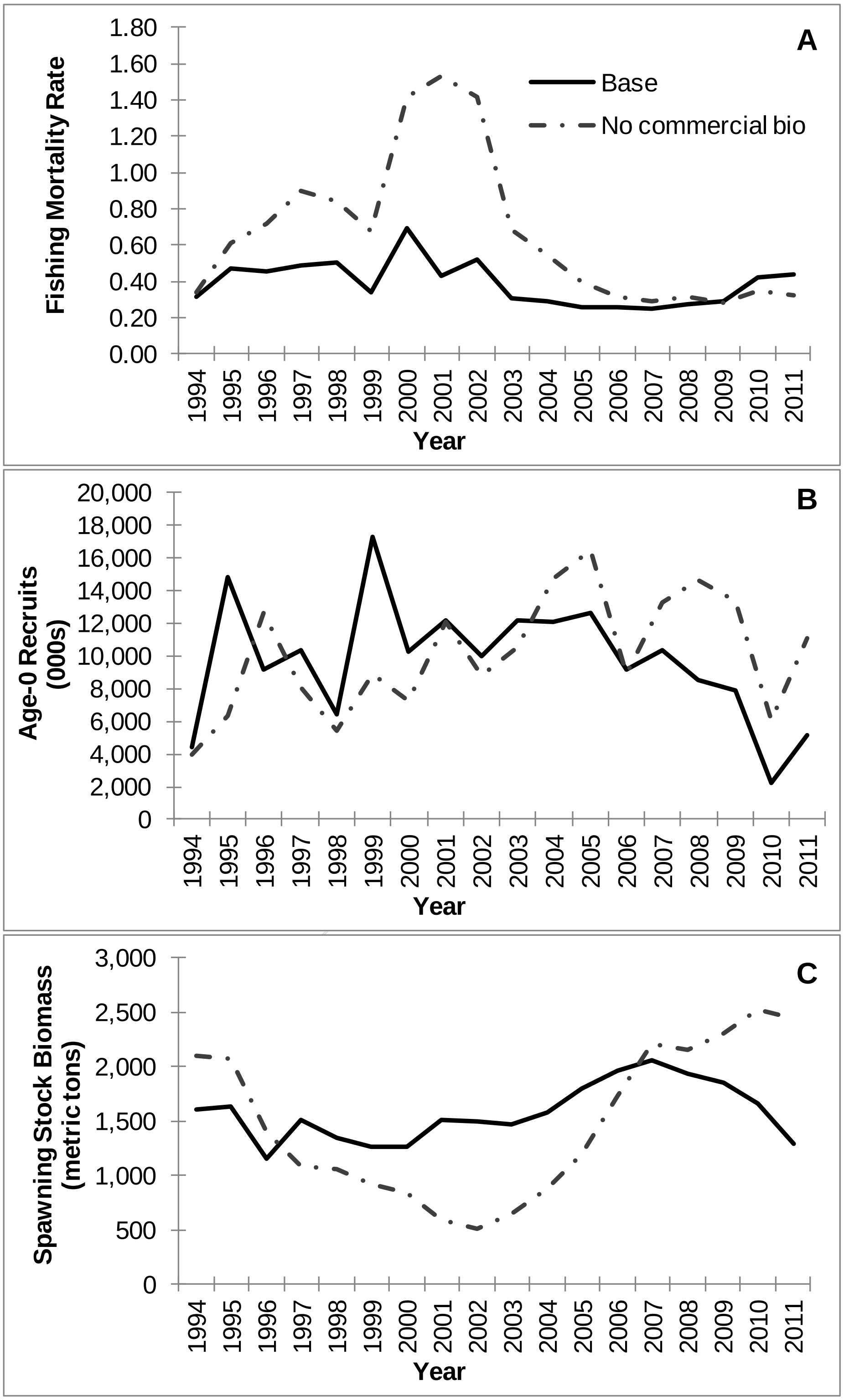

Figure 3.42. Sensitivity of model-predicted (A) *F*, (B) recruitment, and (C) SSB to removal of biological data collected from the commercial fishery. Note that commercial landings were included in the sensitivity run.

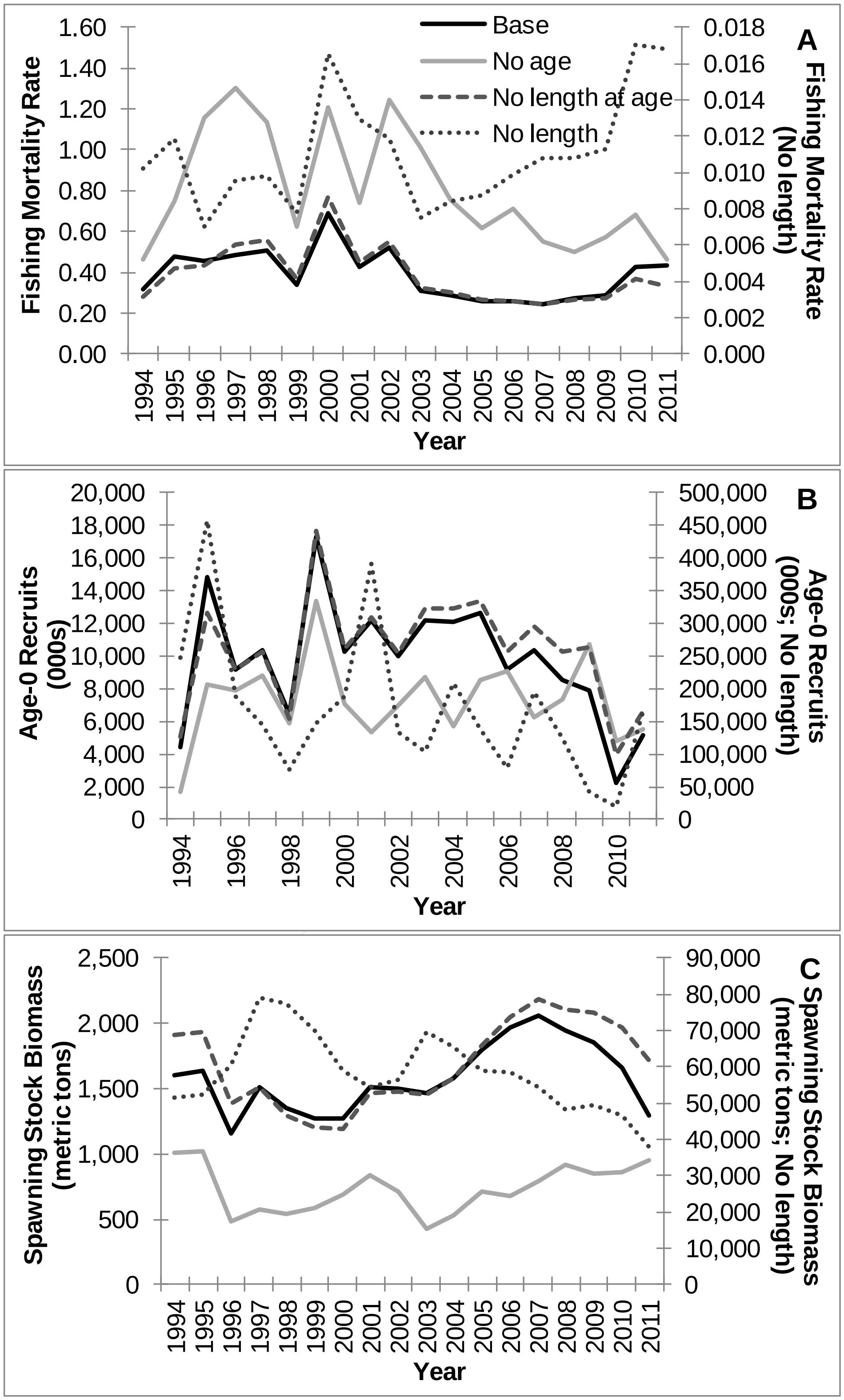

Figure 3.43. Sensitivity of model-predicted (A) *F*, (B) recruitment, and (C) SSB to removal of various types of biological data.

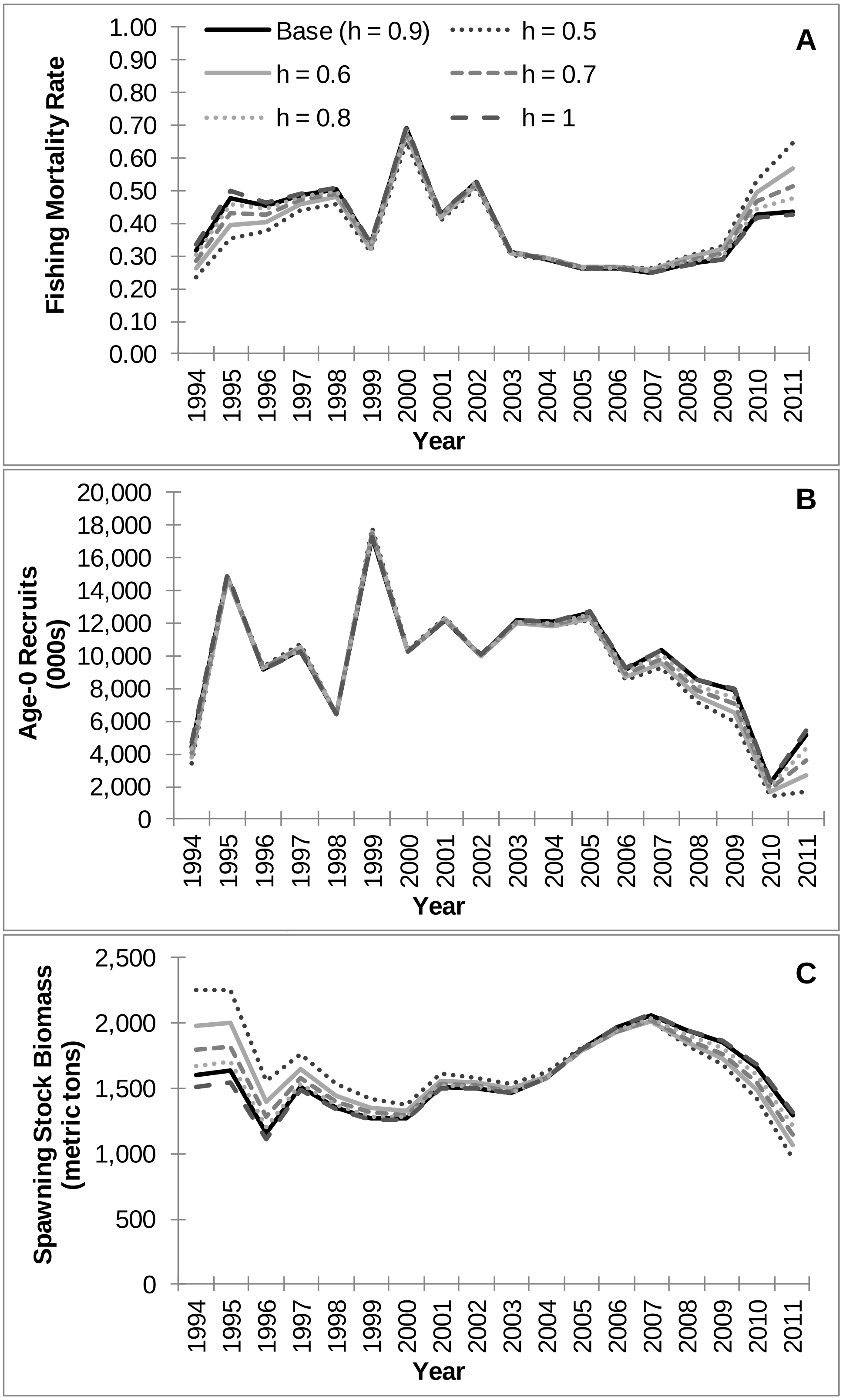

Figure 3.44. Sensitivity of model-predicted (A) *F*, (B) recruitment, and (C) SSB to a range of steepness values.

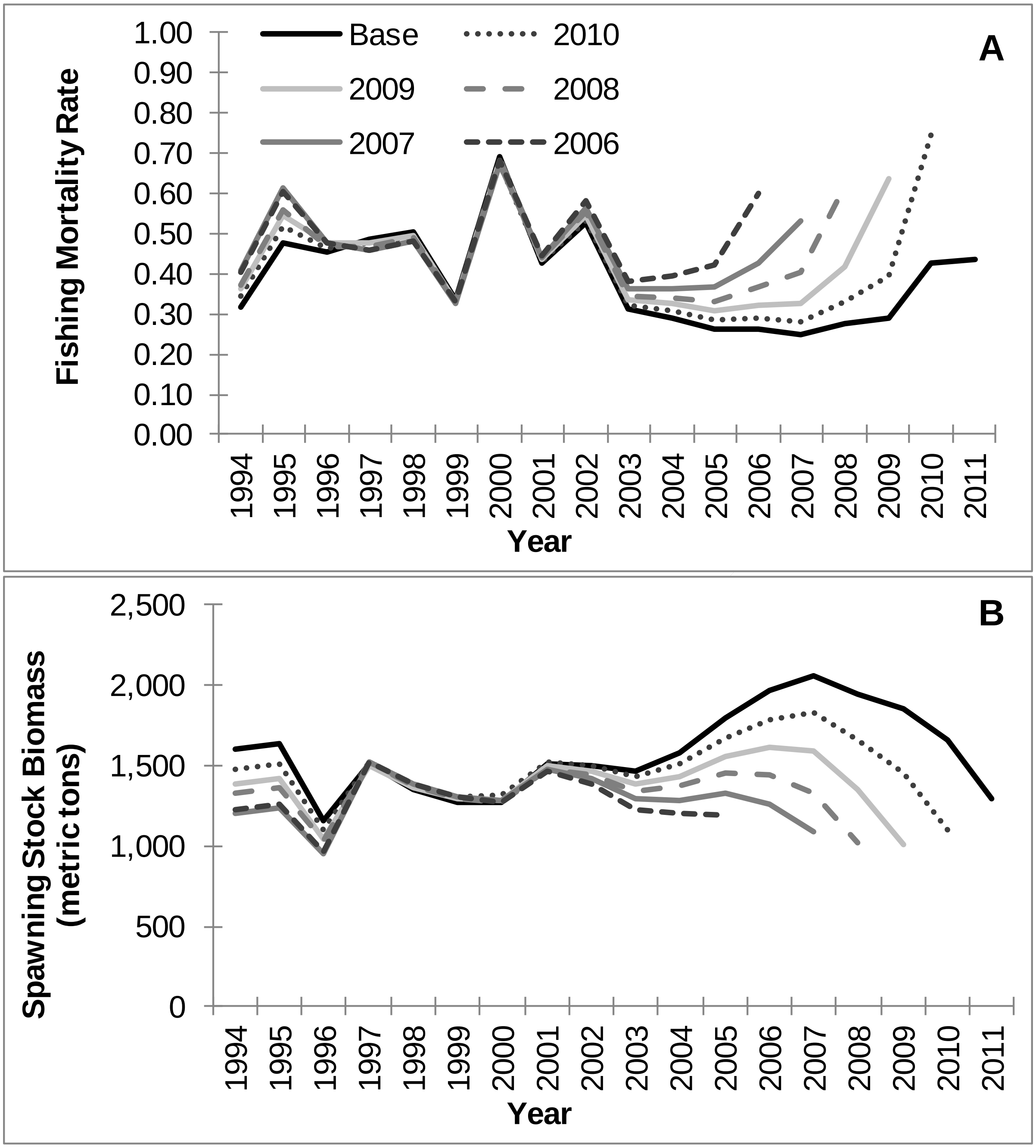

Figure 3.45. Model-predicted (A) *F* and (B) SSB from retrospective analyses.

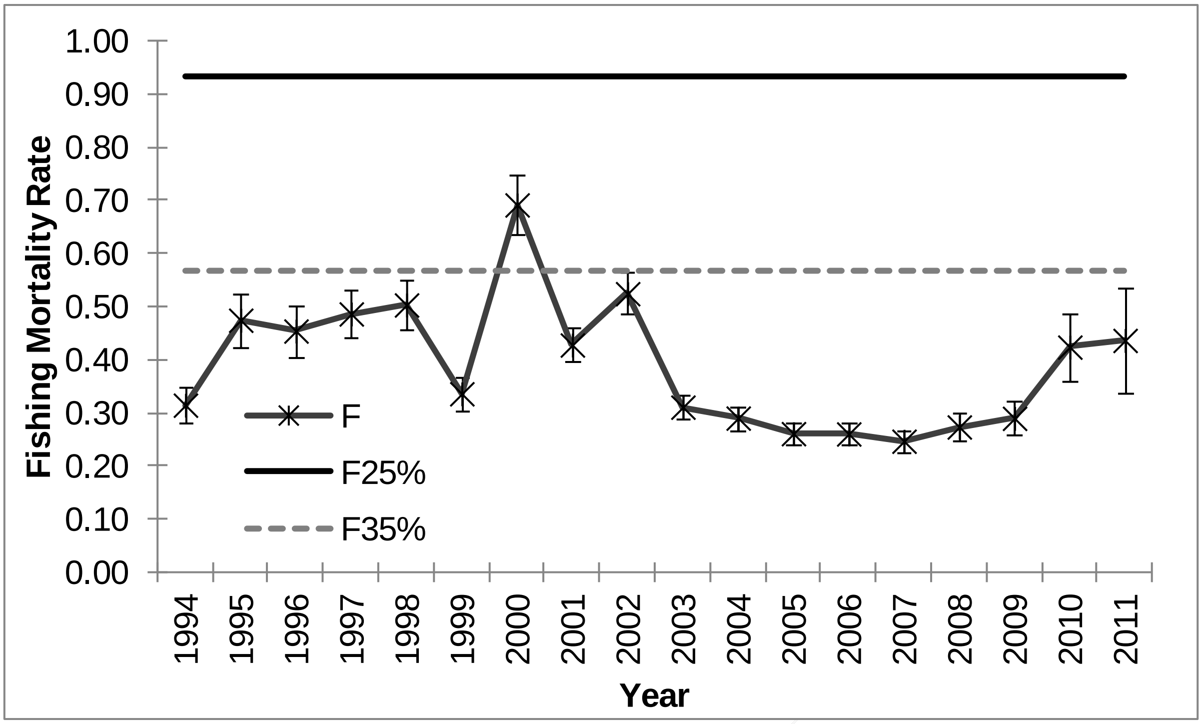

Figure 3.46. Annual predicted fishing mortality rates (numbers-weighted, ages 2–5) compared to estimated *F*-threshold ($F_{25\%}$) and *F*-target ($F_{35\%}$). Error bars represent ± 1 standard deviation of fishing mortality rate.

10.0 APPENDIX 1 INPUT DATA FILE FOR THE BASE RUN OF THE STOCK SYNTHESIS MODEL

```
#V3.24f
#C  NCDMF Striped Mullet Stock Assessment
#C  Incorporates Rick's suggestions
#C  Incorporates peer review recommendations
#C  Uses conditional age'-at-length
1994 #_styr
2011 #_endyr
1 #_nseas
12#_months/season
1 #_spawn_seas
1 #_Nfleet
3 #_Nsurveys
1 #_N_areas
Comm%P135%P915%P146 #Comm includes rec harv
-0.83 0.99 0.92 0.25 #_surveytiming_in_season
1 1 1 1 #_area_assignments_for_each_fishery_and_survey
1     #_units of catch:  1=bio; 2=num
0.05 #_se of log(catch) only used for init_eq_catch and for Fmethod 2 and 3
2 #_Ngenders
14 #_Nages
908 #_init_equil_catch_for_each_fishery
18 #_N_lines_of_catch_to_read
#_catch_biomass(mtons):_columns_are_fisheries,year,season
783.01  1994    1
1042.56         1995    1
796.90  1996    1
1107.97         1997    1
1006.12         1998    1
662.63  1999    1
1283.25         2000    1
1051.27         2001    1
1177.66         2002    1
739.04  2003    1
725.12  2004    1
735.00  2005    1
```

784.08	2006	1
756.96	2007	1
760.16	2008	1
764.58	2009	1
944.67	2010	1
737.62	2011	1

#
34 #_N_cpue_and_surveyabundance_observations
#_Units: 0=numbers; 1=biomass; 2=F
#_Errtype: -1=normal; 0=lognormal; >0=T
#_Fleet Units Errtype
1 1 0 # Comm
2 0 0 # P135
3 0 0 # P915
4 0 0 # P146
#_year seas index obs err

1994	1	2	1.91	0.428	#P135_1994
1995	1	2	5.70	0.421	#P135_1995
1996	1	2	3.39	0.441	#P135_1996
1997	1	2	1.41	0.398	#P135_1997
1998	1	2	8.58	0.471	#P135_1998
1999	1	2	0.401	0.542	#P135_1999
2000	1	2	2.71	0.388	#P135_2000
2001	1	2	3.63	0.325	#P135_2001
2002	1	2	2.12	0.374	#P135_2002
2003	1	2	4.40	0.390	#P135_2003
2004	1	2	10.5	0.360	#P135_2004
2005	1	2	5.29	0.366	#P135_2005
2006	1	2	1.12	0.430	#P135_2006
2007	1	2	2.59	0.418	#P135_2007
2008	1	2	1.05	0.452	#P135_2008
2009	1	2	9.77	0.386	#P135_2009
2010	1	2	17.4	0.378	#P135_2010
2011	1	2	1.24	0.416	#P135_2011
2004	1	3	8.23	0.206	#P915_2004
2005	1	3	5.41	0.208	#P915_2005
2006	1	3	5.30	0.207	#P915_2006
2007	1	3	19.6	0.209	#P915_2007
2008	1	3	9.20	0.220	#P915_2008

2009	1	3	10.5	0.201	#P915_2009
2010	1	3	12.4	0.191	#P915_2010
2011	1	3	14.3	0.193	#P915_2011
2004	1	4	31.8	0.286	#P146_2004
2005	1	4	21.4	0.289	#P146_2005
2006	1	4	33.0	0.265	#P146_2006
2007	1	4	15.1	0.319	#P146_2007
2008	1	4	35.7	0.264	#P146_2008
2009	1	4	17.5	0.262	#P146_2009
2010	1	4	14.9	0.292	#P146_2010
2011	1	4	37.9	0.265	#P146_2011

#
0 #_N_fleets_with_discard
#_discard_units (1=same_as_catchunits(bio/num); 2=fraction; 3=numbers)
#_discard_errtype: >0 for DF of T-dist(read CV below); 0 for normal with CV; -1 for normal with se; -2 for lognormal
#Fleet Disc_units err_type
0 #N discard obs
#_year seas index obs err
#
41 #_N_meanbodywt_obs
30 #_DF_for_meanbodywt_T-distribution_like
#_Yr Seas Flt/Svy Part Value CV

1998	1	1	2	0.689	0.664
1999	1	1	2	0.743	0.564
2000	1	1	2	0.769	0.671
2001	1	1	2	0.790	0.450
2002	1	1	2	1.04	0.545
2003	1	1	2	0.930	0.545
2004	1	1	2	0.957	0.672
2005	1	1	2	1.45	0.524
2006	1	1	2	1.13	0.46
2007	1	1	2	0.689	1.717
2010	1	1	2	0.640	0.420
2011	1	1	2	0.694	0.693
1998	1	2	2	0.526	0.378
1999	1	2	2	0.599	0.294
2000	1	2	2	1.08	0.217
2001	1	2	2	0.486	0.0876
2002	1	2	2	0.506	0.209

2003	1	2	2	0.438	0.572
2004	1	2	2	0.413	0.560
2005	1	2	2	0.478	0.414
2006	1	2	2	0.470	0.463
2007	1	2	2	0.605	0.571
2008	1	2	2	0.616	0.659
2009	1	2	2	0.501	0.512
2010	1	2	2	0.441	0.665
2011	1	2	2	0.402	0.504
2004	1	3	2	0.886	0.554
2005	1	3	2	0.788	0.560
2006	1	3	2	0.532	0.389
2007	1	3	2	0.705	0.438
2008	1	3	2	0.747	0.457
2009	1	3	2	0.861	0.648
2010	1	3	2	0.846	0.518
2011	1	3	2	0.847	0.554
2004	1	4	2	0.554	0.566
2005	1	4	2	0.527	1.19
2006	1	4	2	0.644	0.636
2007	1	4	2	0.723	0.607
2008	1	4	2	0.589	0.717
2009	1	4	2	0.791	0.671
2010	1	4	2	0.480	0.668

1 # length bin method: 1=use databins; 2=generate from binwidth,min,max below; 3=read vector
-.010 #_comp_tail_compression #Rick set negative to turn off this feature to see fit to tails of distribution bette
1e-007 #_add_to_comp
0 #_combine males into females at or below this bin number
34 #_N_LengthBins
#Rick: revise lower bins to avoid having Lorenzen create such a high M for age 0
10 10.2 10.4 10.6 10.8 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68
45 #_N_Length_obs
#Rick: verify that sizecomp gender should be 0 (combined sex)
#Yr Seas Flt/Svy Gender Part Nsamp datavector(female-male)

#1995	1	1	3	2	3	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
1997	1	1	3	2	200	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	2	13	58	90	81	33	18	11	4	2	1	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10	48	52	55	52	22	21	7	2	2	1	1	0	0	0	0	0
	0	0	0	0	0												
1998	1	1	3	2	200	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	7	23	86	126	90	32	12	5	1	0	0	0	0	1	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	9	41	85	81	27	5	3	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
1999	1	1	3	2	200	0	0	0	0	0	0	0	0	0	0	0	0
	0	3	5	12	45	138	123	88	50	23	8	1	0	0	1	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	13	24	26	46	53	60	28	6	1	3	0	1	1	0	0	0	0
	0	0	0	0	0												
2000	1	1	3	2	200	0	0	0	0	0	0	0	0	0	0	0	0
	0	1	28	405	956	670	414	262	111	46	15	9	5	1	0	1	1
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
	2	38	360	690	262	100	40	8	2	0	1	0	0	0	0	0	0
	0	0	0	0	0												
2001	1	1	3	2	200	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	5	73	428	966	878	341	95	17	6	3	2	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	10	65	270	404	164	40	12	1	1	0	0	0	0	0	0	0
	0	0	0	0	0												
2002	1	1	3	2	200	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	23	316	1060	1308	739	408	225	79	29	8	3	2	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	6	40	253	782	621	237	68	27	6	1	2	0	0	0	0	0	0
	0	0	0	0	0												
2003	1	1	3	2	200	0	0	0	0	0	0	0	0	0	0	0	0
	1	2	4	99	466	690	460	252	140	70	29	5	10	1	1	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
	25	76	79	199	254	107	56	25	4	4	1	0	0	0	0	0	0
	0	0	0	0	0												
2004	1	1	3	2	200	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	26	289	641	833	640	439	196	91	35	12	5	0	1	0	0

	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	3	21	114	297	234	148	44	12	6	3	0	0	0	0	0	0	0
	0	0	0	0	0												
2005	1	1	3	2	200	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	7	132	398	776	676	429	168	91	49	39	17	6	1	1	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	8
	44	73	217	525	579	304	105	42	8	1	2	0	0	0	0	0	0
	0	0	0	0	0												
2006	1	1	3	2	200	0	0	0	0	0	0	0	0	0	0	0	0
	0	2	28	260	811	851	671	577	340	165	70	24	8	5	0	2	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	1
	11	149	412	806	645	336	146	65	22	14	2	2	0	0	0	0	0
	0	0	0	0	0												
2007	1	1	3	2	200	0	0	0	0	0	0	0	0	0	0	0	0
	0	3	49	290	753	948	710	346	205	70	23	10	4	3	1	2	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	8	86	370	834	756	407	192	92	43	9	5	2	1	0	0	0	0
	0	0	0	0	0												
2008	1	1	3	2	200	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	5	32	226	915	1053	595	261	108	63	25	9	4	2	1	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	3	49	400	1104	776	276	120	44	4	4	3	1	0	0	0	0
	0	0	0	0	0												
2009	1	1	3	2	200	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	19	124	458	675	524	253	82	19	2	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6	8	16	128	428	444	175	46	5	0	0	0	0	0	0	0	0
	0	0	0	0	0												
2010	1	1	3	2	200	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	7	157	600	923	801	486	267	104	42	13	10	4	2	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	3	85	413	475	282	135	44	23	5	0	1	0	0	0	0	0
	0	0	0	0	0												
2011	1	1	3	2	200	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	5	44	272	556	596	461	250	118	45	18	8	0	1	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	2	3	47	262	472	228	109	49	23	7	2	4	0	0	0	0	0
	0	0	0	0	0												

1998	1	2	3	2	73	0	0	0	0	0	0	0	0	0	0	0	5
	0	24	32	71	36	14	8	2	2	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	2	10
	30	72	95	14	9	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
1999	1	2	3	2	47	0	0	0	0	0	0	0	0	0	0	0	0
	1	8	31	8	7	3	0	5	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	6
	14	25	15	16	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
2000	1	2	3	2	121	0	0	0	0	0	0	0	0	0	0	1	6
	20	33	29	36	17	7	13	4	5	5	1	0	0	1	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	13
	28	34	20	18	6	2	2	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
2001	1	2	3	2	88	0	0	0	0	0	0	0	0	0	0	0	0
	2	11	0	50	17	12	10	1	1	0	0	0	0	1	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	17
	38	75	73	33	9	1	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
2002	1	2	3	2	121	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	3	8	19	23	7	2	2	2	4	1	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	31
	49	55	73	44	19	6	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
2003	1	2	3	2	97	0	0	0	0	0	0	0	0	0	0	8	15
	57	57	54	21	29	10	5	2	0	0	5	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46
	9	28	18	21	7	3	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
2004	1	2	3	2	103	0	0	0	0	0	0	0	0	0	0	4	8
	47	83	30	39	54	8	12	3	3	1	0	0	2	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	9	66
	12	0	30	16	16	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
2005	1	2	3	2	118	0	0	0	0	0	0	0	0	0	1	8	0
	0	0	70	40	111	24	22	14	3	2	0	0	1	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	66

	62	114	28	81	0	24	22	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
2006	1	2	3	2	48	0	0	0	0	0	0	0	0	0	0	0	3
	2	5	7	15	16	10	6	1	1	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	9
	4	1	9	8	0	2	1	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
2007	1	2	3	2	66	0	0	0	0	0	0	0	0	0	0	1	2
	1	8	24	6	22	13	7	3	7	3	4	2	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
	3	14	24	8	3	3	1	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
2008	1	2	3	2	45	0	0	0	0	0	0	0	0	0	0	2	2
	3	6	12	3	0	3	10	6	2	2	1	0	0	1	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	5
	1	2	0	9	8	5	0	2	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
2009	1	2	3	2	48	0	0	0	0	0	0	0	0	0	1	9	62
	29	33	50	39	25	23	18	4	2	1	1	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21
	43	33	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
2010	1	2	3	2	97	0	0	0	0	0	0	0	0	0	0	5	29
	24	33	22	7	18	10	11	1	2	3	1	1	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	19
	19	62	22	7	4	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
2011	1	2	3	2	35	0	0	0	0	0	0	0	0	0	0	0	1
	1	2	6	5	3	1	1	2	1	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	1	2	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
2004	1	3	3	2	47	0	0	0	0	0	0	0	0	0	0	0	1
	10	49	29	47	56	43	23	8	6	1	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3
	13	25	29	0	0	0	5	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
2005	1	3	3	2	43	0	0	0	0	0	0	0	0	0	0	0	0
	0	19	17	11	28	26	15	7	3	0	0	0	0	0	0	0	0

	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	1	19	44	23	0	6	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
2006	1	3	3	2	39	0	0	0	0	0	0	0	0	0	0	0	0
	1	26	29	24	33	20	16	8	3	3	3	0	1	1	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	17	29	24	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
2007	1	3	3	2	57	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	31	22	38	63	37	15	9	3	2	1	1	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
	2	26	47	87	56	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
2008	1	3	3	2	48	0	0	0	0	0	0	0	0	0	0	0	0
	1	11	12	24	30	36	23	12	10	3	2	1	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	13	12	10	14	5	3	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
2009	1	3	3	2	46	0	0	0	0	0	0	0	0	0	0	0	0
	0	6	27	31	33	31	22	20	12	8	3	2	0	1	1	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	21	35	23	7	5	4	3	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
2010	1	3	3	2	51	0	0	0	0	0	0	0	0	0	0	0	0
	0	30	24	34	49	53	29	11	14	8	2	3	2	0	1	1	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	10	30	36	45	6	12	4	2	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
2011	1	3	3	2	42	0	0	0	0	0	0	0	0	0	0	0	0
	6	26	31	57	44	43	20	10	8	5	2	0	1	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6	57	80	57	30	12	2	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
2004	1	4	3	2	37	0	0	0	0	0	0	0	0	0	0	0	0
	74	365	394	342	256	114	44	23	12	6	1	1	1	0	1	0	0
	0	0	0	0	0	0	0	0	0	0	0	1	0	8	11	20	67
	184	146	29	0	0	0	0	0	1	0	1	0	0	0	0	0	0
	0	0	0	0	0												

2005	1	4	3	2	35	0	0	0	0	0	1	5	22	55	55	106	507
	895	709	290	354	301	135	43	29	7	5	2	1	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	2	10	27	49	33	46	152
	189	105	145	0	0	0	9	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
2006	1	4	3	2	37	0	0	0	0	0	0	0	0	0	10	64	237
	0	734	460	473	501	255	110	50	16	12	2	1	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	1	0	3	38	152	349
	973	294	173	53	0	0	0	0	0	0	0	0	1	0	0	0	0
	0	0	0	0	0												
2007	1	4	3	2	35	0	0	0	0	0	0	0	0	0	1	4	51
	304	484	644	310	238	137	35	22	14	11	6	1	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	14
	60	88	0	155	0	0	7	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
2008	1	4	3	2	41	0	0	0	0	0	0	1	11	33	71	107	180
	524	577	590	407	481	323	124	54	20	15	2	0	1	0	1	0	0
	0	0	0	0	0	0	0	0	0	0	1	7	49	85	106	96	94
	162	96	0	116	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
2009	1	4	3	2	31	0	0	0	0	0	0	0	2	6	15	32	42
	127	0	193	165	230	272	124	31	17	6	5	2	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	3	8	54	85	109	124	85
	136	242	64	83	46	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
2010	1	4	3	2	34	0	0	0	0	0	0	0	0	1	3	14	61
	120	239	166	0	135	87	44	29	11	8	1	2	0	1	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	2	2	19	28	79	179
	184	160	166	192	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0												
2011	1	4	3	2	33	0	0	0	0	0	0	0	3	32	124	112	210
	362	311	143	231	294	257	116	42	19	17	4	5	1	1	0	0	0
	0	0	0	0	0	0	0	0	0	0	1	1	2	26	83	62	99
	142	102	143	54	73	37	0	7	2	0	4	5	0	0	0	0	0
	0	0	0	0	0												

#
8 #_N_age_bins
 1 2 3 4 5 6 7 8

1 #_N_ageerror_definitions
0.5 1.5 2.5 3.5 4.5 5.5 6.5 7.5 8.5 9.5 10.5 11.5 12.5 13.5 14.5
0.001 0.001 0.001 0.001 0.001 0.001 0.001 0.001 0.001 0.001 0.001 0.001 0.001 0.001 0.001
42 #_N_Agecomp_obs
1 #_Lbin_method: 1=poplenbins; 2=datalenbins; 3=lengths
1 #_combine males into females at or below this bin number
#Yr Seas Flt/Svy Gender Part Ageerr Lbin_lo Lbin_hi Nsamp datavector(female-male)

1998	1	1	3	2	1	10	32	27	18	6	85	58	9	3	3	1	14
	10	55	4	0	0	0	0										
1999	1	1	3	2	1	9	28	17	0	28	43	46	12	4	2	1	14
	39	34	2	1	0	0	0										
2000	1	1	3	2	1	13	29	11	0	1	64	15	17	4	3	2	0
	6	36	0	1	0	0	0										
2001	1	1	3	2	1	13	24	2	0	12	16	17	1	1	0	0	0
	25	10	7	0	0	0	0										
2002	1	1	3	2	1	15	27	4	0	4	36	9	10	3	1	0	0
	0	22	0	0	0	0	0										
2003	1	1	3	2	1	13	27	8	0	17	33	42	9	6	0	0	0
	8	14	3	1	0	0	0										
2004	1	1	3	2	1	12	30	13	0	12	38	22	14	4	1	3	0
	12	24	0	0	0	0	0										
2005	1	1	3	2	1	13	32	6	0	9	9	17	6	1	0	2	0
	3	7	0	0	0	0	0										
2006	1	1	3	2	1	15	28	14	0	11	24	8	9	3	1	0	0
	8	3	0	0	0	0	0										
2007	1	1	3	2	1	14	34	3	0	4	1	1	1	1	0	0	0
	0	1	0	0	0	0	0										
2010	1	1	3	2	1	14	22	3	0	1	9	3	0	0	0	0	0
	0	5	2	0	0	0	0										
2011	1	1	3	2	1	16	27	2	0	0	1	12	0	2	0	0	0
	0	1	3	0	0	0	0										
1998	1	2	3	2	1	12	20	4	0	3	19	7	0	0	0	0	1
	7	11	0	0	0	0	0										
1999	1	2	3	2	1	15	20	6	0	0	7	2	0	0	0	0	0
	2	1	0	0	0	0	0										
2000	1	2	3	2	1	19	22	2	0	0	1	1	0	0	0	0	0
	0	0	0	0	0	0	0										
2001	1	2	3	2	1	15	17	1	0	0	0	8	0	0	0	0	0
	0	0	6	0	0	0	0										

2002	1	2	3	2	1	17	21	1	0	5	3	0	0	0	0	0	0
	1	1	0	0	0	0	0										
2003	1	2	3	2	1	7	26	9	1	12	6	8	0	0	0	1	0
	4	6	0	0	0	0	0										
2004	1	2	3	2	1	11	22	21	0	0	30	4	1	0	0	0	0
	2	16	1	0	0	0	0										
2005	1	2	3	2	1	10	21	13	0	6	12	6	0	0	0	0	1
	9	10	2	0	0	0	0										
2006	1	2	3	2	1	10	20	13	1	28	3	1	1	0	0	0	6
	15	2	0	0	0	0	0										
2007	1	2	3	2	1	11	24	25	0	7	34	10	2	6	0	0	0
	12	17	1	0	0	0	0										
2008	1	2	3	2	1	11	26	11	3	12	10	0	0	1	1	0	5
	3	5	0	0	0	0	0										
2009	1	2	3	2	1	10	23	11	0	15	10	4	2	0	0	0	1
	3	2	1	0	0	0	0										
2010	1	2	3	2	1	11	24	16	0	17	8	4	2	1	0	0	0
	19	6	0	0	0	0	0										
2011	1	2	3	2	1	11	22	25	0	5	22	6	0	0	0	0	0
	6	17	4	0	0	0	0										
2004	1	3	3	2	1	14	25	10	0	12	17	7	2	0	0	0	0
	3	2	0	0	0	0	0										
2005	1	3	3	2	1	14	27	12	0	13	7	5	3	0	0	0	0
	7	1	1	0	0	0	0										
2006	1	3	3	2	1	14	19	5	0	6	2	2	0	0	0	0	0
	5	0	0	0	0	0	0										
2007	1	3	3	2	1	14	22	9	0	11	11	2	0	1	0	0	1
	13	1	0	0	0	0	0										
2008	1	3	3	2	1	13	26	20	1	13	36	27	2	0	0	1	0
	15	8	1	2	0	0	0										
2009	1	3	3	2	1	13	33	19	0	25	16	15	14	2	2	0	2
	21	4	3	0	0	0	0										
2010	1	3	3	2	1	13	28	33	0	19	84	19	14	12	1	0	0
	11	39	1	2	0	0	0										
2011	1	3	3	2	1	13	29	24	1	27	34	49	2	2	2	1	0
	25	22	2	0	0	0	0										
2004	1	4	3	2	1	10	27	10	0	0	50	52	43	6	8	2	0
	5	16	0	0	0	0	2										

```
2005 1 4 3 2 1 13 24 4 0 8 25 23 4 4 0 0 0
     1 1 1 0 0 0 0
2006 1 4 3 2 1 13 25 6 0 1 34 33 34 6 0 0 0
     2 12 1 0 0 0 2
2007 1 4 3 2 1 13 29 5 0 0 27 27 22 10 4 2 0
     0 3 0 1 0 0 0
2008 1 4 3 2 1 13 26 4 0 0 18 26 8 8 2 0 0
     0 2 1 0 0 0 0
2009 1 4 3 2 1 13 24 4 0 0 7 20 24 5 1 4 0
     0 2 1 1 0 0 0
2010 1 4 3 2 1 13 24 1 0 0 10 8 3 0 1 0 0
     0 5 0 0 0 0 0
2011 1 4 3 2 1 -1 -1 3 0 0 2 25 11 3 5 1 0
     1 1 4 2 0 0 1
#
42 #_N_MeanSize-at-Age_obs
#Yr Seas Flt/Svy Gender Part Ageerr Ignore datavector(female-male)
#                                  samplesize(female-male)
1998 1 1 3 2 1 27 24.3 28.3 36.1 39.8 45.1 45.8 49.3 49.0 24.8 29.1 32.5
     36.9 -999 -999 -999 -999 18 6 85 58 9 3 3 1 14 10 55 4
     0 0 0 0
1999 1 1 3 2 1 17 -999 33.4 37.2 40.6 45.4 50.2 52.6 57.8 22.8 31.8 34.7
     33.1 41.3 -999 -999 -999 0 28 43 46 12 4 2 1 11 39 34 2
     1 0 0 0
2000 1 1 3 2 1 11 -999 37.5 34.1 42.1 44.9 47.2 46.4 57.2 -999 32.4 31.4
     -999 37.8 -999 -999 -999 0 1 64 15 17 4 3 2 0 6 36 0
     1 0 0 0
2001 1 1 3 2 1 2 -999 36.4 40.6 40.9 43.7 48.5 -999 -999 -999 31.8 34.7
     35.6 -999 -999 -999 -999 0 12 16 17 1 1 0 0 0 25 10 7
     0 0 0 0
2002 1 1 3 2 1 4 -999 35.5 38.3 46.8 49.2 50.1 49.5 -999 -999 -999 34.0
     -999 -999 -999 -999 -999 0 4 36 9 10 3 1 0 0 0 22 0
     0 0 0 0
2003 1 1 3 2 1 8 -999 32.1 38.3 42.9 46.8 47.3 -999 -999 -999 30.0 33.0
     33.6 41.3 -999 -999 -999 0 19 33 42 9 6 0 0 0 10 14 3
     1 0 0 0
2004 1 1 3 2 1 13 -999 30.6 38.5 46.4 50.3 51.2 46.5 55.2 -999 32.5 35.3
     -999 -999 -999 -999 -999 0 12 38 22 14 4 1 3 0 12 24 0
     0 0 0 0
```

2005	1 -999 0	1 -999 0	3 -999 0	2 -999 0	1 -999	6 0	-999 9	39.6 9	46.6 17	46.7 6	50.1 1	51.6 0	-999 2	58.6 0	-999 3	31.1 7	34.2 0
2006	1 -999 0	1 -999 0	3 -999 0	2 -999 0	1 -999	14 0	-999 11	36.8 24	40.2 8	44.3 9	48.2 3	46.5 1	54.5 0	-999 0	-999 8	35.3 3	35.9 0
2007	1 -999 0	1 -999 0	3 -999 0	2 -999 0	1 -999	3 0	-999 4	30.2 1	40.0 1	38.5 1	38.7 1	69.8 0	-999 0	-999 0	-999 0	-999 1	36.0 0
2010	1 36.9 0	1 -999 0	3 -999 0	2 -999 0	1 -999	3 0	-999 1	28.2 9	35.4 3	39.6 0	-999 0	-999 0	-999 0	-999 0	-999 0	-999 5	31.2 2
2011	1 33.4 0	1 -999 0	3 -999 0	2 -999 0	1 -999	2 0	-999 0	-999 1	36.5 12	34.9 0	-999 2	54.0 0	-999 0	-999 0	-999 0	-999 1	33.2 3
1998	1 -999 0	2 -999 0	3 -999 0	2 -999 0	1 -999	4 0	-999 3	31.5 19	34.3 7	37.0 0	-999 0	-999 0	-999 0	-999 1	25.2 7	29.0 11	29.4 0
1999	1 -999 0	2 -999 0	3 -999 0	2 -999 0	1 -999	6 0	-999 0	-999 7	33.5 2	39.1 0	-999 0	-999 0	-999 0	-999 0	-999 2	31.2 1	32.8 0
2000	1 -999 0	2 -999 0	3 -999 0	2 -999 0	1 -999	2 0	-999 0	-999 1	39.1 1	44.2 0	-999 0	-999 0	-999 0	-999 0	-999 0	-999 0	-999 0
2001	1 32.8 0	2 -999 0	3 -999 0	2 -999 0	1 -999	1 0	-999 0	-999 0	-999 8	33.5 0	-999 0	-999 0	-999 0	-999 0	-999 0	-999 0	-999 6
2002	1 -999 0	2 -999 0	3 -999 0	2 -999 0	1 -999	1 0	-999 5	36.6 3	41.9 0	-999 0	-999 0	-999 0	-999 0	-999 0	-999 1	36.9 1	34.7 0
2003	1 -999 0	2 -999 0	3 -999 0	2 -999 0	1 -999	9 1	24.2 11	27.7 6	34.1 8	37.4 0	-999 0	-999 0	-999 1	52.0 0	-999 4	26.4 6	31.9 0
2004	1 35.6 0	2 -999 0	3 -999 0	2 -999 0	1 -999	21 0	-999 0	-999 30	30.7 4	33.8 1	44.5 0	-999 0	-999 0	-999 0	-999 2	28.0 16	27.4 1
2005	1 33.6 0	2 -999 0	3 -999 0	2 -999 0	1 -999	13 0	-999 6	31.7 12	32.2 6	36.7 0	-999 0	-999 0	-999 0	-999 1	24.1 9	29.4 10	30.6 2

2006	1 -999 0	2 -999 0	3 -999 0	2 -999 0	1 -999	13 1	25.0 28	33.0 3	38.2 1	40.2 1	37.6 0	-999 0	-999 0	-999 5	24.2 15	28.8 2	37.2 0
2007	1 38.7 0	2 -999 0	3 -999 0	2 -999 0	1 -999	25 0	-999 7	30.6 34	33.4 10	39.7 2	44.0 6	46.3 0	-999 0	-999 0	-999 12	28.0 17	31.5 1
2008	1 -999 0	2 -999 0	3 -999 0	2 -999 0	1 -999	11 3	25.0 12	31.2 10	40.8 0	-999 0	-999 1	53.7 1	46.0 0	-999 5	24.2 3	29.7 5	36.4 0
2009	1 33.3 0	2 -999 0	3 -999 0	2 -999 0	1 -999	11 0	-999 15	29.4 10	33.8 4	33.9 2	45.8 0	-999 0	-999 0	-999 1	24.9 3	26.5 2	29.7 1
2010	1 -999 0	2 -999 0	3 -999 0	2 -999 0	1 -999	16 0	-999 17	27.7 8	33.0 4	41.2 2	44.9 1	44.9 0	-999 0	-999 0	-999 19	28.3 6	30.4 0
2011	1 33.0 0	2 -999 0	3 -999 0	2 -999 0	1 -999	25 0	-999 5	33.3 22	29.5 6	39.0 0	-999 0	-999 0	-999 0	-999 0	-999 6	28.4 17	27.8 4
2004	1 -999 0	3 -999 0	3 -999 0	2 -999 0	1 -999	10 0	-999 12	32.6 17	39.6 7	44.0 2	48.7 0	-999 0	-999 0	-999 0	-999 3	30.5 2	35.2 0
2005	1 37.4 0	3 -999 0	3 -999 0	2 -999 0	1 -999	12 0	-999 13	34.4 7	39.4 5	43.5 3	41.7 0	-999 0	-999 0	-999 0	-999 7	30.9 1	33.0 1
2006	1 -999 0	3 -999 0	3 -999 0	2 -999 0	1 -999	5 0	-999 6	30.3 2	36.4 2	37.1 0	-999 0	-999 0	-999 0	-999 0	-999 5	30.6 0	-999 0
2007	1 -999 0	3 -999 0	3 -999 0	2 -999 0	1 -999	9 0	-999 11	34.2 11	40.3 2	40.4 0	-999 1	39.7 0	-999 0	-999 1	29.5 13	32.0 1	31.7 0
2008	1 35.4 2	3 38.2 0	3 -999 0	2 -999 0	1 -999	20 1	29.9 13	32.3 36	36.5 27	39.9 2	42.9 0	-999 0	-999 1	44.5 0	-999 15	30.6 8	34.3 1
2009	1 34.6 0	3 -999 0	3 -999 0	2 -999 0	1 -999	19 0	-999 25	33.6 16	38.2 15	40.9 14	44.4 2	54.6 2	47.5 0	-999 2	27.8 21	32.2 4	30.6 3
2010	1 37.3 2	3 36.4 0	3 -999 0	2 -999 0	1 -999	33 0	-999 19	31.6 84	38.9 19	40.8 14	43.6 12	43.8 1	47.5 0	-999 0	-999 11	30.0 39	33.2 1

2011	1	3	3	2	1	24	28.5	34.5	38.0	41.8	45.3	48.2	47.7	45.5	-999	31.7	33.3
	38.4	-999	-999	-999	-999	1	27	34	49	2	2	2	1	0	25	22	2
	0	0	0	0													
2004	1	4	3	2	1	10	-999	-999	31.1	36.1	39.5	39.9	44.1	43.9	-999	23.1	27.4
	-999	-999	-999	-999	44.6	0	0	50	52	43	6	8	2	0	5	16	0
	0	0	0	2													
2005	1	4	3	2	1	4	-999	38.7	34.3	38.7	37.5	45.3	-999	-999	-999	31.6	30.7
	39.0	-999	-999	-999	-999	0	8	25	23	4	4	0	0	0	1	1	1
	0	0	0	0													
2006	1	4	3	2	1	6	-999	28.8	32.4	38.8	42.2	41.0	-999	-999	-999	27.7	28.5
	30.4	-999	-999	-999	51.5	0	1	34	33	34	6	0	0	0	2	12	1
	0	0	0	2													
2007	1	4	3	2	1	5	-999	-999	31.2	40.3	43.3	44.5	48.2	55.2	-999	-999	30.7
	-999	38.2	-999	-999	-999	0	0	27	27	22	10	4	2	0	0	3	0
	1	0	0	0													
2008	1	4	3	2	1	4	-999	-999	33.1	35.9	41.9	43.2	39.6	-999	-999	-999	30.8
	32.5	-999	-999	-999	-999	0	0	18	26	8	8	2	0	0	0	2	1
	0	0	0	0													
2009	1	4	3	2	1	4	-999	-999	30.8	37.3	42.3	44.2	44.7	46.6	-999	-999	30.1
	33.4	34.7	-999	-999	-999	0	0	7	20	24	5	1	3	0	0	2	1
	1	0	0	0													
2010	1	4	3	2	1	1	-999	-999	32.5	37.1	42.3	-999	49.1	-999	-999	-999	30.4
	-999	-999	-999	-999	-999	0	0	10	8	3	0	1	0	0	0	5	0
	0	0	0	0													
2011	1	4	3	2	1	3	-999	-999	34.5	39.3	42.5	40.6	45.4	41.0	-999	22.3	41.0
	36.0	44.6	-999	-999	48.6	0	0	2	25	11	3	5	1	0	1	1	4
	2	0	0	1													

0 #_N_environ_variables
0 #_N_environ_obs
0 # N sizefreq methods to read

0 # no tag data

0 # no morphcomp data

999

11.0 APPENDIX 2 INPUT CONTROL FILE FOR THE BASE RUN OF THE STOCK SYNTHESIS FILE

```
#V3.24f
#C NCDMF Striped Mullet Stock Assessment
#C Incorporates Rick's suggestions
#C Incorporates peer review recommendations
#C Uses conditional age'-at-length
1  #_N_Growth_Patterns
1  #_N_Morphs_Within_GrowthPattern
#_Cond 1 #_Morph_between/within_stdev_ratio (no read if N_morphs=1)
#_Cond 1 #vector_Morphdist_(-1_in_first_val_gives_normal_approx)
#
#2  #_Cond 0  #  N recruitment designs goes here if N_GP*nseas*area>1
#0  #_Cond 0  #  placeholder for recruitment interaction request
#1 1 1 #_Cond 1 1 1  # example recruitment design element for GP=1, seas=1, area=1
#1 2 1 #_Cond # recruitment design element for GP=1, seas=2, area=1
#
#_Cond 0 # N_movement_definitions goes here if N_areas > 1
#_Cond 1.0 # first age that moves (real age at begin of season, not integer) also cond on do_migration>0
#_Cond 1 1 1 2 4 10 # example move definition for seas=1, morph=1, source=1 dest=2, age1=4, age2=10
#
0 #_Nblock_Patterns
#_Cond 0 #_blocks_per_pattern
# begin and end years of blocks
#
0.5 #_fracfemale  # This needs to be the ratio at birth.  Should be 0.5 unless exceptional circumstances
2 #_natM_type:_0=1Parm; 1=N_breakpoints;_2=Lorenzen;_3=agespecific;_4=agespec_withseasinterpolate
  #_no additional input for selected M option; read 1P per morph
2 #_Cond 2 #_Reference_Age_for_Lorenzen_M if natM_type = 2
1 # GrowthModel: 1=vonBert with L1&L2; 2=Richards with L1&L2; 3=not implemented; 4=not implemented
2 #_Growth_Age_for_L1  #Rick  change to age 2 because so few age 1's observed
999 #_Growth_Age_for_L2 (999 to use as Linf)
0 #_SD_add_to_LAA (set to 0.1 for SS2 V1.x compatibility)
0 #_CV_Growth_Pattern:  0 CV=f(LAA); 1 CV=F(A); 2 SD=F(LAA); 3 SD=F(A)
1 #_maturity_option:  1=length logistic; 2=age logistic; 3=read age-maturity matrix by growth_pattern; 4=read age-fecundity; 5=read fec and wt
from wtatage.ss
#_placeholder for empirical age-maturity by growth pattern
1 #_First_Mature_Age
```

```
1 #_fecundity option:(1)eggs=Wt*(a+b*Wt);(2)eggs=a*L^b;(3)eggs=a*Wt^b
0 #_hermaphroditism option:  0=none; 1=age-specific fxn
1 #_parameter_offset_approach (1=none, 2= M, G, CV_G as offset from female-GP1, 3=like SS2 V1.x)
2 #_env/block/dev_adjust_method (1=standard; 2=logistic transform keeps in base parm bounds; 3=standard w/ no bound check)
#
#_growth_parms
#_LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr dev_stddev Block Block_Fxn
0.01	0.8	0.464	0.464	-1	0.8	-3	0	0	0	0	0.5	0	0	#Natmort_at_ref_age2_fem
10		50	35.5	35.5	-1	0.2	-2	0	0	0	0	0.5	0	0	#Lmin_age2_fem #Rick:
allow to estimate; lots of data in model
25		85	45.2	45.2	-1	0.2	-2	0	0	0	0	0.5	0	0	#Lmax_Linf_fem
0.01	2	0.503	0.503	-1	0.8	-2	0	0	0	0	0.5	0	0	#VBK_fem
0.01	0.5	0.136	0.136	-1	0.8	-3	0	0	0	0	0.5	0	0	#CV_age2_fem
0.01	0.5	0.13	0.13	-1	0.8	-5	0	0	0	0	0.5	0	0	#CV_Linf_fem

0.01	0.8	0.509	0.509	-1	0.8	5	0	0	0	0	0.5	0	0	#Natmort_at_ref_age2_mal
#Rick: allow to estimate at phase 5
10		50	31.9	31.9	-1	0.2	-2	0	0	0	0	0.5	0	0	#Lmin_age2_mal #Rick:
setting to 0 would same as females
25		85	33.6	33.6	-1	0.2	-2	0	0	0	0	0.5	0	0	#Lmax_Linf_mal
0.01	2	1.11	1.11	-1	0.8	-2	0	0	0	0	0.5	0	0	#VBK_mal
0.01	0.5	0.116	0.116	-1	0.8	-3	0	0	0	0	0.5	0	0	#CV_age2_mal
0.01	0.5	0.020	0.020	-1	0.8	-5	0	0	0	0	0.5	0	0	#CV_Linf_mal

-3	3	1.63E-05		1.63E-05		-1	0.2	-3	0	0	0	0	0.5	0	0	#Lenwt_a_fem
2.5	3.5	2.97	2.97	-1	0.2	-3	0	0	0	0	0.5	0	0	#Lenwt_b_fem

25	37	29.0	29.0	-1	0.8	-3	0	0	0	0	0.5	0	0	#Mat_inflect_fem
-3	3	-0.269	-0.269	-1	0.8	-3	0	0	0	0	0.5	0	0	#Mat_slope_fem

-3	3	1	0.001744		-1	0.8	-3	0	0	0	0	0.5	0	0	#Egg/kg_incpt
-3	4	0	0.0654	-1	0.8	-3	0	0	0	0	0.5	0	0	#Egg/kg_slope

-3	3	1.92E-05		1.92E-05		-1	0.2	-3	0	0	0	0	0.5	0	0	#Lenwt_a_mal
2.5	3.5	2.92	2.92	-1	0.2	-3	0	0	0	0	0.5	0	0	#Lenwt_b_mal

-4 4 0 0 -1 0 -4 0 0 0 0 0 0 0 # RecrDist_GP_1
-4 4 0 0 -1 0 -4 0 0 0 0 0 0 0 # RecrDist_Area_1
-4 4 0 0 -1 0 -4 0 0 0 0 0 0 0 # RecrDist_Seas_1
```

```
-4 4 0 0 -1 0 -4 0 0 0 0 0 0 0 # CohortGrowDev
#
#_Cond 0  #custom_MG-env_setup (0/1)
#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no MG-environ parameters
#
#_Cond 0  #custom_MG-block_setup (0/1)
#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no MG-block parameters
#_Cond No MG parm trends
#
#_seasonal_effects_on_biology_parms
 0 0 0 0 0 0 0 0 0 0 #_femwtlen1,femwtlen2,mat1,mat2,fec1,fec2,Malewtlen1,malewtlen2,L1,K
#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no seasonal MG parameters
#
#_Cond -4 #_MGparm_Dev_Phase
#
#_Spawner-Recruitment
3 #_SR_function: 1=B-H_flattop; 2=Ricker; 3=std_B-H; 4=SCAA; 5=Hockey; 6=Shepard_3Parm
#_LO HI INIT PRIOR PR_type SD PHASE
 3 12 6.0 10.3 -1 10 1 # SR_R0  #Rick: reduce starting value to get in more reasonable range of biomass
 0.2 1 0.9 0.9 1 0.05 -4 # SR_steep; Rick recommends fixing steepness at a reasonable value for now because not enough contrast to estimate
 0 2 0.6 0.8 -1 0.8 -4 # SR_sigmaR
 -5 5 0.1 0 -1 1 -3 # SR_envlink
 -5 5 0 0 -1 1 -4 # SR_R1_offset
 0 0 0 0 -1 0 -99 # SR_autocorr
0 #_SR_env_link
0 #_SR_env_target_0=none;1=devs;_2=R0;_3=steepness
1 #do_recdev:  0=none; 1=devvector; 2=simple deviations
1994 # first year of main recr_devs; early devs can preceed this era
2011 # last year of main recr_devs; forecast devs start in following year
2 #_recdev phase
1 # (0/1) to read 13 advanced options
 0 #_recdev_early_start (0=none; neg value makes relative to recdev_start)
 -4 #_recdev_early_phase
 0 #_forecast_recruitment phase (incl. late recr) (0 value resets to maxphase+1)
 1 #_lambda for Fcast_recr_like occurring before endyr+1
 1900 #_last_early_yr_nobias_adj_in_MPD
 1900 #_first_yr_fullbias_adj_in_MPD
 2011 #_last_yr_fullbias_adj_in_MPD
 2012 #_first_recent_yr_nobias_adj_in_MPD
```

```
 1 #_max_bias_adj_in_MPD (-1 to override ramp and set biasadj=1.0 for all estimated recdevs)
 0 #_period of cycles in recruitment (N parms read below)
 -5 #min rec_dev
 5 #max rec_dev
 0 #_read_recdevs
#_end of advanced SR options
#
#_placeholder for full parameter lines for recruitment cycles
# read specified recr devs
#_Yr Input_value
#
# all recruitment deviations

#
#Fishing Mortality info
0.3 # F ballpark for tuning early phases
-2001 # F ballpark year (neg value to disable)
3 # F_Method:  1=Pope; 2=instan. F; 3=hybrid (hybrid is recommended)
4 # max F or harvest rate, depends on F_Method
# no additional F input needed for Fmethod 1
# if Fmethod=2; read overall start F value; overall phase; N detailed inputs to read
# if Fmethod=3; read N iterations for tuning for Fmethod 3
4  # N iterations for tuning F in hybrid method (recommend 3 to 7)
#
#_initial_F_parms
#_LO HI INIT PRIOR PR_type SD PHASE
0       1       0.01    0.01    0       99      1       # InitF_comm
#
#_Q_setup
 # Q_type options:  <0=mirror, 0/1=float, 2=parameter, 3=parm_w_random_dev, 4=parm_w_randwalk)
 #_Den-dep  env-var  extra_se  Q_type
0       0       0       0       # Comm
1       0       1       2       # P135
1       0       1       2       # P915
1   0   1   2   # P146

#0 #_Cond 0 #_If q has random component, then 0=read one parm for each fleet with random q; #=read a parm for each year of index
#_Q_parms(if_any)
# LO HI INIT PRIOR PR_type SD PHASE
```

```
-25	25	1.2	0	0	10	4	#P135_power
-25	25	1.1	0	0	10	4	#P915_power
-25	25	1.0	0	0	10	4	#P146_power
0	5	0	0.05	1	0	4 #P135_extra_SD
0	5	0	0.05	1	0	4 #P915_extra_SD
0	5	0	0.05	1	0	4 #P146_extra_SD
-25	15	-6.38	-10	-1	10	1	# P135_base_q
-25	15	-4.31	-10	-1	10	1	# P915_base_q
-25 15	-5	-10	-1	10	1	# P146_base_q
#
#_size_selex_types
#_Pattern Discard Male Special
 24 0 0 0 # Comm
 24 0 0 0 # P135
 24 0 0 0 # P915
 24 0 0 0 # P146
#
#_age_selex_types
#_Pattern ___ Male Special
 0 0 0 0 # Comm
 0 0 0 0 # P135
 0 0 0 0 # P915
 0 0 0 0 # P146

#_size_selex_parameters
#_LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr dev_stddev Block Block_Fxn
15	60	36	36	-1	10	2	0	0	0	0	0.5	0	0	#Comm_SizeSel_p1
-10	1	-3	-3	-1	10	3	0	0	0	0	0.5	0	0	#Comm_SizeSel_p2  #Rick
reduce max on this parameter
-2	9	5	5	-1	10	3	0	0	0	0	0.5	0	0	#Comm_SizeSel_p3
-2	9	4	4	-1	10	3	0	0	0	0	0.5	0	0	#Comm_SizeSel_p4
-1000	15	-999	-999	-1	10	-2	0	0	0	0	0.5	0	0	#Comm_SizeSel_p5  #Rick -
999 allows for gradual decline controlled only by the slope parameter
-1000	15	-999	-999	-1	10	-2	0	0	0	0	0.5	0	0	#Comm_SizeSel_p6  #Rick -
999 allows for gradual decline controlled only by the slope parameter
15	60	26	26	-1	10	3	0	0	0	0	0.5	0	0	#P135_SizeSel_p1
-10	1	-3	-3	-1	10	-3	0	0	0	0	0.5	0	0	#P135_SizeSel_p2
-2	9	3	3	-1	10	4	0	0	0	0	0.5	0	0	#P135_SizeSel_p3
-2	9	5	5	-1	10	-4	0	0	0	0	0.5	0	0	#P135_SizeSel_p4
```

-1000	15	-999	-999	-1	10	-2	0	0	0	0	0.5	0	0	#P135_SizeSel_p5 #Rick -999 allows for gradual decline controlled only by the slope parameter
-15	15	15	-2	-1	10	-2	0	0	0	0	0.5	0	0	#P135_SizeSel_p6 #Rick -999 allows for gradual decline controlled only by the slope parameter
15	60	28	28	-1	10	3	0	0	0	0	0.5	0	0	#P915_SizeSel_p1
-10	1	-3	-4	-1	10	-3	0	0	0	0	0.5	0	0	#P915_SizeSel_p2
-2	9	2.5	3.8	-1	10	4	0	0	0	0	0.5	0	0	#P915_SizeSel_p3
-2	9	8	4	-1	10	-4	0	0	0	0	0.5	0	0	#P915_SizeSel_p4
-1000	15	-999	-999	-1	10	-2	0	0	0	0	0.5	0	0	#P915_SizeSel_p5 #Rick -999 allows for gradual decline controlled only by the slope parameter
-15	15	15	-2	-1	10	-3	0	0	0	0	0.5	0	0	#P915_SizeSel_p6
15	60	28	28	-1	10	3	0	0	0	0	0.5	0	0	#P146_SizeSel_p1
-10	1	-2	-2	-1	10	3	0	0	0	0	0.5	0	0	#P146_SizeSel_p2
-2	9	4	4	-1	10	4	0	0	0	0	0.5	0	0	#P146_SizeSel_p3
-2	9	4	4	-1	10	4	0	0	0	0	0.5	0	0	#P146_SizeSel_p4
-1000	15	-999	-999	-1	10	2	0	0	0	0	0.5	0	0	#P146_SizeSel_p5 #Rick -999 allows for gradual decline controlled only by the slope parameter
-15	15	15	-2	-1	10	3	0	0	0	0	0.5	0	0	#P146_SizeSel_p6

#_age_selex_parameters
#_LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr dev_stddev Block Block_Fxn

#_Cond 0 #_custom_sel-env_setup (0/1)
#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no enviro fxns

#_Cond 0 #_custom_sel-blk_setup (0/1)
#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no block usage
#_Cond No selex parm trends
#_Cond -4 # placeholder for selparm_Dev_Phase
#_Cond 0 #_env/block/dev_adjust_method (1=standard; 2=logistic trans to keep in base parm bounds; 3=standard w/ no bound check)

Tag loss and Tag reporting parameters go next
0 # TG_custom: 0=no read; 1=read if tags exist
#_Cond -6 6 1 1 2 0.01 -4 0 0 0 0 0 0 0 #_placeholder if no parameters

1 #_Variance_adjustments_to_input_values
#_fleet: Comm P135 P915 P146
0 0 0 0 #_add_to_survey_CV
0 0 0 0 #_add_to_discard_stddev

```
  0 0 0 0 #_add_to_bodywt_CV
  1 1 1 1 #_mult_by_lencomp_N
  1 1 1 1 #_mult_by_agecomp_N
  1 1 1 1 #_mult_by_size-at-age_N
#
5 #_maxlambdaphase
1 #_sd_offset
#
0 # number of changes to make to default Lambdas (default value is 1.0)
# Like_comp codes:  1=surv; 2=disc; 3=mnwt; 4=length; 5=age; 6=SizeFreq; 7=sizeage; 8=catch;
# 9=init_equ_catch; 10=recrdev; 11=parm_prior; 12=parm_dev; 13=CrashPen; 14=Morphcomp; 15=Tag-comp; 16=Tag-negbin
#like_comp fleet/survey  phase  value  sizefreq_method
#10 1 4 0.001 1
# set lambda for init equilibrium catch to nil value so SS ignores lack of fit to input catch level
#
# lambdas (for info only; columns are phases)
#  0 0 0 0 #_CPUE/survey:_1
#  1 1 1 1 #_CPUE/survey:_2
#  1 1 1 1 #_CPUE/survey:_3
#  1 1 1 1 #_lencomp:_1
#  1 1 1 1 #_lencomp:_2
#  0 0 0 0 #_lencomp:_3
#  1 1 1 1 #_agecomp:_1
#  1 1 1 1 #_agecomp:_2
#  0 0 0 0 #_agecomp:_3
#  1 1 1 1 #_size-age:_1
#  1 1 1 1 #_size-age:_2
#  0 0 0 0 #_size-age:_3
#  1 1 1 1 #_init_equ_catch
#  1 1 1 1 #_recruitments
#  1 1 1 1 #_parameter-priors
#  1 1 1 1 #_parameter-dev-vectors
#  1 1 1 1 #_crashPenLambda
0 # (0/1) read specs for more stddev reporting
# 1 1 -1 5 1 5 1 -1 5 # selex type, len/age, year, N selex bins, Growth pattern, N growth ages, NatAge_area(-1 for all), NatAge_yr, N Natages
# 5 15 25 35 43 # vector with selex std bin picks (-1 in first bin to self-generate)
# 1 2 14 26 40 # vector with growth std bin picks (-1 in first bin to self-generate)
# 1 2 14 26 40 # vector with NatAge std bin picks (-1 in first bin to self-generate)
999
```