NC Marine Fisheries Commission

Fishery Management Plans

May 2024 Business Meeting

Document

Striped Mullet FMP Amendment 2 Decision Document

Striped Mullet FMP Amendment 2 (Draft)

2024 Revision to the N.C. Estuarine Striped Bass FMP Amendment 2 Memo

2024 Revision to the N.C. Estuarine Striped Bass FMP Amendment 2

Blue Crab Stock Assessment Update

Blue Crab Adaptive Management Decision Document

DECISION DOCUMENT

Striped Mullet Fishery Management Plan

Amendment 2

This document was developed to help the MFC track previous activity and prepare for upcoming actions for Striped Mullet FMP Amendment 2.

April 4, 2024

Background

The 2022 stock assessment indicated the striped mullet stock is overfished and overfishing is occurring. The North Carolina Fishery Reform Act of 1997 requires the State to implement management to end overfishing and to achieve a sustainable harvest within a 10-year time period. To achieve sustainable harvest within this time frame, management measures estimated to achieve a 20—33% reduction in total removals from 2019 landings are required.

Amendment 2 to the Striped Mullet Fishery Management Plan is being developed to address the overfished status of the North Carolina striped mullet stock. The recently adopted Supplement A to Amendment 1 to the Striped Mullet FMP implemented management measures to end overfishing with a season closure. Amendment 2 will contain additional management measures that will replace the supplemental management.

Review of Supplement A to Amendment 1 Decisions and Discussion

In September 2022, the DEQ Secretary determined it was in the long-term interest of the striped mullet stock to develop temporary management through a Supplement. The Division developed the Striped Mullet Fishery Management Plan Amendment 1 Supplement A to address the overfishing status of the stock while the Division works on comprehensive management to address sustainable harvest in Amendment 2. At its May 2023 business meeting, the Marine Fisheries Commission approved the following season closures:

Region	Closure Dates
North of the Highway 58 Bridge	November 7 – December 31
South of the Highway 58 Bridge	November 10 – December 31

The management adopted in Supplement A is temporary and will be replaced with the management adopted in Amendment 2. While a season closure may still be a part of long-term management for the species, other options will be explored and could be used in combination to achieve the necessary harvest reductions.

Sustainable harvest primarily focuses on reductions in the commercial fishery, where most striped mullet harvest occurs. In 2019, recreational striped mullet harvest accounted for 1.7% of total harvest, while the commercial fishery accounted for 98.3% of total harvest. Likewise, from 1994 to 2019 recreational striped mullet harvest accounted for 4.2% of total harvest. While management options are proposed for the recreational fishery to improve the status of the stock, recreational harvest reductions are not quantifiable due to data limitations.

Several management tools are available to achieve sustainable harvest in the striped mullet fishery, including combinations of management measures. All are discussed fully

in Appendix 2 and Appendix 3 of Amendment 2 to the Striped Mullet FMP. References to those documents are included in the discussion of the management options below.

Amendment Timing (Grey indicates a step is complete.)

September – October 2022	Division holds public scoping period
November 2022	MFC approves goal and objectives of FMP
November 2022 – May 2023	Supplemental Management (*Supplement A to Striped Mullet FMP Amendment 1 Adopted*)
November 2022 – June 2023	Division drafts FMP
July 2023	Division held workshop to review and further develop draft FMP with the Striped Mullet FMP Advisory Committee
August – October 2023	Division updates draft plan
November 2023	MFC Reviews draft and votes on sending draft FMP for public and AC review
December - January 2024	Public Comment Period and MFC Advisory Committees meet to review draft FMP
February 2024	MFC selects preferred management options
March-April 2024	DEQ Secretary and Legislative review of draft FMP
May 2024	**MFC votes on final adoption of FMP**
TBD	DMF and MFC implement management strategies

Developed Temporary Management (label pointing to November 2022 – May 2023 row)

You Are Here (label pointing to May 2024 row)

Goal and Objectives

The goal of Amendment 2 is to manage the striped mullet fishery to achieve a self-sustaining population that provides sustainable harvest using science-based decision-making processes. The following objectives will be used to achieve this goal.

Objectives:
- Implement management strategies within North Carolina that sustain and/or restore the striped mullet spawning stock with adequate age structure abundance to maintain recruitment potential and prevent overfishing.
- Promote the restoration, enhancement, and protection of critical habitat and environmental quality in a manner consistent with the Coastal Habitat Protection Plan, to maintain or increase growth, survival, and reproduction of the striped mullet stock.

- Use biological, social, economic, fishery, habitat, and environmental data to effectively monitor and manage the fishery and its ecosystem impacts.
- Advance stewardship of the North Carolina striped mullet stock by promoting practices that minimize bycatch and discard mortality.

Management Options, Ordered by Issue

Sustainable Harvest

The intent of these management options is to allow for traditional use of striped mullet in the commercial fishery while meeting sustainable fishery requirements. They are predicted to reduce harvest of striped mullet in ways that are quantifiable using existing data. The data used to quantify harvest reductions are collected from commercial fishermen through the Division's Trip Ticket and fish house sampling programs. Because they are quantifiable, they are used to meet the legal requirements of the Fisheries Reform Act to address overfishing and rebuild overfished stocks. Because harvest reductions from the recreational fishery are not quantifiable, sustainable harvest options are specific to the commercial fishery, where most striped mullet harvest occurs.

A 21.3 to 35.4% reduction in commercial harvest relative to commercial landings in 2019 is needed to rebuild the striped mullet spawning stock biomass to a sustainable level. Because of low recruitment observed in recent years (p.45 of FMP, Figure 2.1), the Division recommends a harvest reduction closer to the upper end of the reduction range to increase the probability of rebuilding success.

Option 1: Size Limit Options (Striped Mullet FMP Amendment 2, p. 48)
On its own, implementation of a striped mullet minimum size limit set at the L50, or the length at which 50% of the population are mature, would be unlikely to meet sustainability objectives and would eliminate the bait fishery for finger mullet. A maximum size limit, focused on the spawning season (October-December), would have a more direct impact on the spawning stock; however, it would negatively affect the roe fishery, the most valuable portion of the commercial striped mullet fishery. Slot limits should not be considered because it would exclude harvest of both "finger mullet" for bait as well as large roe mullet. Implementing a minimum or maximum size limit would need to be accompanied by corresponding changes to minimum or maximum mesh sizes used in gill nets to reduce dead discards. This would likely impact other small mesh gill net fisheries targeting other species. To read full discussion of size limits, see p. 48 in draft Amendment 2.

a. *Status Quo – Manage fishery without minimum or maximum size limits (0% Reduction)*

b. *Minimum Size Limit and 3.25 ISM Minimum Gill Net Mesh Size*

Example Size Limit Options (Inches FL)	
Minimum	Percent Reduction

13.5	27.2
14.0	37.2

c. *Maximum Size Limit and 3.75 or 4.0 ISM Maximum Gill Net Mesh Size*

Example Size Limit Options (Inches FL)	
Maximum	Percent Reduction
15.0	39.8
15.5	28.4

d. *Seasonal Maximum Size Limit and 3.75 or 4.0 ISM Maximum Gill Net Mesh Size*

Example Size Limit Options (Inches FL)	
Oct-Dec Maximum	Percent Reduction
14.5	51.4
15.0	27.0

Option 2. Season Closure Options (Striped Mullet FMP Amendment 2, p. 55)
Season closures, specifically end of year season closures, are considered an effective and efficient management option to end overfishing of the striped mullet stock and rebuild SSB. To read the full discussion of seasonal closures, see p.55 in Amendment 2.

2.a   No Season Closure (0% Reduction)

	Season Closure	Reduction
2.b*	October 29 - December 31	33.7
2.c	November 7 - December 31	22.1

*Adding one more closure day exceeds the minimum 35.4% reduction necessary to reach the SSB Target.

	Season Closure		
	North	South	Reduction
2.d	Oct. 28-Dec. 31	Oct. 30-Dec.31	35.6
2.e	Nov. 7-Dec. 31	Nov. 10-Dec. 31	21.7

Option 3: Trip limits (Striped Mullet FMP Amendment 2, p. 57)
Unless otherwise specified all trip limit options are daily trip limits and applied to a commercial fishing operation regardless of the number of persons, license holders, or vessels involved. Yardage limits on runaround gill nets in tandem with trip limits could be helpful in minimizing discards but would affect other fisheries. To read the full discussion of trip limits, see p.57 in Amendment 2.

Table 2.10. Percent harvest reduction from 2019 commercial landings based on various daily trip limits and time periods.

Trip Limit (lb)	Reduction (%)		
	Jan-Sept, Dec	Oct-Nov	Total
50	33.1	50.4	83.4
75	30.3	47.8	78.1
100	27.9	45.5	73.5
150	24.3	41.7	66.0
200	21.3	38.5	59.8
300	16.8	33.3	50.2
400	13.6	29.4	42.9
500	11.0	26.1	37.2
600	9.0	23.4	32.4
1,000	3.8	15.5	19.3
1,100	3.0	14.1	17.1
1,250	2.1	12.3	14.4
1,500	1.2	10.0	11.2
1,750	0.7	8.2	9.0
2,000	0.4	6.8	7.2
2,500	0.1	4.8	4.9

Option 4: Day of week closures (Striped Mullet FMP Amendment 2, p. 59)
To read the full discussion of day of week closures, see p.59 in Amendment 2.

Table 2.11. Percent of harvest by day of week or combination of days, 2019 and 2017-2021.

Day(s) of Week	2019 Landings	Landings (%)	2017-2021 Landings	Landings (%)
Sunday	162,709	11.9	780,061	10.4
Monday	209,707	15.4	1,201,290	16.1
Tuesday	247,756	18.2	1,273,991	17.0
Wednesday	190,343	14.0	1,148,997	15.4
Thursday	191,313	14.0	1,038,243	13.9
Friday	173,090	12.7	1,048,743	14.0
Saturday	187,294	13.7	984,763	13.2
Saturday-Sunday	350,003	25.7	1,764,823	23.6
Friday-Sunday	523,093	38.4	2,813,566	37.6
Saturday-Monday	559,710	41.1	2,966,113	39.7
Friday-Monday	732,800	53.8	4,014,856	53.7

Table 2.12. Percent of commercial landings by day of week for each month, 2017-2021.

Month	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
January	8.5	18.2	18.7	16.4	15.2	13.5	9.5
February	8.6	14.7	20.6	13.8	15.2	14.1	13.1
March	9.7	20.2	15.8	15.8	17.1	14.2	7.1
April	11.0	13.7	15.1	17.6	16.2	12.0	14.4
May	11.7	10.4	17.4	19.0	14.0	13.1	14.3
June	10.9	16.3	15.4	14.4	12.8	17.0	13.2
July	10.1	16.0	15.5	15.9	16.8	15.3	10.4
August	9.1	19.6	14.4	13.4	15.4	17.4	10.7
September	14.3	14.3	14.2	15.1	13.2	12.5	16.4
October	10.8	16.7	19.1	15.0	11.4	11.4	15.5
November	9.7	14.7	17.9	16.0	15.1	15.3	11.4
December	10.2	18.1	10.0	14.8	15.2	19.3	12.5

Option 5: Combination of Measures (Striped Mullet FMP Amendment 2, p. 60)

Table 2.13. Management measure combinations to end overfishing and achieve sustainable harvest, compared to 2019 commercial landings. Unless otherwise specified, all options for day of week closures or day of week reduced trip limits are applied year-round. All trip limit options are daily trip limits and applied to a commercial fishing operation regardless of the number of persons, license holders, or vessels involved.

MFC's Preferred Management Option

Option	Season Closure	Daily Trip Limit (lb.)	Day of Week Closure	% Reduction	% Reduction with 30k Stop Net Cap
5.a*	.	.	Sat-Sun	25.7	24.0
5.b	Dec 1-Dec 31	Jan-Sep 1,000; Sat-Sun 50 lb	.	28.1	26.4
5.c*	.	Jan-Sep 1,000	Sat-Sun	28.5	26.9
5.d	Dec 1-Dec 31	Jan-Oct 15 1,000; Sat-Sun 50 lb	.	28.9	27.3
5.e	Nov 12-Dec 31	1,000	.	29.1	27.5
5.f*	.	Jan-Oct 15 1,000 lb	Sat-Sun	29.3	27.7
5.g			Jan-Oct Sat-Sun; Nov-Dec Sat-Mon	30.0	28.5
5.h		Jan-Oct 15 and Dec 500; Sat-Sun 50 lb		31.3	29.8
5.i	Dec 1-Dec 31	Jan-Sep 1,000	Sat-Sun	31.8	30.2
5.j		Jan and Dec 100 lb; Feb-Sep 500 lb; Sat-Sun 50 lb		32.4	30.9
5.k	Dec 1-Dec 31	Jan-Oct 15 1,000	Sat-Sun	32.6	31.1
5.l	Nov 8-Dec 31	1,000	.	34.6	33.1
5.m	.	Jan and Dec 50 lb; Sat-Sun 50 lb; Feb-Oct 15 500 lb	.	34.6	33.2
5.n[+][◊][¥]			Jan-Sept Sat-Sun; Oct-Dec Sat-Mon	34.9	33.4
5.o		Jan-Oct 15 and Dec 500	Sat-Sun	35.4	33.9
5.p		Jan1-31 and Nov16-Dec31 50 lb., Sat-Sun 50 lb, Feb1-Oct15 500lb		36.9	35.5
5.q	.	Jan and Dec 100 lb; Feb-Sep 500 lb	Sat-Sun	36.5	36.0
5.r	Nov 12-Dec 31	1,000	Sat	38.6	37.2

*Endorsed by Striped Mullet FMP AC
[+]DMF Recommendation
[◊]Selected by MFC
[¥]Harvest will be closed from 6:00 P.M. Friday through 6:00 A.M. Monday for Jan-Sept and from 6:00 P.M. Friday through 6:00 A.M. Tuesday for Oct-Dec.

Visual Representation of Option 5.n

6:00 P.M. Friday – 6:00 A.M. Monday

6:00 P.M. Friday – 6:00 A.M. Tuesday

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

MFC's Preferred Management Option
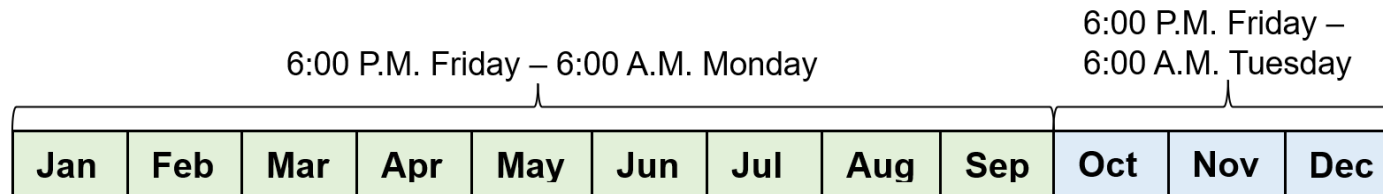
a. Status Quo – DMF recommends managing the stop net fishery with the same management measures applied to the rest of the fishery. Further, DMF recommends the stop net season open annually no sooner than October 15 and close no later than December 31. All other stop net and associated gill net regulations will be set by proclamation consistent with, but not limited to, previous management (see proclamations M-17-2020, M-18-2020, M-20-2021, M-21-2021, M-22-2022, and M-23-2022).

b. Stop Net Specific Catch Cap –

Option 7: Seasonal Catch Limit (Striped Mullet FMP Amendment 2, p. 64)
a. Status Quo – Manage fishery without Seasonal Catch Limit

b. Implement Statewide Seasonal Catch Limit

c. Implement Regional (North/South) Seasonal Catch Limit

Option 8: Area Closures (Striped Mullet FMP Amendment 2, p. 68)

Option 9: Limited Entry (Striped Mullet FMP Amendment 2, p. 69)

MFC's Preferred Management Option

Option 10: Adaptive Management Framework (Striped Mullet FMP Amendment 2, p. 72)
If adaptive management is adopted as part of Amendment 2, the specifications would apply to the commercial and recreational fisheries for mullet. Parts 1-3 are explicitly tied to a stock assessment update. Part 4 allows for adjustment of management to ensure compliance with and effectiveness of management strategies and would be a tool to respond to concerns with stock conditions and fishery trends.

1) Update the stock assessment at least once in between full reviews of the FMP, timing at discretion of the division.

   a. If current management is not projected to meet management targets (management targets are minimum SSB remaining between $SSB_{Threshold}$ and SSB_{Target}, and maximum F remaining between $F_{Threshold}$ and F_{Target}), then management measures shall be adjusted via an adaptive management update and implemented using the Fisheries Director's proclamation authority to reduce harvest to a level that is projected to meet the F_{Target} and SSB_{Target}.
   b. If management targets are being met, then new management measures would not be needed, or current management measures could possibly be relaxed provided projections still meet the management targets. When management targets are met, a striped mullet industry workgroup will be convened to discuss the possibility of "guard rail management" to maintain a sustainable harvest for the striped mullet stock.

2) Management measures that may be adjusted using adaptive management include:

a. Season closures
    b. Day of week closures
    c. Trip limits
    d. Gill net yardage or mesh size restrictions in support of the measures listed in a-c
3) Use of the Director's proclamation authority for adaptive management to meet management targets is contingent on:
    a. Consultation with the Northern, Southern, and Finfish advisory committees
    b. Approval by the Marine Fisheries Commission.
4) Upon evaluation by the division, if a management measure adopted to achieve sustainable harvest (either through Amendment 2 or a subsequent revision) is not achieving its intended purpose, it may be revised or removed and replaced using the Director's proclamation authority; provided it conforms to part 2 above and provides similar protection to the striped mullet stock. If a revised management measure is anticipated to reduce or increase harvest compared to measures implemented through Amendment 2, it must comply with parts 2 and 3 above.

Recreational Fishery

The intent of these management options is to allow traditional use of striped mullet in the recreational fishery while supporting sustainability objectives. Due to recreational fishery data collection methods and recreational fishery practices, it is not possible to calculate harvest reductions from the proposed management options. While recreational harvest currently accounts for only a small percentage of the striped mullet harvest, there is concern that the reduced availability of commercially harvested bait could lead to a significant shift in directed recreational harvest. The proposed options will reduce the potential for that type of shift and therefore support successfully meeting sustainability objectives.

Option 1. Recreational Vessel and Bag Limit (Striped Mullet FMP Amendment 2, p. 81)
    a. Status Quo

    b. Reduce Recreational Bag Limit (100 fish)

    c. Reduce Recreational Bag Limit (100 fish) and Implement Vessel Limit (400 fish)

    d. Bag Limit (10, 15, 20, 25, etc.) for Fish Over 8-Inches

    e. Seasonal (October-December) Bag Limit (10, 15, 20, 25, etc.) for Fish Over 8-Inches

Option 2. For Hire Vessel and Bag limit (Striped Mullet FMP Amendment 2, p. 83)

    a. For Hire Vessel Limit (500 fish, etc.)

MFC's Preferred Management Option

b. Exception for For Hire Vessel Operations to Possess a Bag Limit for the Number of Anglers They are Licensed to Carry (Including in Advance of a Trip).

c. Exception for For Hire Vessel Operations to Possess a Bag Limit for the Number of Anglers Fishing Up to the 400-fish Maximum (Including in Advance of a Trip).

d. Mirror Option 1 management decision

Next Steps

The MFC selected its preferred management options at its February 2024 business meeting. The Fisheries Reform Act of 1997, section 113-182.1(e), requires that the DEQ Secretary monitor progress in the development and adoption of Fishery Management Plans and report to the Joint Legislative Oversight Committee on Agriculture and Natural and Economic Resources and the Fiscal Research Division. The draft Striped Mullet Fishery Management Plan Amendment 2 was submitted to the appropriate legislative entities for review, and the MFC will be presented any comments and recommendations from that review at its May 2024 business meeting. The MFC will then vote on final adoption of Amendment 2.

List of the Marine Fisheries Commission's Preferred Management Options

- **Day of Week Closures**

    January-September: Saturday and Sunday Closures (harvest closed from 6:00 p.m. Friday through 6:00 a.m. Monday)

    October-December: Saturday, Sunday, Monday Closures (harvest closed from 6:00 p.m. Friday through 6:00 a.m. Tuesday)

- **Stop Net Fishery Management**

    The stop net fishery will be managed with the same management measures as applied to the rest of the fishery. The stop net season will open annually no sooner than October 15 and close no later than December 31. All other stop net and associated gill net regulations will be set by proclamation consistent with, but not limited to, previous management (see proclamations M-17-2020, M-18-2020, M-20-2021, M-21-2021, M-22-2022, and M-23-2022).

- **Recreational Fishery**

    Reduce recreational bag limit to 100 fish and implement a 400 fish vessel limit. For-Hire Vessel Operations may possess a bag limit for the number of anglers fishing up to the 400 fish maximum (including in advance of a trip).

- **Adaptive Management Framework**

    1) Update the stock assessment at least once in between full reviews of the FMP, timing at discretion of the division.
        a. If current management is not projected to meet management targets (management targets are minimum SSB remaining between SSBThreshold and SSBTarget, and maximum F remaining between FThreshold and FTarget), then management measures shall be adjusted via an adaptive management update and implemented using the Fisheries Director's proclamation authority to reduce harvest to a level that is projected to meet the FTarget and SSBTarget.
        b. If management targets are being met, then new management measures would not be needed, or current management measures could possibly be relaxed provided projections still meet the management targets. When management targets are met, a striped mullet industry workgroup will be convened to discuss the possibility of "guard rail management" to maintain a sustainable harvest for the striped mullet stock.

2) Management measures that may be adjusted using adaptive management include:
   a. Season closures
   b. Day of week closures
   c. Trip limits
   d. Gill net yardage or mesh size restrictions in support of the measures listed in a-c
3) Use of the Director's proclamation authority for adaptive management to meet management targets is contingent on:
   a. Consultation with the Northern, Southern, and Finfish advisory committees
   b. Approval by the Marine Fisheries Commission.
4) Upon evaluation by the division, if a management measure adopted to achieve sustainable harvest (either through Amendment 2 or a subsequent revision) is not achieving its intended purpose, it may be revised or removed and replaced using the Director's proclamation authority; provided it conforms to part 2 above and provides similar protection to the striped mullet stock. If a revised management measure is anticipated to reduce or increase harvest compared to measures implemented through Amendment 2, it must comply with parts 2 and 3 above.

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STRIPED MULLET
FISHERY MANAGEMENT PLAN
AMENDMENT 2

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

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CONTENTS

DRAFT

List of Tables

List of Figures

DRAFT

DRAFT

EXECUTIVE SUMMARY

North Carolina's historic striped mullet fishery had a prominent role in the early development of the North Carolina commercial fishing industry. Striped mullet were ranked as the most abundant and important saltwater fish of North Carolina in the early 1900s, and were originally harvested primarily by the historic beach seine fishery that still exists today off of Bogue Banks in Carteret County. Striped mullet are prized for their roe in the commercial fishery and are an important bait species for recreational anglers, especially for anglers targeting flounder and red drum.

The 2022 stock assessment of the North Carolina striped mullet stock, including data through 2019, determined the stock is overfished and overfishing is occurring. North Carolina law requires management action be taken to end overfishing within two years and to recover the stock from an overfished status within 10 years, with at least a 50% probability of success from the date the plan is adopted. A 9.3% reduction in total removals relative to 2019 commercial harvest is needed to end overfishing of the striped mullet stock. Supplement A to Amendment 1 of the Striped Mullet Fishery Management Plan (FMP) was adopted in May 2023 with the goal of ending overfishing in one year by implementing an end of season closure to reduce commercial harvest by 22.1%. A minimum reduction of 21.3-35.4% in commercial removals by weight relative to 2019 commercial harvest is needed to rebuild spawning stock biomass to a sustainable level within 10 years. Management measures under Supplement A to Amendment 1 will expire once Amendment 2 measures are adopted by the Marine Fisheries Commission.

The goal of Amendment 2 is to manage the striped mullet fishery to achieve a self-sustaining population that provides sustainable harvest using science-based decision-making processes. The following objectives will be used to achieve this goal: implement management strategies within North Carolina that sustain and/or restore the striped mullet spawning stock with adequate age structure abundance to maintain recruitment potential and prevent overfishing; promote the restoration, enhancement, and protection of critical habitat and environmental quality in a manner consistent with the Coastal Habitat Protection Plan, to maintain or increase growth, survival, and reproduction of the striped mullet stock; use biological, social, economic, fishery, habitat, and environmental data to effectively monitor and manage the fishery and its ecosystem impacts; and advance stewardship of the North Carolina striped mullet stock by promoting practices that minimize bycatch and discard mortality.

To meet statutory requirements to achieve a self-sustaining striped mullet stock, sustainable harvest is addressed in this FMP to ensure the long-term viability of the commercial and recreational fisheries. Quantifiable management measures are discussed for management of the commercial fishery while non-quantifiable management options are discussed for the recreational fishery, and information about the small mesh gill net fishery for striped mullet is also presented. Specific management measures selected by the NCMFC at its February 2024 business meeting are as follows:

1) Sustainable Harvest:
   - Implement a Saturday through Sunday commercial harvest closure for January 1 through September 30 and a Saturday through Monday closure for October 1 through December 31 to achieve a 34.9% reduction in harvest relative to 2019 commercial landings.
   - Manage the stop net fishery with the same management measures as the rest of the fishery.

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- Adopt an adaptive management framework that allows the Fisheries Director to use proclamation authority to specifically adjust season closures, day of week closures, trip limits, and gill net yardage or mesh restrictions to help ensure management targets are being met, based on the results of stock assessment updates or in response to concerning stock conditions or fishery trends observed outside of a stock assessment update.

2) Recreational Fishery:
   - Implement an individual bag limit of 100 fish per person per day.
   - Implement a vessel limit of 400 fish per vessel.
   - Provide an exception for For Hire Vessel Operations to possess a bag limit for the number of anglers fishing, up to the 400-fish maximum, including in advance of a trip.

INTRODUCTION

This is Amendment 2 to the Striped Mullet Fishery Management Plan (FMP). By law, each FMP must be reviewed at least once every five years (G.S. 113-182.1). The N.C. Division of Marine Fisheries (DMF) reviews each FMP annually and a comprehensive review is undertaken about once every five years. FMPs are the product that brings all information and management considerations for a species into one document. The DMF prepares FMPs for adoption by the North Carolina Marine Fisheries Commission (MFC) for all commercially and recreationally significant species or fisheries that comprise state marine or estuarine resources. The goal of these plans is to ensure long-term viability of these fisheries. All management authority for the North Carolina striped mullet fishery is vested in the State of North Carolina. The MFC adopts rules and policies and implements management measures for the striped mullet fishery in Coastal Fishing Waters in accordance with G.S. 113-182.1. Until Amendment 2 is approved for management, striped mullet are managed under Supplement A to Amendment 1 to the Striped Mullet Fishery Management Plan (NCDMF 2023).

Results of the 2022 Striped Mullet Stock Assessment (NCDMF 2022) indicate striped mullet in North Carolina are overfished and that overfishing is occurring, the terminal year of the assessment was 2019. An external peer review panel and the DMF concluded the 2022 assessment model and results are suitable for providing management advice for at least the next five years and considers the current assessment to be a substantial improvement from previous assessments, representing the best scientific information available for the stock. For More information about previous and current management and results of previous stock assessments, see the original Striped Mullet FMP (NCDMF 2006), Amendment 1 to the Striped Mullet FMP (NCDMF 2015), Supplement A to Amendment 1 (NCDMF 2023) and previous stock assessments (NCDMF 2013, NCDMF 2018, NCDMF 2022). These are available on the North Carolina Division of Marine Fisheries Fishery Management Plan website.

Fishery Management Plan History

Original FMP Adoption:	April 2006
Amendments:	Amendment 1 (2015)
Revisions:	None
Supplements:	Supplement A to Amendment 1 (2023)
Information Updates:	None
Schedule Changes:	None
Comprehensive Review:	

Past versions of the Striped Mullet FMP (NCDMF 2006, NCDMF 2015, NCDMF 2023) are available on the DMF fishery management plan website.

Management Unit

The management unit of this FMP includes all striped mullet inhabiting North Carolina coastal and inland fishing waters.

<u>Goal and Objectives</u>

The goal of Amendment 2 is to manage the striped mullet fishery to achieve a self-sustaining population that provides sustainable harvest using science-based decision-making processes. The following objectives will be used to achieve this goal.

Objectives:

- Implement management strategies within North Carolina that sustain and/or restore the striped mullet spawning stock with adequate age structure abundance to maintain recruitment potential and prevent overfishing.
- Promote the restoration, enhancement, and protection of critical habitat and environmental quality in a manner consistent with the Coastal Habitat Protection Plan, to maintain or increase growth, survival, and reproduction of the striped mullet stock.
- Use biological, social, economic, fishery, habitat, and environmental data to effectively monitor and manage the fishery and its ecosystem impacts.
- Advance stewardship of the North Carolina striped mullet stock by promoting practices that minimize bycatch and discard mortality.

DESCRIPTION OF THE STOCK

<u>Biological Profile</u>

PHYSICAL DESCRIPTION
Striped Mullet (*Mugil cephalus*) have a long, rounded, silvery body, with a dark bluish green back, fading into silver sides and a white underside. Several dark, horizontal stripes run head to tail along the body. The mouth is small, and the snout is short and blunt.

DISTRIBUTION
Striped mullet occur in fresh, brackish, and marine waters in tropical and subtropical latitudes worldwide. 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, Wong and Buckel 2005). 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 (Ibanez Aguirre, Gallardo Cabello and Sanchez Rueda 1995, Leard, et al. 1995). Striped mullet are used as food and bait, supporting commercial and recreational fisheries worldwide. In North Carolina, striped mullet are distributed coastwide and are found in most coastal habitats including rivers, estuaries, marshes, and the ocean. Tagging studies in North Carolina suggest a residential adult stock (Wong 2001; Bacheler et al. 2005) since most (98.2%) striped mullet dart-tagged in North Carolina between 1997 and 2001 were recovered in state waters (Wong 2001). In general, striped mullet tagging studies reveal a small mark-recapture distance and a general southward spawning migration along the South Atlantic Bight (SAB; Mahmoudi et al. 2001; McDonough 2001; Wong 2001). A northward movement pattern during and after the spawning period suggests adults return to North Carolina estuarine habitats (Bacheler et al. 2005).

SPECIES
Three Mugilid species exist in North Carolina: 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 (Figure 1, Figure 2) (M. R. Collins 1985a, M. R. Collins 1985b). As juveniles, both striped and white mullet cohabitate in estuarine waters making differentiation difficult (Martin and Drewry 1978); however, 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).
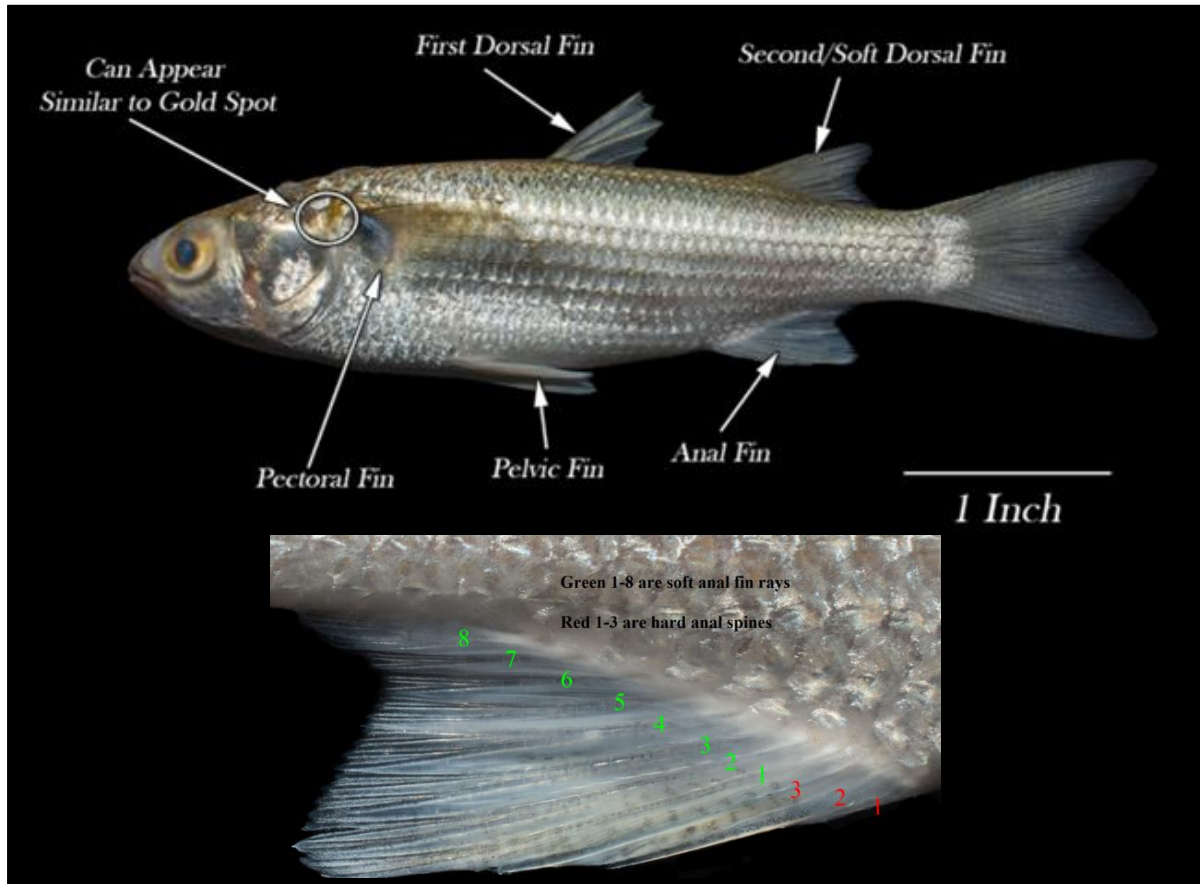
Figure 1. Identifying features for striped mullet. Striped mullet have eight soft anal fin rays and do not have a gold spot on the opercle that white mullet sometimes have. Photo By Scott Smith.

AGE AND GROWTH

Large variability in size at age has been observed for striped mullet in North Carolina (Figure 3), South Carolina, and Georgia (Charmichael and Gregory 2001, Foster 2001, C. J. McDonough 2001). Male and female fish tend to reach similar lengths at early ages (before age 2), after which, females grow larger and live longer (Mahmoudi, et al. 2001). Adult striped mullet grow at a rate of 38 mm to 64 mm (1.5 to 2.5 inches) per year (Broadhead 1953, Wong 2001) and grow twice as fast during the spring and summer than during the winter (Broadhead 1953, Rivas 1980). Male and female maximum ages of 14 and 13 years respectively have been observed in striped mullet collected by the DMF, and one striped mullet of undetermined sex was observed at 15 years old in the Neuse River, making it the oldest ever to be recorded in North Carolina (NCDMF 2022). Maximum reported sizes have ranged from 698 mm (27.5 inches) TL in North Carolina (NCDMF 2022) to 914 mm (36 inches) TL in India (Gopalakrishnan 1971).
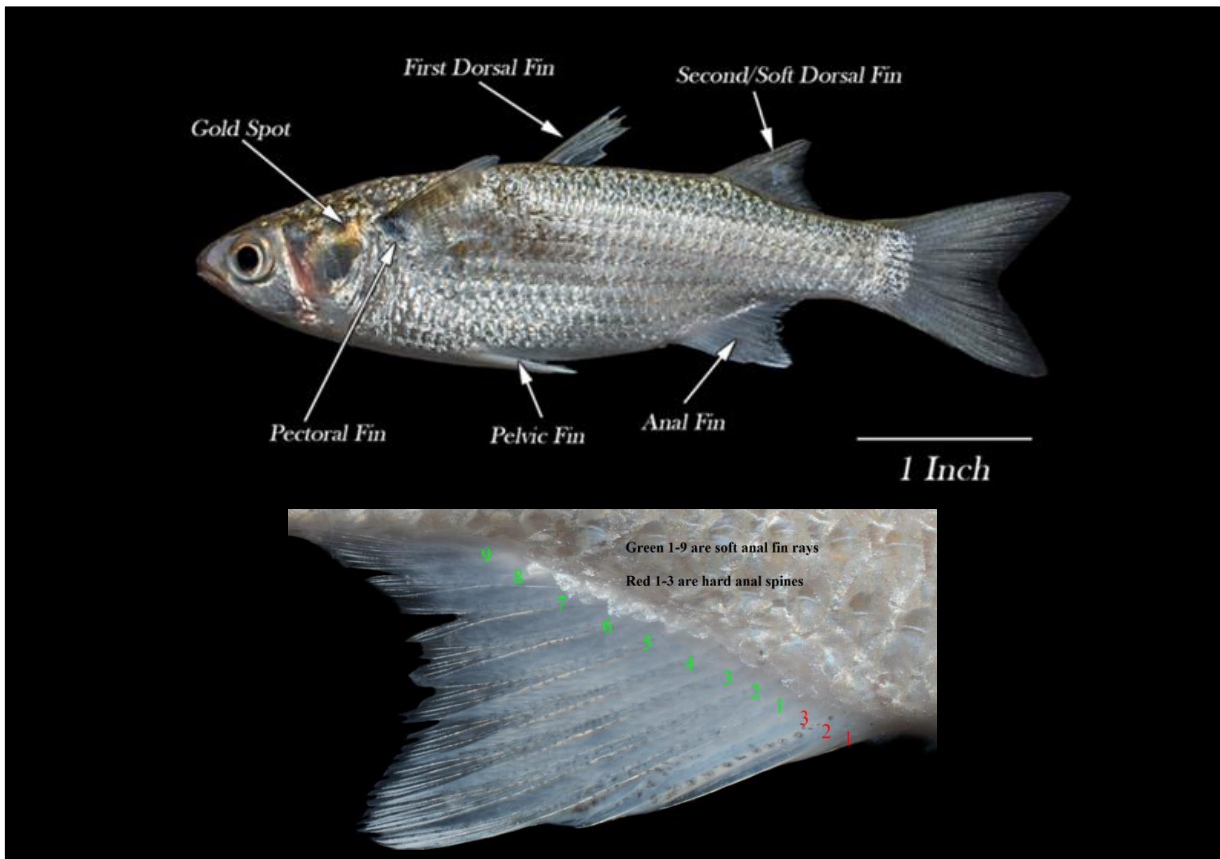
Figure 2. Identifying features for white mullet. White mullet have nine soft anal fin rays and a gold spot on the opercle. Photo By Scott Smith.
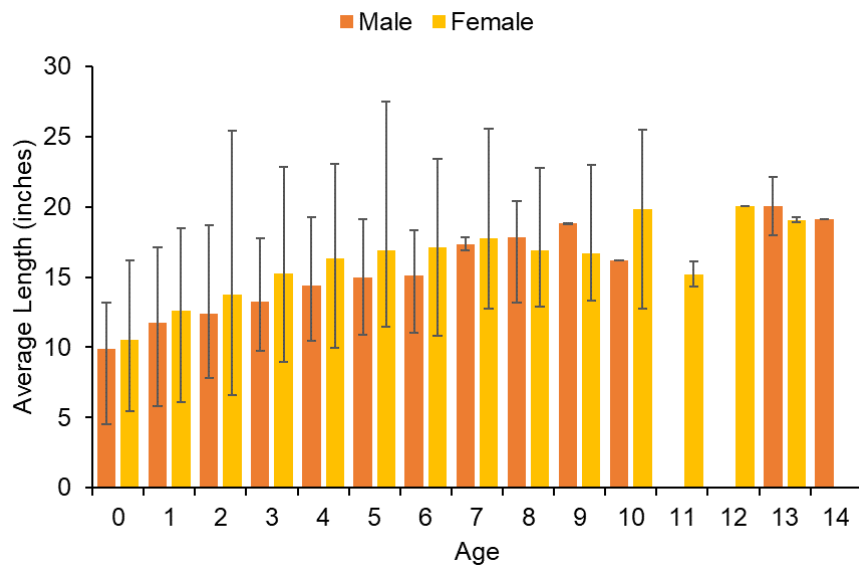

Figure 3. Average length at age for male and female striped mullet from DMF data. For some ages, only one sex or one specimen has been observed. Error bars show the range of lengths observed at each age by sex.

DRAFT

LIFE CYCLE

Larval and juvenile striped mullet begin their lives offshore, eventually moving inshore into a range of estuarine and shallow-water habitats as they reach adulthood (Anderson 1958, Leard, et al. 1995) where they remain from spring into summer (Leard, et al. 1995). In the southeast US, most adult movement occurs in the fall and winter months during the spawning migration from rivers and estuaries to ocean spawning grounds (M. R. Collins 1985a, Leard, et al. 1995, J. B. Bichy 2000). Increased migratory movement has been associated with north or northwest winds and cold fronts (Jacot 1920, Apekin and Vilenskaya 1979, Mahmoudi, et al. 2001) while hurricanes and unseasonably warm fall water temperatures may delay or disrupt the usual timing of spawning migrations (Thompson, et al. 1991).

REPRODUCTION

Striped mullet spawn once per year and may spawn many times throughout their lives. In North Carolina, striped mullet reach maturity at greater lengths compared to other regions, with males reaching maturity at 283 mm (J. B. Bichy 2004) and females reaching maturity at 319 mm (NCDMF 2021). It is estimated that 50% of striped mullet in North Carolina reach maturity at one year old for both males and females (J. B. Bichy 2000), one to two years earlier than in states south of North Carolina (Pafford 1983, Mahmoudi, et al. 2001). Maximum fecundity is reported to be from 0.5 to 4.2 million eggs per female, with fecundity being positively related to body size (larger fish produce more eggs) (Whitfield and Blaber 1978, Pafford 1983, J. B. Bichy 2000, Wenner 2001, Bichy and Taylor 2002, McDonough, Roumillat and Wenner 2003)

Striped mullet are catadromous, migrating in large schools from freshwater or brackish water habitats to marine spawning areas (Martin and Drewry 1978, M. R. Collins 1985a, S. M. Blaber 1987). The spawning location of North Carolina striped mullet is inferred largely based on indirect evidence, and likely occurs offshore, in and around the edge of the South Atlantic Bight (Broadhead 1953, Anderson 1958, Arnold and Thompson 1978, Martin and Drewry 1978, Powles 1981, Collins and Stender 1989, Ditty and Shaw 1996, Able and Fahay 1998). Spawning also likely occurs in nearshore coastal waters, lower estuarine areas, sounds, and (rarely) in freshwater (Jacot 1920, Breder 1940, Johnson and McClendon 1969, Shireman 1975, Martin and Drewry 1978, Collins and Stender 1989, Bettaso and Young 1999). Spawning is believed to occur at night near the surface (Anderson 1958, Arnold and Thompson 1978) and temporally around new and full moon spring tides (Greeley, Calder and Wallace 1987). The spawning season usually lasts from September to March in North Carolina, peaking in October and November (Jacot 1920, Bichy and Taylor 2002).

PREDATOR-PREY RELATIONSHIPS

Striped mullet act as an important ecological bridge among a wide range of trophic levels connecting base food chain items such as detritus, diatomaceous microalgae, phytoplankton, zooplankton, and marine snow (Odum 1968, Moore 1974, M. R. Collins 1985a, Larson and Shanks 1996, Cardona 2000, Torras, Cardona and Gisbert 2000), with top-level predators such as birds, sharks, and dolphins (Breuer 1957, J. M. Thompson 1963, M. R. Collins 1985a, Barros and Odell 1995, Fertl and Wilson 1997, Bacheler, Wong and Buckel 2005, Kiszka, et al. 2014). However, striped mullet likely contribute minimally to the diets of red drum (Facendola and Scharf 2012, Peacock 2014), striped bass (Rudershausen, et al. 2005) and other finfish species (Binion-Rock 2018). Carnivorous feeding on copepods, mosquito larvae, and microcrustaceans is common in striped mullet larvae and small juveniles (Desilva 1980, Harrington and Harrington 1961) followed by an increasing dependence on benthic and epiphytic detritus, microalgae, and microorganisms with increasing body size (DeSilva and Wijeyaratne 1977, Ajah and Udoh 2013, Bekova, et al. 2013). Adult striped mullet are primarily "interface feeders", feeding on the water

surface, water bottom, or surfaces of objects, but will occasionally feed on mid-water polychaetas and live bait of anglers in non-interface areas (Bishop and Miglarese 1978).

HABITAT

Striped mullet live in both fresh and saline water (M. R. Collins 1985a, Hotos and Vlahos 1998) and can be found in rivers, estuaries, and ocean habitats. Adult striped mullet are found in almost all shallow marine and estuarine habitats including beaches, tidal flats, lagoons, bays, rivers, channels, marshes, and seagrass beds (Moore 1974, Pattillo, et al. 1999, Nordlie 2000). Striped mullet are highly mobile, allowing them to use a wide range of habitats (Baker, et al. 2013). Field specimens have been collected in salinities ranging from 0 to 75 parts per thousand (ppt); however, striped mullet prefer a salinity range of 20 ppt to 26 ppt (M. R. Collins 1985a, Leard, et al. 1995, Pattillo, et al. 1999). Young-of-the-year striped mullet are capable of full osmoregulation and can tolerate freshwater to full seawater salinities by 40 mm, when they are 7 to 8 months old (Nordlie 2000).

Striped mullet do not seem to live permanently in waters with temperatures below 16°C (M. R. Collins 1985a), but have been observed in waters colder than 2°C in low salinity habitats (<2 ppt) in North Carolina (NCDMF unpublished data). Smaller striped mullet (<50 mm) prefer higher water temperatures, 30.0°C to 32.4°C, while larger fish prefer cooler temperatures, 19.5°C to 29.0°C (Major 1977, M. R. Collins 1985a). Peak growth of juveniles of mixed *Mugil* species (striped mullet and white mullet) occurs at temperatures greater than 25°C in laboratory settings (Peterson, et al. 2000). Additionally, striped mullet can tolerate low levels of dissolved oxygen and can capture air from the surface to supplement their oxygen supply for respiration (Pattilo, et al. 1999). They live at depths ranging from a few centimeters to over 1,000 meters but are mostly observed within 40 meters of the surface. Once inshore, they prefer depths of 3 meters or less.

Unit Stock and Management Unit

Based on available movement, migration, and life history data, the unit stock and management unit for striped mullet are defined as all striped mullet inhabiting North Carolina coastal and inland fishing waters.

Assessment Methodology

The stock assessment used a model to estimate historical and current population sizes for striped mullet in North Carolina. Data used in the assessment were collected from 1950 to 2019, from fish within North Carolina coastal and inland fishing waters (the range of the assumed biological unit stock). Commercial harvest data used in the assessment were collected by the North Carolina Trip Ticket Program, and recreational harvest data were collected through the National Oceanic and Atmospheric Administration's (NOAA) Marine Recreational Information Program (MRIP). Biological samples and environmental data were collected by DMF as part of several fishery-independent and fishery-dependent data collection programs. Several environmental variables including salinity, dissolved oxygen, water temperature, and bottom composition were incorporated into calculation of abundance indices. Following completion of the stock assessment, an external peer review workshop was held in April 2022. The DMF and peer review panel both concluded that the assessment model and results are suitable for providing management advice for at least the next five years.

Stock assessments often use a measure of female spawning stock biomass (SSB) to determine the status of the population relative to the level that is adequate for the recruitment class of a fishery to replace the spawning class of the fishery. Female spawning stock biomass includes

female fish that are mature and capable of producing offspring. The fishing mortality rate (*F*) is a measure of how quickly fish are being removed from the population by commercial and recreational fisheries combined. Removals include those fish that are kept and those that die after being released or discarded.

The 2019 estimates for female SSB and *F* were compared to thresholds that are considered sustainable. Sustainable harvest is defined 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 (G.S. 113-129 14a). These levels are based on two types of established reference points: a target level and a threshold level. The threshold is the minimum level required to end overfishing or allow the stock to rebuild from an overfished status. The target is intended to provide a buffer that accounts for variable conditions that may impact the efficacy of management actions. Managing to the target may increase the probability of successfully limiting fishing mortality to a level that allows the fishery to achieve sustainable harvest levels. If female SSB is less than the SSB threshold the stock is overfished, meaning that 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 (G.S. 113-129 12c). If *F* is above the *F* threshold the rate of removals is too high and overfishing is occurring. Overfishing is fishing that causes a level of mortality that prevents a fishery from producing a sustainable harvest (G.S. 113-129 12d).

The threshold and target fishing mortality and spawning stock biomass reference points used in stock assessments are selected to achieve a desired spawning potential ratio (SPR). SPR describes the expected reproductive output of an "average" individual fish over its lifetime when the population is fished, compared to what would be expected for that same individual in the absence of fishing. When choosing an SPR level for management decisions, the goal is to ensure the number of new fish (recruits) joining the spawning stock each year is not greatly decreased compared to what the stock would produce if it were not experiencing fishing pressure. Higher SPR levels do not necessarily result in more fish recruiting to the spawning stock because as more fish are added to the population, they compete for resources such as food and habitat, and survival decreases. Alternatively, when SPR drops too low, not enough new fish are produced and recruitment to the adult population declines, eventually resulting in a stock that is overfished. The appropriate SPR for a given stock is dependent on life history characteristics of the species and how associated fisheries operate. An SPR level of 20-50% is usually appropriate (Caddy and Mahon 1995). A greater SPR level is used when a more conservative management strategy is desired for the fishery.

For more details about assessment methodology, please refer to the 2022 Striped Mullet Stock Assessment (NCDMF 2022).

<u>Stock Status</u>

The North Carolina striped mullet stock is overfished, and overfishing is occurring in 2019, the terminal year of the 2022 stock assessment (NCDMF 2022). The observed data and model predictions suggest a decreased presence of larger, older striped mullet in the population. The model estimates declining trends in age-0 recruitment and SSB over the last several decades (Figure 4). Model results also indicate consistent overestimation of biomass and the greatest risk for overfishing.
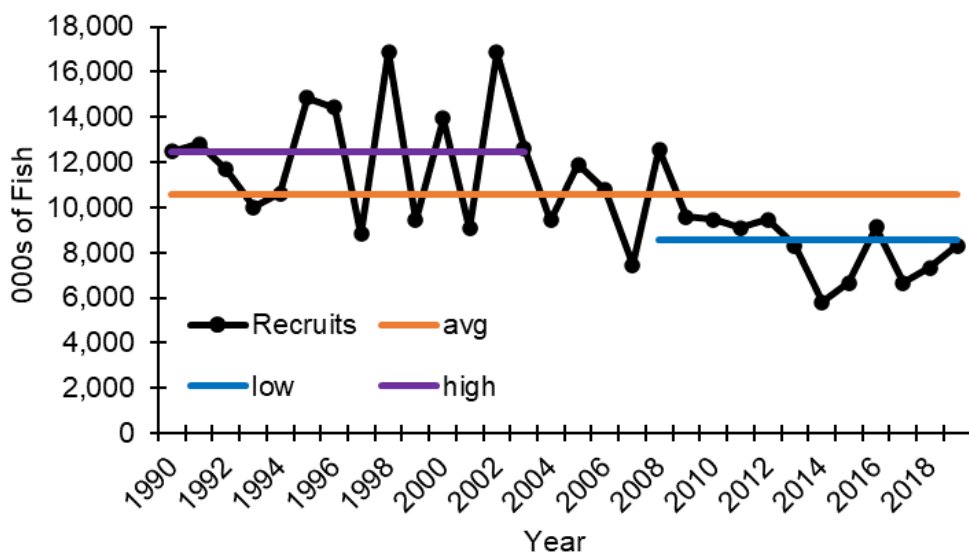
Figure 4. Estimates of striped mullet recruitment from the 2022 striped mullet stock assessment (NCDMF 2022). Average recruitment is the average number of recruits from 1990 to 2019, high recruitment is the average number of recruits from 1990 to 2003, and low recruitment is the average number of recruits from 2008 to 2019.

The stock assessment model estimated a value of 0.37 for the $F_{25\%}$ threshold and a value of 0.26 for the $F_{35\%}$ target. In 2019, the terminal year of the assessment, F was 0.42, greater than the $F_{25\%}$ threshold, indicating overfishing is occurring (Figure 5). The probability that the stock is undergoing overfishing is 80%. The model estimated a value of 1,364,895 pounds for the $SSB_{25\%}$ threshold and a value of 2,238,075 pounds for the $SSB_{35\%}$ target. Female SSB in 2019 was estimated at 579,915 pounds, lower than the $SSB_{25\%}$ threshold, indicating the stock is overfished (Figure 6). The probability that the stock is overfished is 95%

PROJECTIONS
Please refer to the 2022 stock assessment (NCDMF 2022) and the Achieving Sustainable Harvest in the North Carolina Striped Mullet Fishery Issue Paper (Appendix 2) for more information about stock projections and reductions necessary to end overfishing and achieve sustainable harvest for the North Carolina striped mullet stock.

DESCRIPTION OF THE FISHERY

Additional in-depth analyses and discussion of North Carolina's historical commercial and recreational striped mullet fisheries can be found in earlier versions of the Striped Mullet FMP (NCDMF 2006, NCDMF 2015). Commercial and recreational landings can be found in the License and Statistics Annual Report (NCDMF 2022) on the DMF Fisheries Statistics website.

Discussion of socio-economic information describes the fishery as of 2021 and is not intended to be used to predict potential impacts from management changes. This and other information pertaining to the FMPs are included to help inform decision-making regarding the long-term viability of the state's commercially and recreationally significant species and fisheries. For a

detailed explanation of the methodology used to estimate economic impacts, please refer to the DMF License and Statistics Section Annual Report (NCDMF 2022).
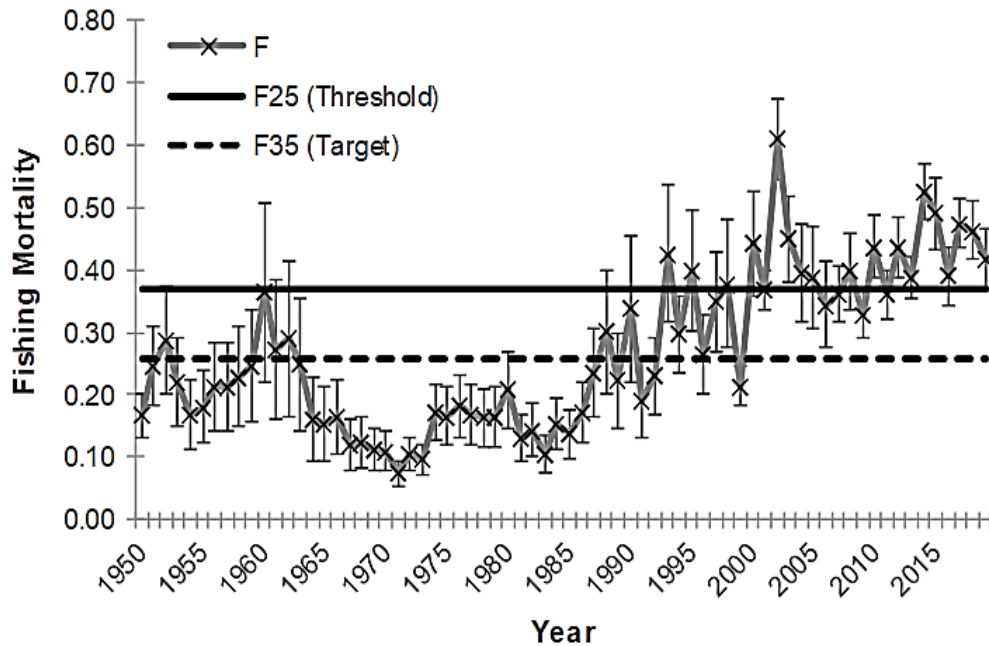
Figure 5. Comparison of annual estimates of fishing mortality (numbers weighted, ages 1-5) to the fishing mortality target (F35%) and threshold (F25%). Error bars represent plus or minus 2 standard deviations.
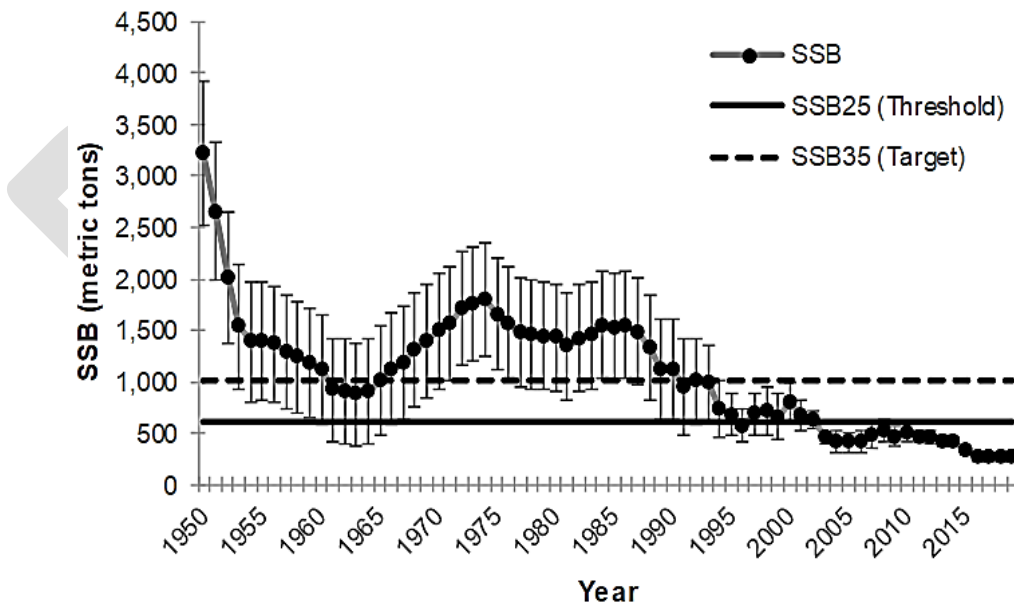
Figure 6. Comparison of annual estimates of female spawning stock biomass (SSB) to the SSB target (SSB35%) and threshold (SSB25%). Error bars represent plus or minus 2 standard deviations.

Commercial Fishery

COLLECTION OF COMMERCIAL HARVEST DATA

DMF instituted a mandatory, dealer-based, trip-level, reporting system known as the North Carolina Trip Ticket Program (NCTTP) for all commercial species in 1994. All seafood landed in North Carolina and sold by licensed commercial fishermen must be reported on a trip ticket by a licensed seafood dealer. For more information about licensing requirements for purchasing and selling seafood in North Carolina and how commercial fishing data were collected prior to 1994, please refer to the DMF License and Statistics Section Annual Report (NCDMF 2022). In 2021, 148 seafood dealers reported striped mullet on trip tickets, landed by 664 fishery participants during 11,432 fishing trips (Figure 7).
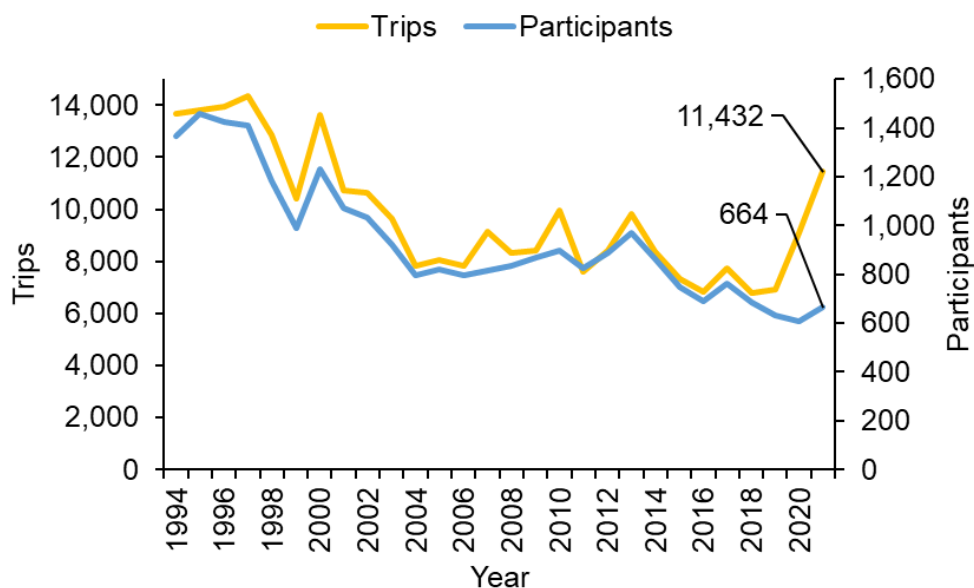
Figure 7. Annual number of trips and participants for the North Carolina striped mullet commercial fishery from 1994 to 2021.

HISTORICAL LANDINGS AND VALUE

The historic striped mullet fishery had a prominent role in the early development of the North Carolina commercial fishing industry and striped mullet were ranked as the most abundant and important saltwater fish of North Carolina in the early 1900s (Smith 1907). The fishery's historical importance is illustrated by 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 pounds annually during the late 1800s (Figure 8) (Chestnut and Davis 1975) and enormous catches of greater than 1 million pounds of striped mullet landed in a single day were not an uncommon event during fall spawning migrations (Smith 1907). The greatest recorded annual landings of over 6.7 million pounds and 5.1 million pounds were harvested in 1902 and 1908, respectively (Figure 8) (Chestnut and Davis 1975).

The fishery and market for striped mullet changed markedly in the late 1980s. 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 pounds 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% (Figure 9). A depressed Asian economy in the late 1990s may have led to a decline in roe demand.
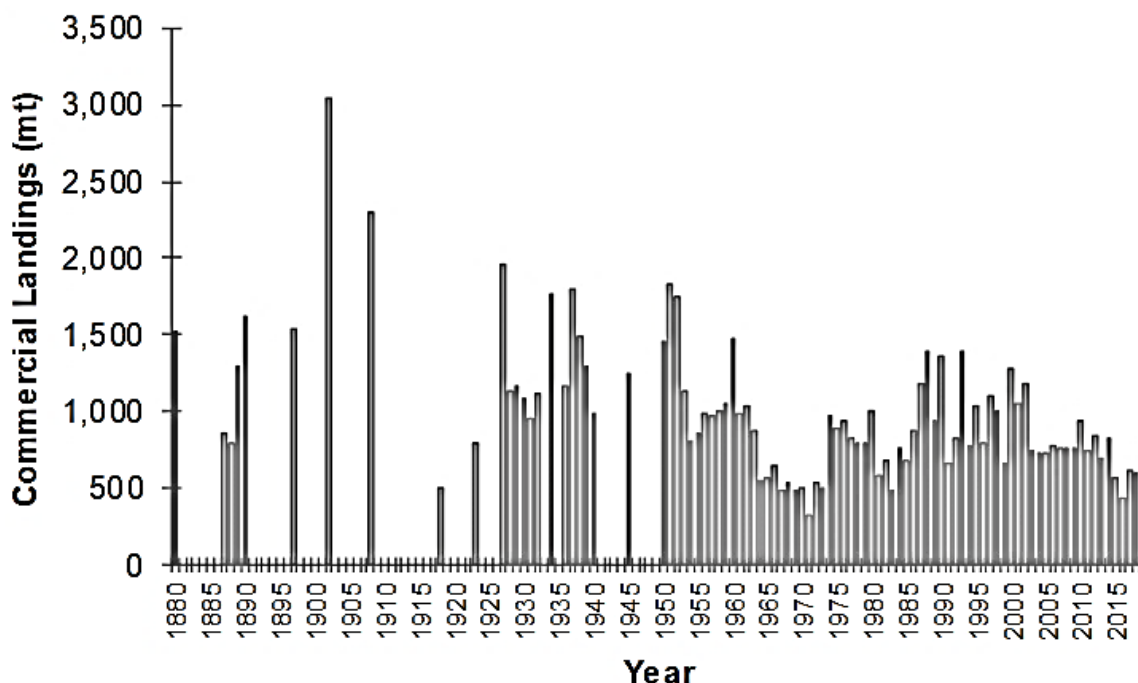
Figure 8. Historical striped mullet landings in the North Carolina commercial striped mullet fishery, for 1880 to 2021.

From 2000 to 2021, the price per pound for striped mullet has been variable, ranging from a low of $0.40 per pound in 2008 to $0.91 per pound in 2013. Since the early 2000s, landings in the striped mullet fishery have stabilized to around 1.5 to 2.0 million pounds annually, except for 2016, when total landings dipped to just under 1 million pounds (Figure 9). Because the commercial fishery primarily targets striped mullet roe, the greatest demand, intensity of harvest, and price per pound occurs in October and November (Figure 10), coinciding with the peak spawning period of striped mullet (Bichy and Taylor 2002, Jacot 1920).

LANDINGS BY MARKET GRADE

Striped mullet harvest is categorized by size and market grades when purchased by seafood dealers from fishermen. 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, roe, and white roe market categories. For the market grade analyses in this FMP, landings reported as extra small, small, medium, large, jumbo, and mixed were combined into the "Mixed" market grade category and landings reported as roe or red roe were combined into the "Red Roe" market grade category. From 1994 to 2021, striped mullet landings were sorted into either mixed (54%), red roe (40%), or white roe (spawning male striped mullet; 6%) market grades (Figure 11). During the same time period 42% of the value came from mixed market grade striped mullet, 55% of the value came from red roe, and 3% of the value came from white roe.

Mixed market grade harvest occurs year-round but increases in late summer, early fall, and January, likely because of the increased availability of striped mullet to the commercial fishery during their spawning migration. From 1994 to 2021, 97% of the annual red roe harvest, 95% of the annual white roe harvest, and 23% of the annual mixed market grade harvest occurred in November and December. Most spawning striped mullet are graded as mixed after Thanksgiving,

even though ripe (ready to spawn) fish are occasionally harvested into February and March. The roe market typically shifts from North Carolina to Florida in December. From 1994 to 2021, landings of Red Roe and Mixed grade mullet have fluctuated, with mixed grade landings increasing substantially since 2016 (Figure 12).
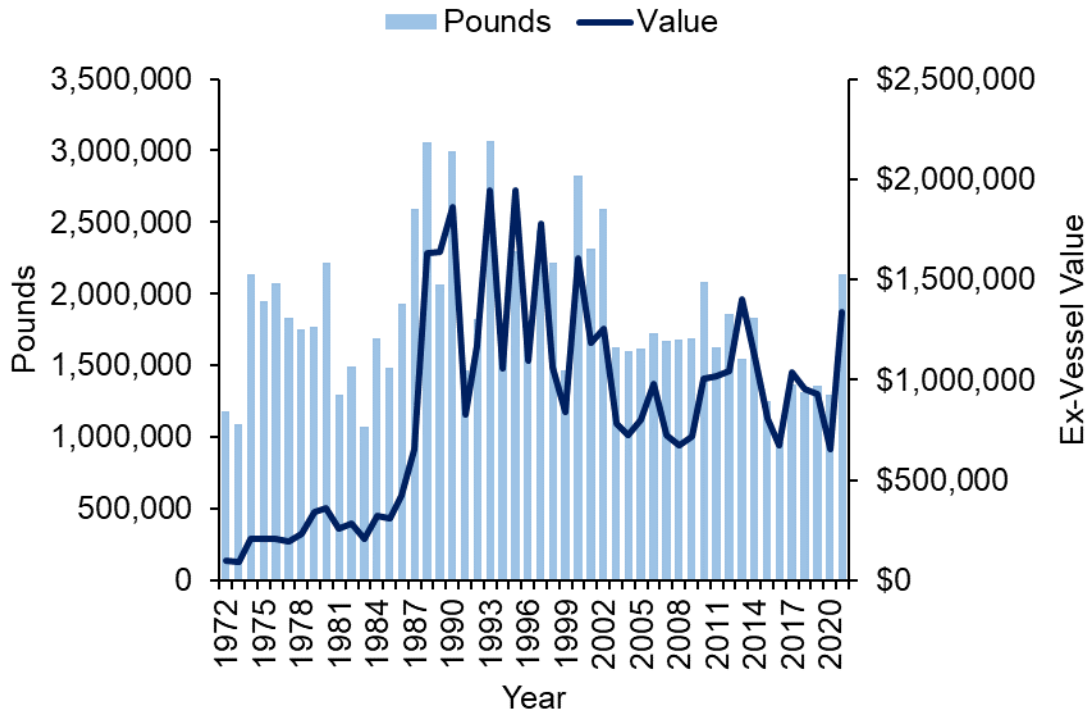
Figure 9. North Carolina annual striped mullet commercial landings and ex-vessel value for 1972 to 2021. Values include all market grades and are not adjusted for inflation.
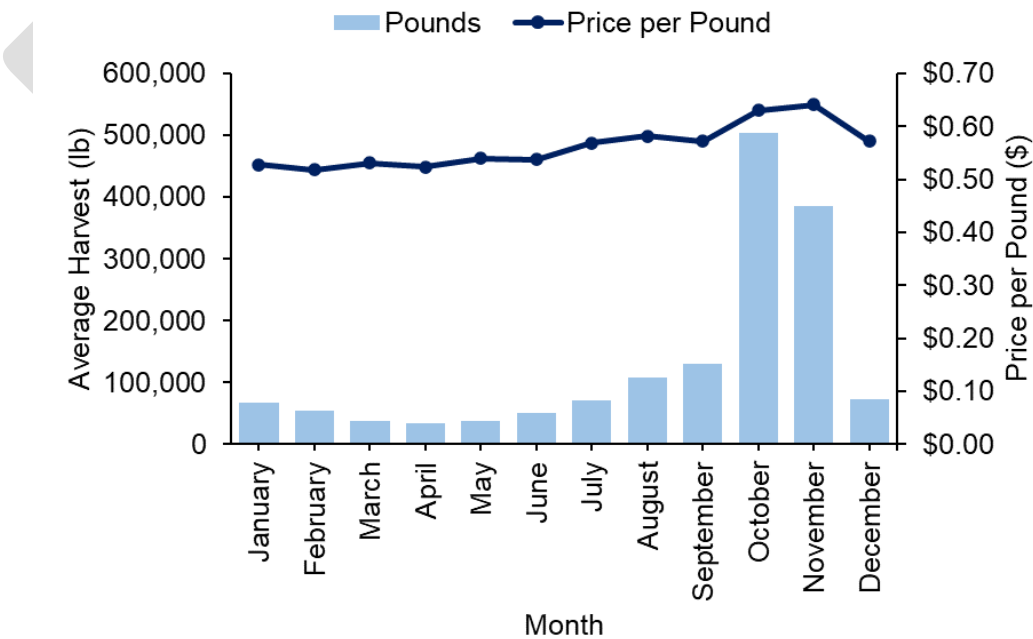
Figure 10. North Carolina striped mullet average monthly landings and average price per pound for 2010 to 2021. Averages include all market grades and are not adjusted for inflation.
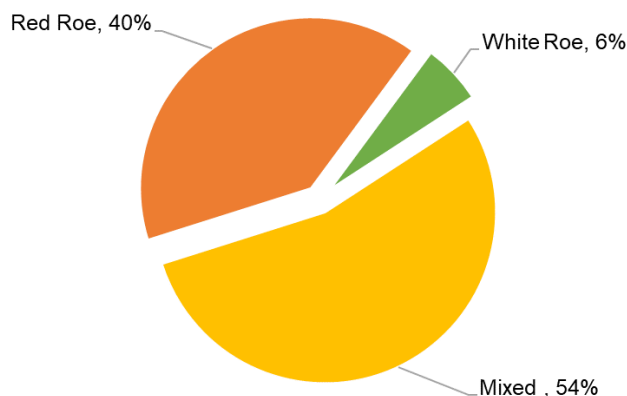
Figure 11. Percent of total landings by market grade in the North Carolina striped mullet commercial fishery, for 1994 to 2021. Landings reported as extra small, small, medium, large, jumbo, and mixed were combined into the "Mixed" market grade category. Landings reported as roe or red roe were combined into the "Red Roe" market grade category.

BAIT LANDINGS

The option for seafood dealers in North Carolina to report the disposition of landings on their trip tickets became available in 2017. Disposition is now a required field on trip tickets for dealers reporting electronically but some seafood dealers reporting on paper trip tickets are still using older, unused trip tickets that are missing the disposition field. Some seafood dealers leave the disposition field blank, an option intended to indicate that the default disposition for mullets of "food" should be used; however, a blank field could also indicate an accidental omission while recording the ticket. Additionally, mullets reported in numbers of fish rather than in pounds are often but not always bait landings, and some dealers report bait mullets using generic bait codes rather than using the correct species codes for "Finger Mullet" or "Jumping Mullet" (white and striped combined). Seafood dealers do not report mullets to the species level on trip tickets, but instead can report landings of larger fish as "Jumping Mullet" (all market grades except for extra-small) or smaller fish as "Finger Mullet" (extra-small market grade).

Commercial landings disposition data for striped mullet are currently considered to be inadequate for use in developing management measures because of the limited time series of disposition data for striped mullet landings and inconsistency in seafood dealers using the correct species and disposition codes when recording trip tickets. Additionally, commercial landings data for extra-small market grade mullet, or "Finger Mullet", used as bait are not recorded to the species level. A DMF study completed in the early 2000s indicated that most of these landings are white mullet, and that species composition can depend on the month and location of harvest (NCDMF 2006).

LANDINGS BY COUNTY AND WATERBODY

For information about trends in striped mullet commercial landings by county and by waterbody, please refer to the Small Mesh Gill Net Fishery Characterization Information Paper (Appendix 1). Most commercial striped mullet landings in North Carolina come from gill net fisheries and are landed in Dare and Carteret counties.
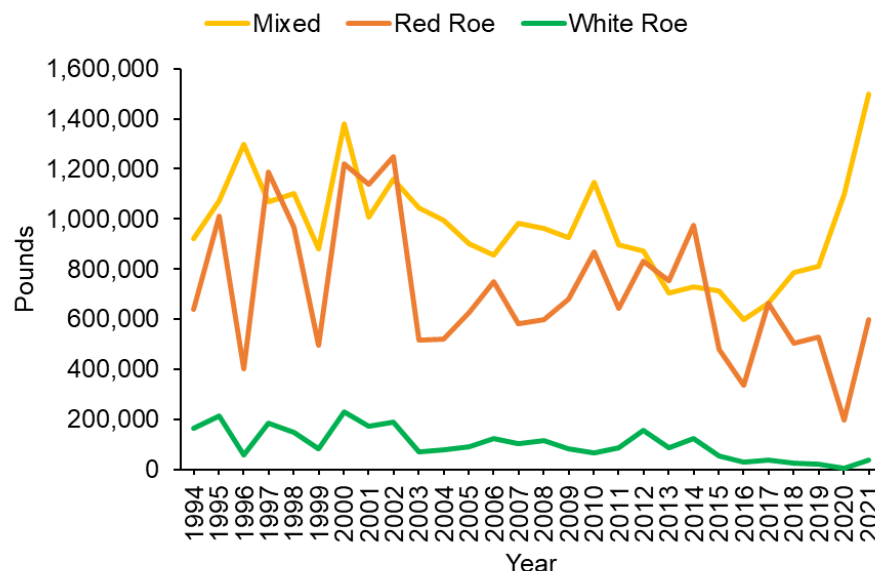
Figure 12. Annual landings by major market grade in the North Carolina striped mullet commercial fishery for 1994 to 2021. Landings reported as extra small, small, medium, large, jumbo, and mixed were combined into the "Mixed" market grade category. Landings reported as roe or red roe were combined into the "Red Roe" market grade category.

LANDINGS BY 1313131414GEAR TYPE

Beach Seines and gill nets have been the two primary gear types used in the striped mullet commercial fishery since the earliest landings were documented in 1887. The beach seine fishery accounted for most commercial harvest for nearly 100 years, from 1887 to 1978. Gill nets replaced beach seines as the dominant gear type in the fishery in 1979 and the yearly proportion of total commercial striped mullet landings harvested by gill nets steadily increased until 1995 (Figure 15). Since then, gill net landings have averaged around 91% of striped mullet landings through 2021. Please refer to the Small Mesh Gill Net Characterization Information Paper (Appendix 1) for more information about gear classifications and small mesh gill nets in the North Carolina striped mullet fishery.

RUNAROUND GILL NETS

The contribution of runaround gill nets to total commercial harvest of striped mullet each year has steadily increased since 1972, and experienced a large increase in the 1990s, possibly resulting from the gill net closure in Florida state waters at the time. 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. Additionally, expanded fishing regulations requiring gill net attendance for anchored small mesh gill nets (less than 5 inch stretched mesh) in North Carolina began in 1998, which may have further prompted a shift from set nets to runaround gill net fishing for striped mullet. (Figure 16).
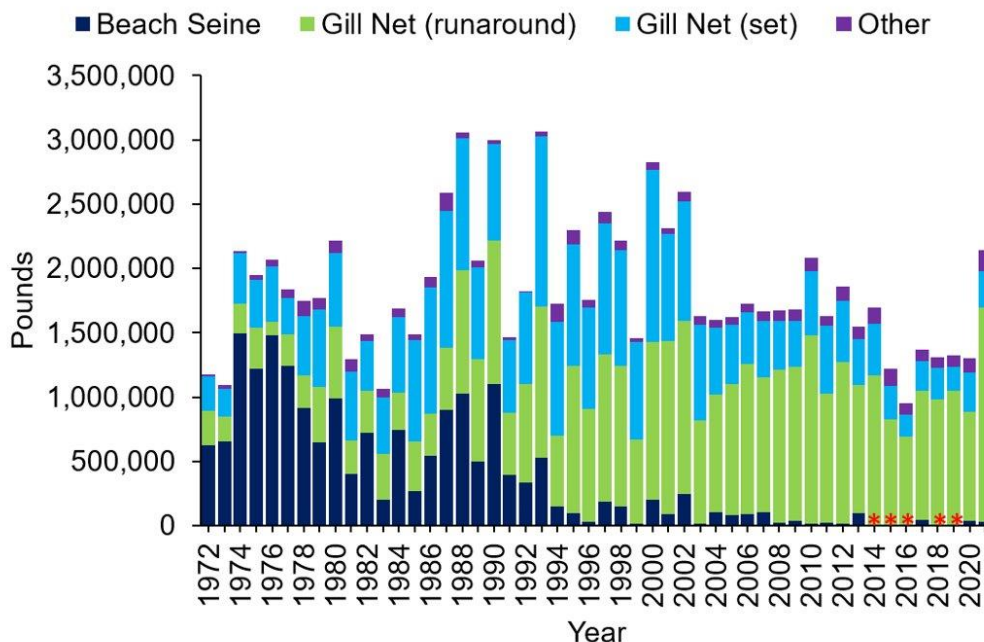
Figure 15. Total landings in pounds by dominant gear type in the North Carolina striped mullet commercial fishery for 1972 to 2021. Beach seine landings for 2014 through 2016 and 2018 through 2019 are confidential due to the number of vessels, dealers, or participants involved and therefore not presented, indicated by asterisks.
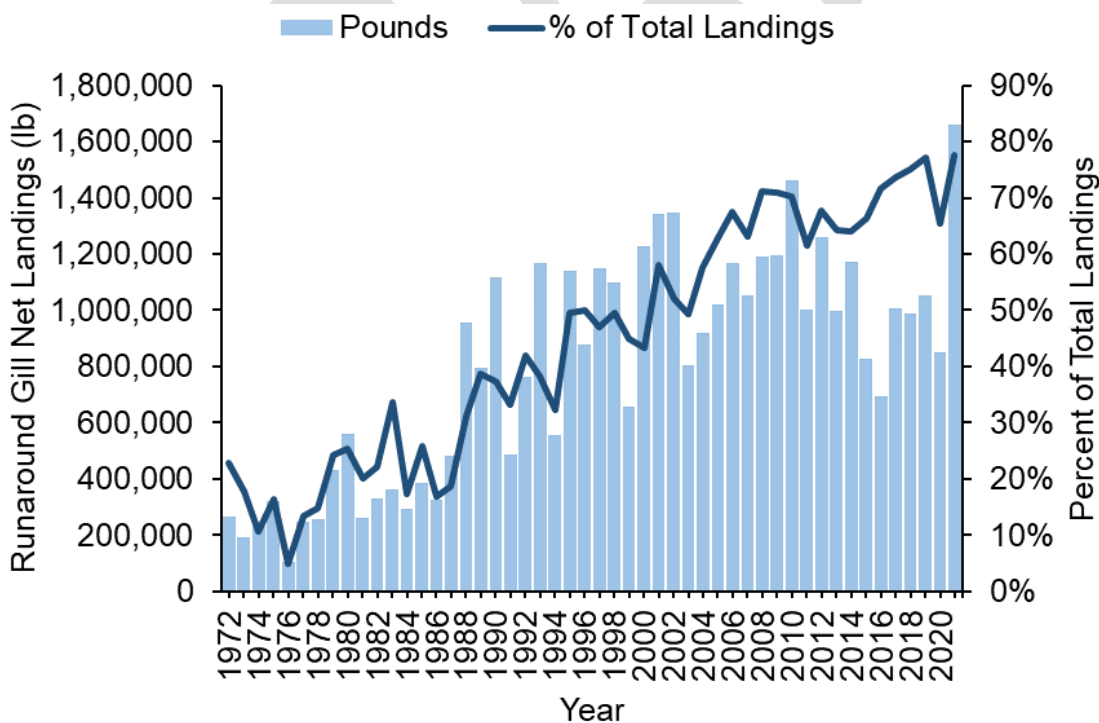
Figure 16. Pounds harvested by runaround gill nets by year and percent of total landings harvested by runaround gill nets by year in the North Carolina striped mullet commercial fishery for 1972 to 2021.

SET GILL NETS

Set gill nets have also become increasingly important in the striped mullet commercial fishery since 1972, although the proportion of total landings harvested by set gill nets has not increased since the mid-1980s (Figure 17). Set gill net trips in North Carolina do not usually target striped mullet, but they do harvest marketable striped mullet incidentally. Small mesh anchored gill nets have accounted for most of the striped mullet landings harvested using set gill nets. Since peaking in 1993 and 2000, annual striped mullet landings from set gill nets have generally declined with the increasing contribution of runaround gill nets to the fishery (Figure 17). Most striped mullet harvested using set gill nets are landed in October and November, coinciding with the roe fishery. Landings from set gill nets at other times of the year tend to be small, reflecting the incidental capture of striped mullet in other fisheries. For more information about the small mesh set gill net fishery for striped mullet in North Carolina, please refer to the Small Mesh Gill Net Fishery Characterization Information Paper (Appendix 1).

Figure 17. Pounds harvested using set gill nets and percent of total landings harvested using set gill nets by year in the North Carolina striped mullet commercial fishery for 1972 to 2021.

BEACH SEINES

The historic striped mullet beach seine fishery was predominantly composed of beach crews scattered among established territories along the central coastline of North Carolina, from Ocracoke Island and 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 tractors 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 in Bogue Banks.

The proportion of annual striped mullet harvest from the beach seine fishery has dwindled since 1972 and landings have fluctuated but declined greatly since 1994 (Figure 18). Beach seine

landings of striped mullet occur almost exclusively in October and November due to the restricted stop net fishery season. Extremely poor landings throughout the 1990s and 2000s may have resulted from fall hurricanes and strong weather conditions, which can have a particularly profound effect on stop net harvest because of its limited fishing season. The majority of striped mullet landings from beach seines are landed in the Ocean (93%) in the stop net fishery along Bogue Banks in Carteret County. 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 (0-3 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. Most striped mullet landings in this fishery occur in October and November during the fall spawning migration (J. B. Bichy 2000, M. R. Collins 1985a, Leard, et al. 1995). Outside of October and November, most of this fishery does not target striped mullet. Seines for spot, spotted seatrout, kingfish, and other species along the Outer Banks account for most trips from December to September of the next year.
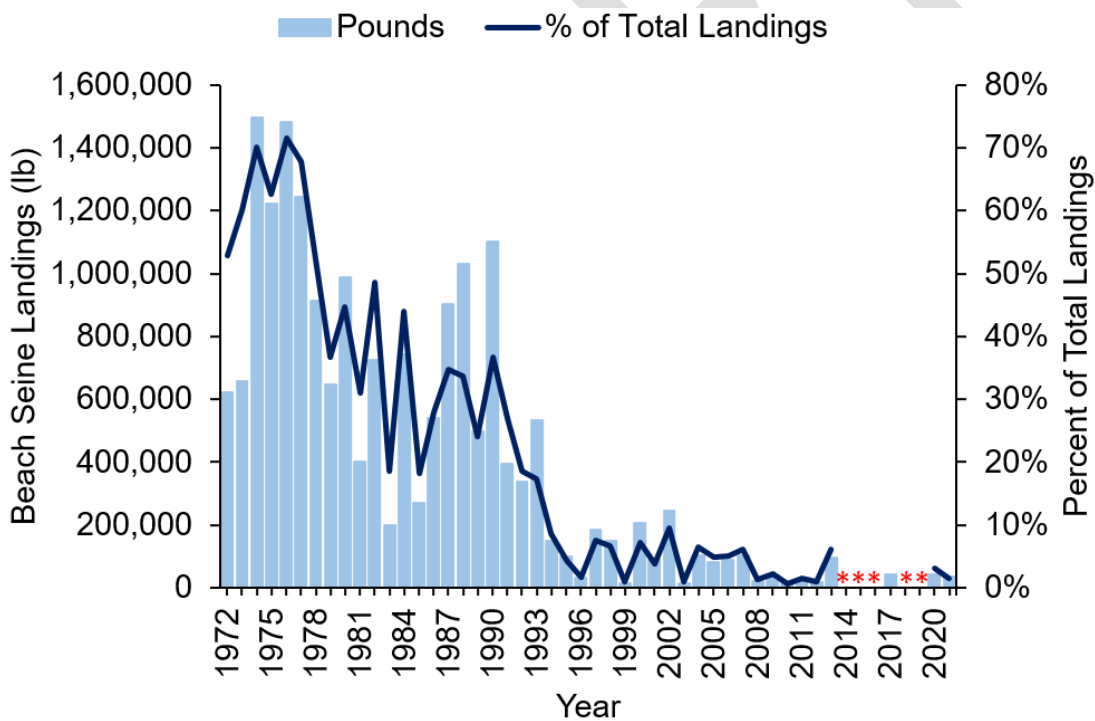
Figure 18. Pounds harvested using beach seins and percent of total landings harvested using beach seines by year in the North Carolina striped mullet commercial fishery for 1972 to 2021. Values for 2014 through 2016 and 2018 through 2019 are confidential and therefore not presented, indicated by asterisks.

CAST NETS
Cast net harvest of striped mullet is predominantly sold as bait. Cast net landings only represent 3% of the total striped mullet landings from 1994 to 2021 and increased from 1994 through 2015 before declining over recent years (Figure 19). In 2015, cast net landings contributed 8% of all

striped mullet landings that year, the highest proportion since 1994, when seafood dealers began reporting cast net landings on trip tickets (Figure 19).

Cast net landings of striped mullet are seasonal, with 76% of the annual harvest occurring in September and October. This seasonality of landings coincides with the spawning migration of white mullet. Most of the bait fish harvested commercially using cast nets that are reported by seafood dealers (striped and white combined) are likely white mullet (NCDMF 2006). A recreational cast net bait mullet fishery characterization study in the early 2000s showed that white mullet make up most commercial cast net landings in September and October, but striped mullet make up the majority of the landings in November in North Carolina (NCDMF 2006). The fall cast net fishery primarily targets mullets that will be used as bait, either as cut, whole (frozen), or live bait, in contrast to other mullet fisheries that almost exclusively target roe fish during this period. The greatest proportion of mullet landed by cast nets from 1994 to 2021 were harvested in the Ocean (0-3 miles; 58%) and the Pamlico Sound (30%).
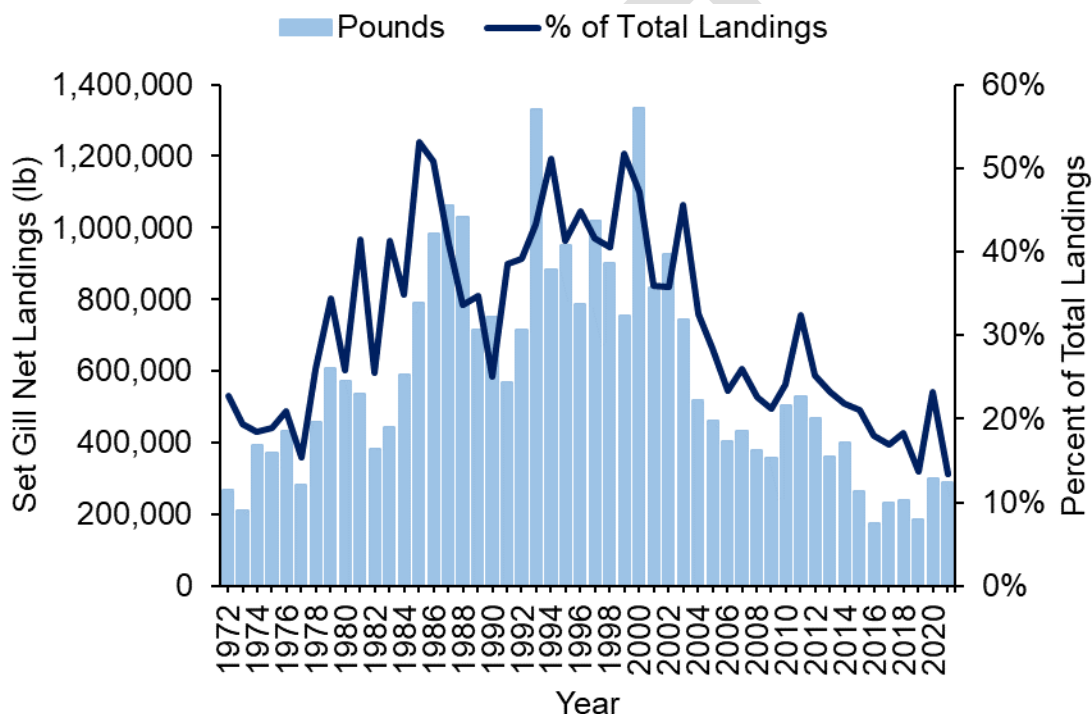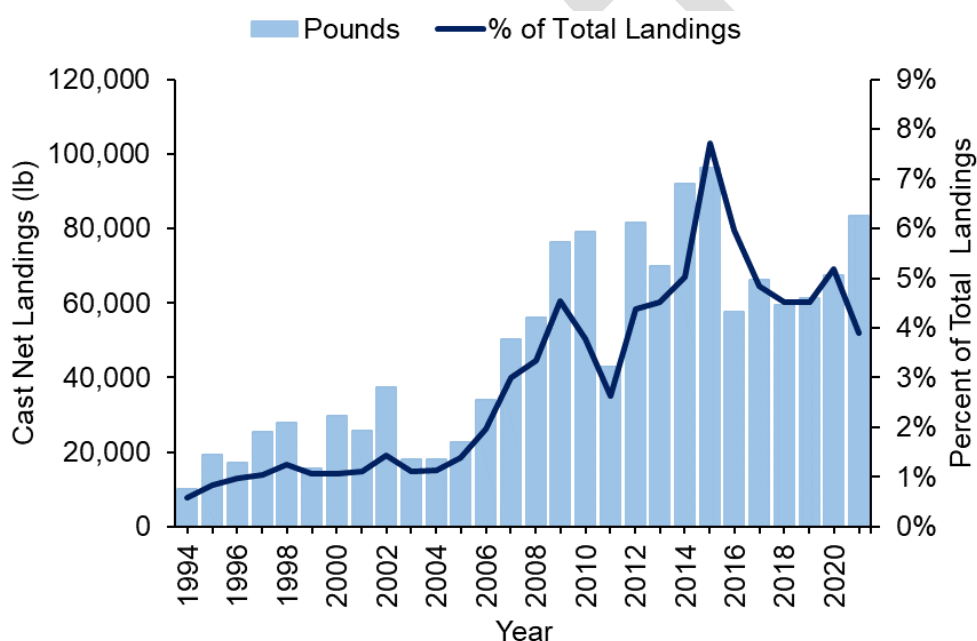

Figure 19. Pounds harvested using cast nets and percent of total landings harvested using cast nets by year in the North Carolina striped mullet commercial fishery for 1972 to 2021.

EFFECTS OF WEATHER ON FISHERY

Hurricanes occur frequently in eastern North Carolina, particularly in the fall during peak striped mullet fishing periods and may impact the striped mullet fishery, though impacts are inconsistent and largely influenced by timing of the hurricane. Hurricanes can damage fishing gear, prevent fishermen from fishing, and may cause striped mullet to leave the estuarine system earlier than normal (Burgess, et al. 2007). Increased migratory movement of striped mullet, sometimes referred to by fishermen as a "mullet blow", has also been associated with north or northwest winds and cold fronts (Jacot 1920, Apekin and Vilenskaya 1979, Mahmoudi, et al. 2001). Hurricanes and unseasonably warm fall water temperatures may delay or disrupt the usual timing of spawning migrations (Thompson, et al. 1991). However, hurricanes and unusual weather conditions are not the only causes of lower striped mullet landings, and the potential reduction in fishing mortality during hurricane years could have a positive effect on spawning stock biomass of the striped mullet stock in subsequent years (Burgess et al. 2007).

DRAFT

Striped Mullet Bycatch

Bycatch is the portion of the catch made up of species not being targeted on the fishing trip, captured because the gear is not selective enough or because of species and size differences. Bycatch can be divided into two categories: incidental catch and discarded catch. Incidental catch is retained, marketable catch of non-target species, while discarded catch is returned to the sea for regulatory, economic, or personal reasons. Fisheries most likely to encounter striped mullet bycatch include the set gill net and crab pot fisheries. Most striped mullet bycatch can be regarded as incidental catch and is not usually discarded unless it is unmarketable. Historically, there have not been regulations that would require striped mullet to be discarded in commercial fisheries, and striped mullet harvested incidentally can be used for food or bait, even outside of the roe fishery season.

SET GILL NET FISHERY
From 2011 to 2021, there were 1,150 anchored small mesh gill net trips observed by DMF of which 389 trips caught striped mullet (35% of observed trips). From these trips, a total of 7,874 striped mullet were caught and 46 were discarded (0.6% of mullet). During the same period, there were 4,439 anchored large mesh gill net trips observed of which 120 trips caught striped mullet (3% of observed trips). From these trips, a total of 166 striped mullet were caught and 25 were discarded (15% of mullet). From 2011 to 2021, there were no commercial harvest restrictions for striped mullet, so most striped mullet caught incidentally in set gill nets were kept and sold. Discarded fish are usually unmarketable. Set gill nets do not appear to be a source of significant striped mullet discarded bycatch.

CRAB POT FISHERY
From 2011 to 2021, annual landings of finfish bycatch (excluding crabs, shrimp, shellfish, and squids) from hard crab pots have averaged at about 1,800 pounds per year. Striped mullet are the eighth most common species overall and third most common finfish (not mollusk or crustacean) landed in crab pots by total weight. Striped mullet make up 11% of total finfish bycatch from hard crab pots by weight yet make up less than 1% of total hard crab pot landings. Annual total landings of striped mullet from hard crab pots averaged 6,054 pounds per year from 2011 to 2021. Striped mullet landings in peeler pots averaged 533 pounds per year during the same period and are the seventh most common species overall by weight landed in peeler pots. Striped mullet are the fourth most common finfish bycatch species by weight in peeler pots and make up about 4% of total finfish bycatch in peeler pots. Striped mullet make up less than 1% of total peeler pot landings.

BYCATCH IN TARGETED STRIPED MULLET FISHERIES
The two most important commercial fisheries in North Carolina that target striped mullet are the runaround gill net fishery and the stop net component of the beach seine fishery that occurs in Carteret County. From 2011 to 2021, Striped mullet have made up most landings by weight in both the runaround gill net fishery (70%) and the in the stop net fishery (89%). Other species harvested incidentally in the runaround gill net fishery include spotted seatrout (10% of total landings by weight), spot (4%), bluefish (4%), menhaden (2%) and red drum (2%). The remaining 8% of total runaround gill net landings from 2011 to 2021 were made up of 83 other species. Other species harvested incidentally in the stop net fishery include spotted seatrout (4% of total landings by weight), bluefish (2%), spot, (2%), and kingfishes (1%). The remaining 2% of total stop net landings from 2011 to 2021 were made up of 16 other species. The stop net component of the beach seine fishery that targets striped mullet has declined in importance over the past 30 years and striped mullet are no longer the top species landed in beach seines. In both targeted

striped mullet fisheries, the species commonly harvested as bycatch are marketable and not likely to be discarded unless regulations or the condition of the fish require them to be discarded.

RECREATIONAL CAST NET FISHERY

The 2006 Striped Mullet FMP (NCDMF 2006) examined the issue of large amounts of bait mullet harvested recreationally by cast net being discarded at the end of fishing trips, and the additional issue of fishermen harvesting large amounts of bait mullet in North Carolina and selling them in other states. Effective July 1, 2006, Marine Fisheries Commission Rule 15A NCAC 03M .0502 was amended to include section (b), which implemented a 200 mullet (white mullet and striped mullet in aggregate) per person per day recreational bag limit for striped mullet. This rule limited the number of bait mullet that may eventually be discarded at the end of fishing trips by recreational fishermen and addressed the issue of large amounts of bait mullet being sold in other states.

<u>Recreational Fishery</u>

Few anglers target striped mullet using hook and line gear; however, striped mullet and white mullet are popular bait fish for anglers targeting a variety of inshore and offshore species. Mullets are used as live, cut, and trolling baits (Nickerson Jr. 1984) and are commonly used by anglers fishing in the surf recreationally. Anglers using cast nets often catch young of the year 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 young of the year striped and white mullet. For more information about the North Carolina recreational striped mullet fishery and how recreational data are collected, please see the Recreational Harvest Information Paper (Appendix 3).

SUMMARY OF ECONOMIC IMPACT

Commercial landings and effort data collected through the DMF trip ticket program were used to estimate the economic impact of the commercial striped mullet fishery. For commercial fishing output, total impacts were estimated by incorporating modifiers from the NOAA Fisheries Economics of the United States report (NMFS 2021), which account for proportional expenditures and spillover impacts from related industries. By assuming the striped mullet fishery contribution to expenditure categories at a proportion equal to its contribution to total commercial ex-vessel values, estimates were generated of the total economic impact of the commercial striped mullet fishery statewide. Modeling software, IMPLAN, was used to estimate the economic impacts of the industry to the state at-large, accounting for revenues and participation. For a detailed explanation of the methodology used to estimate the economic impacts please refer to the latest <u>DMF License and Statistics Annual Report</u>.

From 2011 to 2021 striped mullet economic ex-vessel value has been about $1 million dollars, impacting about 9,000 jobs annually (Table 1). Annual sales impacts have varied over the described decade but averaged $3.5 million from 2011 to 2021 (Table 1). It is estimated the striped mullet fishery contributes to about 1% of commercial fishing sales impact.

The striped mullet commercial fishery is driven by seasonal changes in availability of the stock to commercial fisheries, coinciding with the migration of spawning adult fish from inshore waters through the inlets and into the ocean. Estimated changes in job impacts and sales impacts reflect the accessibility of the population to fishing throughout the year. Most of the economic impacts

are concentrated in October and November of each year when annual commercial harvest levels peak (Table 2).

Table 1 Annual estimates of commercial economic impact to the state of North Carolina from striped mullet harvest for 2011 to 2021.

Year	Pounds Landed	Ex-Vessel Value	Job Impacts	Income Impacts	Value-Added Impacts	Sales Impacts
2021	2,135,952	$ 1,273,639	12,106	$ 1,869,008	$ 3,521,559	$ 4,024,260
2020	1,299,464	$ 651,104	9,100	$ 1,357,820	$ 2,320,755	$ 2,968,469
2019	1,362,212	$ 940,747	7,539	$ 1,402,513	$ 2,629,596	$ 3,022,280
2018	1,312,121	$ 982,925	7,421	$ 1,539,201	$ 2,842,970	$ 3,324,933
2017	1,366,338	$ 1,095,476	8,602	$ 1,557,537	$ 2,964,234	$ 3,348,036
2016	965,337	$ 722,324	7,471	$ 1,038,377	$ 1,969,253	$ 2,233,376
2015	1,247,044	$ 878,666	8,005	$ 1,259,705	$ 2,391,057	$ 2,709,024
2014	1,828,351	$ 1,216,200	9,375	$ 1,748,458	$ 3,315,835	$ 3,760,652
2013	1,549,157	$ 1,558,612	10,930	$ 2,423,011	$ 4,485,190	$ 5,232,261
2012	1,859,587	$ 1,174,215	9,483	$ 1,902,954	$ 3,479,302	$ 4,117,409
2011	1,627,894	$ 1,168,822	8,443	$ 1,912,423	$ 3,486,877	$ 4,139,736
Average	1,504,860	$ 1,060,248	8,952	$ 1,637,364	$ 3,036,966	$ 3,534,585

Table 2. Monthly estimates of commercial economic impact to the state of North Carolina from striped mullet harvest for 2017 to 2021.

Month	Pounds Landed	Ex-Vessel Value	Job Impacts	Income Impacts	Value Added Impacts	Sales Impacts
January	93,518	$ 36,787.74	483	$ 55,122.56	$ 103,188.91	$ 118,813.91
February	68,261	$ 34,269.91	560	$ 51,349.20	$ 96,125.69	$ 110,681.67
March	45,331	$ 20,651.10	428	$ 30,942.78	$ 57,925.11	$ 66,696.75
April	42,875	$ 29,097.26	561	$ 43,599.54	$ 81,617.66	$ 93,976.05
May	45,283	$ 24,951.98	417	$ 37,387.80	$ 69,989.69	$ 80,587.72
June	57,684	$ 31,887.30	474	$ 47,779.04	$ 89,442.44	$ 102,986.47
July	79,218	$ 38,471.98	505	$ 57,645.44	$ 107,912.28	$ 124,253.08
August	120,815	$ 65,723.94	698	$ 98,480.57	$ 184,354.57	$ 212,269.67
September	135,479	$ 73,183.96	810	$ 109,657.51	$ 205,278.52	$ 236,362.79
October	623,868	$ 338,771.88	1,805	$ 507,611.74	$ 950,246.01	$ 1,094,135.29
November	392,134	$ 214,307.87	1,511	$ 321,117.07	$ 601,128.63	$ 692,152.90
December	77,310	$ 53,998.88	785	$ 80,911.09	$ 151,465.19	$ 174,400.68

It is difficult to determine the economic impact and importance of the North Carolina recreational striped mullet fishery because there is a lack of data, and the data are not precise; however, striped mullet are used as bait in several economically important recreational fisheries in North Carolina. Striped mullet are a common bait species for red drum and flounder and for fishing in the surf. Bait mullet are also commonly sold in tackle shops to recreational anglers and are likely an important product for local bait and tackle businesses.

ECOSYSTEM PROTECTION AND IMPACT

Coastal Habitat Protection Plan

The Fisheries Reform Act statutes require that a Coastal Habitat Protection Plan (CHPP) be drafted by the NCDEQ and reviewed every five years (G.S. 143B-279.8). The CHPP is a resource

and guide compiled by NCDEQ staff to assist the Marine Fisheries, Environmental Management, and Coastal Resources commissions in developing goals and recommendations for the continued protection and enhancement of fishery habitats in North Carolina. These three commissions are required by state law (G.S. 143B-279.8) to adopt and implement management strategies specified in the CHPP as part of a coordinated management approach. Habitat recommendations related to fishery management can be addressed directly by the MFC. The MFC has passed rules that provide protection for striped mullet habitat including the prohibition of bottom-disturbing gear in specific areas, and designation of sensitive fish habitat such as nursery areas and SAV beds with applicable gear restrictions. Habitat recommendations not under MFC authority (e.g., water quality management, shoreline development) can be addressed by the other commissions through the CHPP process. The CHPP helps to ensure consistent actions among these commissions as well as their supporting NCDEQ divisions. The CHPP also summarizes the economic and ecological value of coastal habitats to North Carolina, their status, and potential threats to their sustainability (NCDEQ 2016).

Striped mullet use different habitats depending on life stage, season, and location (Able and Fahay 1998, Pattillo, et al. 1999, Cardona 2000) and are found in most habitats identified in the CHPP including: water column, wetlands, submerged aquatic vegetation (SAV), soft bottom, and shell bottom (NCDEQ 2016). Striped mullet are found in almost all shallow marine and estuarine habitats such as beaches, tidal flats, lagoons, bays, rivers, channels, marshes, and grass beds (Moore 1974, Pattillo, et al. 1999, Nordlie 2000). These habitats provide striped mullet with the conditions they need for thriving and maintaining a healthy population. Growth and survival of striped mullet within the habitats they use are maximized when water quality parameters such as temperature, salinity, and dissolved oxygen are within optimal ranges. For further information about habitat use by life stage and optimal water quality parameters, see the DESCRIPTION OF THE STOCK section of this FMP. Additional information on the habitats discussed below, threats to these habitats, water quality degradation, and how these topics relate to fisheries can be found in the CHPP (NCDEQ 2016).

Threats and Alterations

Suitable habitat is a critical element in the ecology and productivity of estuarine systems. Degradation or improvement in one aspect of habitat may have a corresponding impact on water quality. All habitats used by striped mullet are threatened in some way.

Water column habitats in warm oceanic waters are used as spawning habitat for striped mullet. Coastal inlets act as critical water column habitat corridors for adult striped mullet to pass through during their annual spawning migrations out to the ocean, and for larvae to reach estuarine nursery areas. Terminal groins may threaten striped mullet stocks by obstructing inlet passage of striped mullet, impeding recruitment (Kapolnai, Werner and Blanton 1996, Churchill, et al. 1997, Blanton, et al. 1999). Inlets are also hydraulically dredged on a regular basis to ensure safe passage for vessels of all sizes, potentially entraining marine animals, particularly eggs and larval fishes that cannot avoid the suction field of the gear due to their reduced swimming abilities (Todd, et al. 2015). The DMF recommends an in-water-work moratorium from April 1 to July 30 to minimize impacts during peak biological activity; however, most projects are given moratorium relief in favor of public safety.

Soft bottom habitats act as important nursery, refuge and feeding areas for striped mullet. These habitats support zooplankton, detritus, algae, and benthic microorganisms that mullet eat during their early life stages. Dredging threatens soft bottom habitat by impairing water quality and temporarily removing benthic infauna from the areas, reducing food availability to bottom-feeding

species such as striped mullet (NCDEQ 2016). Soft bottom habitats in the surf zone of shallow ocean waters are also used by juvenile striped mullet and may act as transient habitats, orienting fish larvae into estuaries (Kinoshita, et al. 1988, Fujita, et al. 2002, Ross and Lancaster 2002). Beach nourishment projects can temporarily impact benthic prey availability in surf zone habitats, and the increased turbidity generated from beach nourishment projects can impact the growth and survival of marine organisms (Reilly and Bellis 1983, Lindquist and Manning 2001).

Submerged aquatic vegetation habitats are used by striped mullet as nursery, forage, and refuge habitats, where striped mullet feed on epiphytic algae and invertebrates that live on seagrasses and other structures (Odum 1968, M. R. Collins 1985a). Seagrass beds are threatened by physical destruction from bottom disturbing fishing gear, dredging, damage from boat use, and water quality degradation. Shell bottom habitats such as oyster reefs are used as forage habitat for striped mullet (Bliss, et al. 2010) and can be damaged by bottom-disturbing fishing gears, disease, and overfishing. Freshwater and estuarine wetlands, especially surrounding estuarine rivers and marshes, are used transiently by juvenile striped mullet for foraging, refuge, and nursery habitat (Peterson and Turner 1994). Wetlands are threatened by many human activities, including dredging for marinas and channels, filling for development, and ditching and draining for agriculture, silviculture, channelization, and shoreline stabilization.

For more information about these habitats and how they are managed, please refer to the CHPP (NCDEQ 2016).

WATER QUALITY DEGRADATION
Good water quality is essential, both for supporting the various life stages of striped mullet and for maintaining their habitats. Naturally occurring and anthropogenic activities can alter salinity and temperature conditions or elevate levels of toxins, nutrients, and turbidity, as well as lower dissolved oxygen levels, which can degrade water quality and impact striped mullet survival. Water quality degradation through stormwater runoff, discharges, toxic chemicals, sedimentation, and changes in turbidity can threaten striped mullet survival. There are increasing concerns about declining water quality and the influence it is having on habitats such as SAV, shell bottom, and wetlands. Studies have found that macroalgal biomass is directly related to increased nutrient levels and that SAV loss is greater with increased macroalgae (Valiela, et al. 1997). Once macroalgal blooms die, they decompose rapidly, increasing nutrient levels in the water column, stimulating phytoplankton production, further reducing light, and decreasing dissolved oxygen in the water and sediments. These have all been important factors in the decline of SAV up and down the Atlantic seaboard (Hauxwell, et al. 2000).

The 2021 CHPP Amendment includes priority issues with elements of improving water quality, including "Protection and Restoration of Submerged Aquatic Vegetation (SAV) through Water Quality Improvements" and "Protection and Restoration of Wetlands through Nature-based Solutions". Both of these priorities may benefit the North Carolina striped mullet stock. Striped mullet use all three habitats targeted in the amendment throughout their life history, especially wetlands. The recommended actions are expected to not only improve these habitats but strengthen coastal community and ecosystem resilience, bolstering the ability of these habitats to provide ecosystem services and support stocks of economically important marine species such as striped mullet. In 2023, the North Carolina Environmental Management, Marine Fisheries, Coastal Resources, and Soil & Water Conservation commissions unanimously adopted the resolution crafted by the Stakeholder Engagement for Collaborative Coastal Habitats Initiative (SECCHI) workgroup advocating for increased funding for the voluntary cost-share programs that will help landowners protect their property and significantly reduce nutrient loading in North Carolina's coastal waters.

More detailed information on water quality degradation, including the topics of hypoxia, toxins, and temperature in North Carolina and effects on fish stocks can be found in the NCDWQ guides on the NCDWQ website: NCDWQ Water Quality Information (NCDWQ 2000, NCDWQ 2008) and in the CHPP (NCDEQ 2016). More information about the water quality requirements for striped mullet can be found in the DESCRIPTION OF THE STOCK section of this FMP.

<u>Gear Impacts on Habitat</u>

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

The primary gears used in the striped mullet commercial fishery are gill nets (runaround, and set), beach seines, and cast nets. In the recreational fishery, cast nets are the primary gear. Other gears that may harvest striped mullet as incidental catch include pounds nets, crab pots, drift gill nets, and fyke nets. Many gears that interact with striped mullet are static (Barnette 2001, NCDEQ 2016) and generally have minimal impact on habitat.

Beach seines and runaround gill nets are both mobile and may disturb local habitats. Impacts from mobile bottom-disturbing fishing gears such as seines and runaround gill nets include changes in community composition from the removal of species and physical disruption of the habitat (Barnette 2001). Gears may damage or uproot SAV as they are dragged across the seafloor, potentially reducing productivity of these habitats and destroying the structures that provide feeding surfaces and shelter for striped mullet (NCDEQ 2016). Gears that drag across the seafloor may also suspend sediments, temporarily increasing turbidity (Corbett, et al. 2004) and reducing clarity, SAV growth, productivity, and survival (NCDEQ 2016). Sediment suspended by bottom disturbing fishing gears and boat propeller wash may also bury SAV (Thayer, Kenworthy and Fonseca 1984), degrading habitat quality and reducing productivity.

Despite the potential impacts, it has been determined that the bottom impact from actively fished gill nets represent a low disturbance and that impacts from boat propellers during side-setting are likely more significant (Kimel, Corbett and Thorpe 2010). Beach seines are used to encircle schools of fish and may scrape the seafloor with a lead line as they are fished along the beach. The impact of beach seines on habitat is unknown but is likely minor due to the high-energy nature and typical sediment disruption of the surf zone where beach seines are used. Bottom impacts from active gill net fishing and seining are likely to be greater in low energy environments such as bays and creeks than in open high energy areas such as rivers, large sounds, and the surf zone of the ocean. Cast nets do not usually disturb habitat as they are fished in the water column. Crab pots are weighted and rest on the bottom, so they can smother SAV and are capable of ghost fishing if lost or abandoned.

PROTECTED SPECIES INTERACTIONS

Protected species include a variety of animals that are protected by federal or state statutes because their populations are at risk or vulnerable to risk of extinction. Several protected species occur in North Carolina, including diamondback terrapins (*Malaclemys terrapin*), migratory birds, five species of sea turtles, bottlenose dolphins (*Tursiops truncates*), and two species of sturgeon. Entanglement gears such as the gill nets used in some commercial striped mullet fisheries are size-selective; however, gill nets are capable of unintentionally capturing larger, non-targeted species. For more information about protected species in North Carolina, their interactions with

fishing gear, and how the DMF monitors interactions between protected species and commercial fisheries, please refer to the DMF [Observer Program website](). Interactions between protected species and the stop net fishery in Bogue Banks that targets striped mullet are monitored by the National Oceanic and Atmospheric Administration (NOAA).

Climate Change and Resiliency

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

Increasing temperatures could also impact the distribution of finfish and invertebrate populations and the coastal habitats they use. It has been predicted that hundreds of finfish and invertebrate species will be forced to move northward due to increasing temperatures caused by climate change (Morley, et al. 2018). North Carolina already exhibits one of the greatest northward shifts in commercial fishing effort, with average vessel landings occurring 24 km further north each year (Dubik, et al. 2019).

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

FINAL STRIPED MULLET AMENDMENT TWO MANAGEMENT STRATEGY

The NCMFC selected management measures:

APPENDIX 2: ACHIEVING SUSTAINABLE HARVEST IN THE NORTH CAROLINA STRIPED MULLET FISHERY

1. Implement a Saturday through Sunday commercial harvest closure for January 1 through September 30 and a Saturday through Monday closure for October 1 through December 31 to achieve a 34.9% reduction in harvest relative to 2019 commercial landings.

2. Status Quo – Manage stop net fishery with management measures applied to the rest of the commercial fishery.
3. Adopt an Adaptive Management Framework:
   Parts 1-3 of the adaptive management framework are explicitly tied to an updated stock assessment and implementation of management measures intended to reduce or allow for additional harvest to meet or maintain management targets (as defined in part 1.a).

   1) Update the stock assessment at least once in between full reviews of the FMP, timing at discretion of the division
      a. If current management is not projected to meet management targets (management targets are minimum SSB between $SSB_{Threshold}$ and SSB_{Target}, and maximum F between $F_{Threshold}$ and F_{Target}), then management measures shall be adjusted via an adaptive management update and implemented using the Fisheries Director's proclamation authority to reduce harvest to a level that is projected to meet the F_{Target} and SSB_{Target}.
      b. If management targets (as defined in 1.a above) are being met, then new management measures would not be needed, or current management measures could possibly be relaxed provided projections still meet management targets. When management targets are met, a striped mullet industry workgroup will be convened to discuss the possibility of "guard rail management" to maintain a sustainable harvest for the striped mullet stock.
   2) Management measures that may be adjusted using adaptive management include:
      a. Season closures
      b. Day of week closures
      c. Trip limits
      d. Gill net yardage or mesh size restrictions in support of the measures listed in a-c
   3) Use of the Director's proclamation authority for adaptive management to meet management targets is contingent on:
      a. Consultation with the MFC Northern, Southern, and Finfish advisory committees
      b. Approval by the Marine Fisheries Commission

Part 4 of the adaptive management framework allows for adjustment of management measures outside of an updated stock assessment. Part 4 is intended to allow for adjustment of management measures to ensure compliance with and effectiveness of management strategies adopted in Amendment 2 and would be a tool to respond to concerns with stock conditions and fishery trends.

   4) Upon evaluation by the division, if a management measure implemented to achieve sustainable harvest (either through Amendment 2 or a subsequent revision) is not achieving its intended purpose, it may be revised or removed and replaced using the Director's proclamation authority; provided it conforms to part 2 above and provides similar protections to the striped mullet stock. If a revised management measure is anticipated to reduce or increase harvest compared to measures implemented through Amendment 2, it must conform to parts 2 and 3 above.

APPENDIX 3: CHARACTERIZATION AND MANAGEMENT OF THE NORTH CAROLINA RECREATIONAL STRIPED MULLET FISHERY

1. Recreational Individual Bag Limit of 100 Fish and Vessel Limit of 400 Fish.

2. Exception for For Hire Vessel Operations to Possess a Bag Limit for the Number of Anglers Fishing Up to the 400-fish Maximum (Including in Advance of a Trip).

RESEARCH NEEDS

The research recommendations listed below are offered by the division to improve future management strategies of the striped mullet fishery. They are considered high priority as they will help to better understand the striped mullet fishery and meet the goal and objectives of the FMP. A more comprehensive list of research recommendations is provided in the Annual FMP Review and DMF Research Priorities documents.

- Explore effects of offshore and nearshore environmental conditions and climate change on the North Carolina striped mullet stock, including potential changes in recruitment and sex ratios.
- Explore effects of modified shorelines (e.g., beach renourishment projects, hardened shorelines, and development) on striped mullet food sources and habitats.
- Conduct a striped mullet tagging study, including acoustic and satellite tags, to explore movement patterns and range of striped mullet found in North Carolina.
- Repeat and expand the cast net study conducted by the Division in the early 2000s, including use of various net and mesh sizes to characterize cast net effort and catch by net size, mesh size, and user group in the recreational fishery.
- Explore market price drivers for striped mullet in North Carolina, including exploration of the link between fishing target species, market prices, and fisher behavior.

DRAFT

Appendix 1: SMALL MESH GILL NET CHARACTERIZATION IN THE NORTH CAROLINA STRIPED MULLET FISHERY

Issue

The estuarine small mesh gill net fishery in North Carolina is managed and regulated by North FMPs and numerous MFC rules and North Carolina DMF proclamations. However, concerns about biological impacts from the use of small mesh gill nets remain. The primary issues to be addressed concern greater flexibility with constraining harvest in the striped mullet fishery, reducing bycatch, and to the greatest extent practical reducing conflict between gill net users and other stakeholders. Specific management options for gill net regulations can be found in Appendix 2: Sustainable Harvest Issue Paper.

Origination

The North Carolina Marine Fisheries Commission.

Background

At their August 2021 business meeting, the MFC passed a motion to not initiate rulemaking on small mesh gill nets but refer the issue through the FMP process for each species, and any issues or rules coming out of the species-specific FMP to be addressed at that time. In North Carolina, small mesh gill nets are the predominant gear used to harvest striped mullet. Most striped mullet are harvested commercially using runaround or other actively fished gill nets. Per direction from the MFC, small mesh gill nets must be addressed during review of the striped mullet FMP.

North Carolina General Statutes authorize the MFC to adopt rules for the management, protection, preservation, and enhancement of the marine and estuarine resources within its jurisdiction (G.S. 113-134; G.S. 143B-289.52). The MFC has authority to adopt FMPs and the DMF is charged with preparing them (G.S. 113-182.1; G.S. 143B-289.52). Further, the MFC may delegate to the DMF director in its rules the authority to issue proclamations suspending or implementing MFC rules that may be affected by variable conditions (G.S. 113-221.1; G.S. 143B-289.52). Variable conditions include compliance with FMPs, biological impacts, bycatch issues, and user conflict, among others (15A NCAC 03H .0103). The estuarine gill net fishery in North Carolina is managed and regulated by FMPs and numerous MFC rules and DMF proclamations. Rules are periodically amended to implement changes in management goals and strategies for various fisheries and are the primary mechanism for implementing FMPs under the Fisheries Reform Act of 1997 (FRA).

In recent years, modifications to gill net management resulting from the adoption of FMPs or other circumstances have largely been implemented through the DMF director's proclamation authority, not through rulemaking. This is primarily due to the need to implement management changes in a timely fashion and to accommodate variable conditions. Over time, this has resulted in incongruent restrictions between rules and proclamations. Additionally, many of the rules related to small mesh gill nets were first developed prior to the FRA and have not been thoroughly evaluated since the addition of more recent rules developed through the FMP process.

The striped mullet small mesh gill net fishery operates year-round, but the type of gill net used varies by season and area (NCDMF 2018). Multiple species may be landed during a single trip; however, the target species usually dominates the catch (NCDMF 2008). In North Carolina, gill nets are restricted to a minimum mesh size of 2.5 inches stretched mesh (ISM) (15A NCAC 03J .0103 (a)). The DMF categorizes gill nets with ISM from 2.5 to less than 5 inches as small mesh (Daniel 2013). Although the rule uses "mesh length" and not "mesh size", their meanings are

identical for the purpose of this document; this helps to demarcate the discussion of "mesh size" from "net length" throughout the document. Small mesh gill nets are generally classified into three categories based on how the net is deployed and fished: set gill nets, runaround gill nets, and drift gill nets (Figure 1.20; Table 1.1; (Steve, et al. 2001)). For this document, "set" gill nets, or "set nets", includes anchored, fixed, and stationary nets.
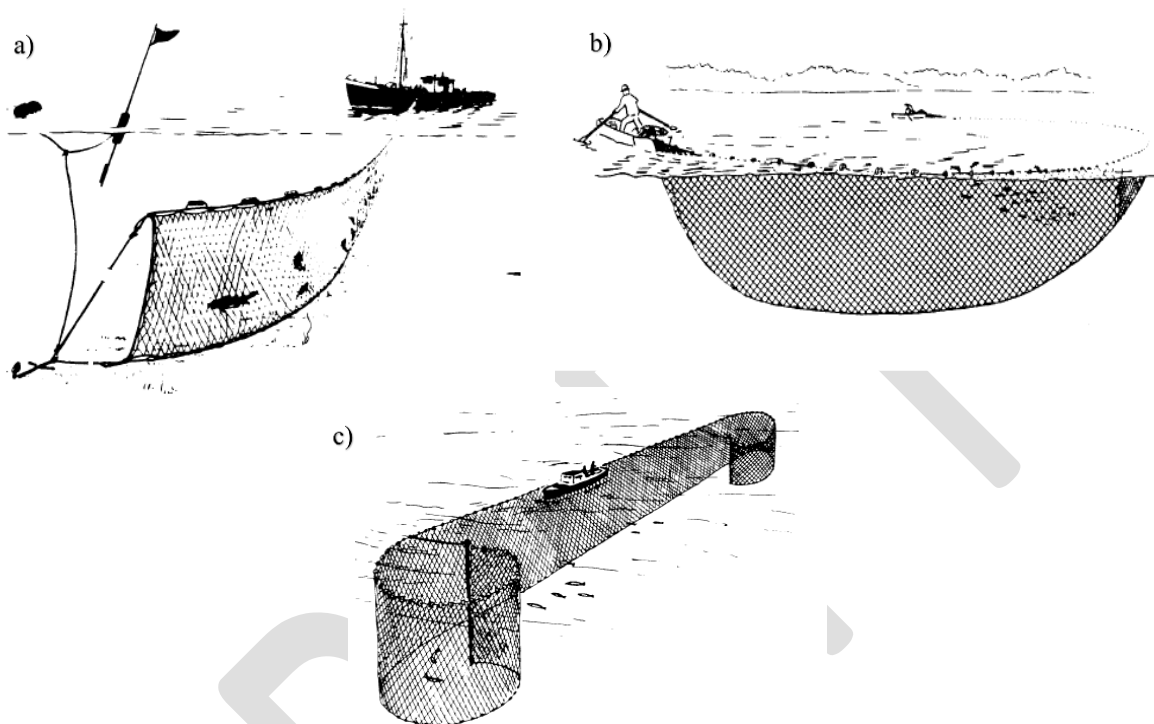
Figure 1.20. Illustrations of (a) set, (b) runaround, and (c) drift gill nets extracted from Steve et al. (2001).

Set nets (Figure 1.1a) are the second most common gill net method used for commercial striped mullet harvest in North Carolina. They are kept stationary with the use of anchors or stakes attached to the bottom or attached to some other structure attached to the bottom, at both ends of the net (15A NCAC 03I .0101). Set nets can be further classified as sink or float gill nets (Steve et al. 2001). A sink gill net fishes from the bottom up into the water column a fixed distance by having a lead line (bottom line) heavy enough to sink to the bottom. Depending on the height of the net and the depth of the water, the float line (top line) may or may not be submerged below the surface of the water. A float gill net may fish the entire water column by having the top line with buoys sufficient for floating on the surface of the water, or a portion of the water column depending on the depth of the net (number of meshes deep). Set nets are deployed by dropping one end of the net and running out the rest of the length of net usually in a line. Once deployed, soak times for fishing set nets vary depending on factors such as target species, water temperature, season, waterbody, and regulations (NCDMF 2018).

A runaround gill net is the most common gill net method used for commercial striped mullet harvest in North Carolina. It is an actively fished gear used to encircle schools of fish (Figure 1.1b). They are deployed with a weight and a buoy at one end that enables the rest of the net to be fed out, creating a closed circle around the school of fish due to the vessel's path. Runaround gill nets tend to be deep nets capable of fishing the entire water column. Mesh sizes and net lengths vary depending on the size of the targeted species (Steve et al. 2001). Another form of

runaround gill net is the strike net or drop net. Rather than deploying the net in a circle, the net is set parallel to shore, often with one end anchored to the bank. Once the net is set, the boat is driven between the net and the shore to drive fish into the net (NCDMF 2018). Soak times for all types of runaround gill nets are almost always an hour or less.

Table 1.3. Small mesh gill net gear categories with descriptions and capture method descriptions.

Small Mesh Gill Net Gear Categories	Sub-Categories	Gear Description	Capture Method
Anchored/Fixed /Stationary/Set	Sink	Attached to bottom or some other structure by anchors or stakes at both ends. Sink nets are fished from the bottom up into the water column.	Passively Fished - For both sink and float set nets the gear is left in place for a period of time. Fish, if appropriately sized, swim into the net and are gilled.
	Float	Attached to bottom or some other structure by anchors or stakes at both ends. Float nets are fished from the top down into the water column. Depending on target species nets fish part of the water column or the entire water column.	
Runaround	Circle	Attached to the bottom at one end. Once the end is set, the rest of the net is then fed out of a boat creating a circle and meeting back at the original set point. Generally, these nets fish the entire water column.	Actively Fished - Used to encircle a school of fish. Primary target species for this gear is striped mullet.
	Strike/Drop	Attached to the bottom at one end. Deployed along shore with the terminal end finishing at another point along the shore. The boat is driven into the blocked section to "drive" the fish into the net and are then retrieved.	Actively Fished - Used to corral or intercept a school of fish and then immediately retrieve. Primary target species for this gear is striped mullet, and spotted seatrout to a lesser extent.
Drift		Attached to boat or free-floating with close attendance. Lighter leadlines and no anchors allow the net to drift. Depending on target species and water depth, nets fish part of the water column or the entire water column. Primarily used in Pamlico Sound to target Spanish mackerel and bluefish.	Actively Fished - Drift with the water current with continuous attendance.

Drift gill nets are unanchored, non-stationary nets that are actively attended (i.e., remain attached to the vessel or the fishing operation remains within 100 yards of the gear) (Figure 1.1c) and tend to have shorter soak times than set nets. They are constructed with lighter lead lines to allow for the net to drift with the current. The small mesh drift gill nets currently employed in North Carolina estuaries are primarily used to target Spanish mackerel and bluefish in Pamlico Sound. This gear can also be used to target spot (as a sink net) and striped mullet (typically fishing the entire water

column) in areas primarily from Core Sound and south (Steve et al. 2001). Drift nets account for less than 0.5% of striped mullet landings.

METHODS

Information specific to the North Carolina estuarine gill net fishery was gathered from two DMF sampling programs briefly described below:

N.C. Trip Ticket Program

The N.C. Trip Ticket Program began in 1994. This program requires licensed commercial fishermen to sell their catch to licensed fish dealers, who are then required to complete a trip ticket for every transaction. Data collected on trip tickets include gear type, area fished, species harvested, and total weights of each species. Information recorded on trip tickets for gear type and characteristics is self-reported by the dealer. This information may be verified by DMF fish house staff after the fact, but the potential exists that some trips may be mischaracterized by dealers. In 2004, trip tickets included mesh size categories for gill nets: small mesh = <5 inch ISM, and large mesh = >5 inch ISM. However, the use of this new field was not prevalent until about 2008 because dealers were still using old trip tickets they had on hand.

Commercial Fish House Sampling

Commercial fishing activity is monitored through fishery dependent (fish house) sampling. Sampling occurs dockside as fish are landed. Commercial fishermen and/or dealers are interviewed by DMF staff, and the catch is sampled. Samplers collect data on location fished, effort (soak time, net length, etc.), gear characteristics (net type, net depth, mesh size, etc.), and the size distribution of landed species.

Commercial Observer Program

On board observations of commercial estuarine gill nets, primarily set nets, occur through Program 466. Observers collect data on effort (soak time, net length, etc.), location fished, gear characteristics, size, and the fate (harvest, discard, etc.) of captured species. The Observer Program was born out of the need to estimate incidental takes of protected species such as sea turtles and Atlantic sturgeon in estuarine set nets per the Endangered Species Act Section 10 Incidental Take Permits (NMFS 2013, 2014). As a result, observations of runaround or drift gill nets are rare.

The following analysis and information are presented to characterize the striped mullet small mesh gill net fishery in North Carolina relative to time, area, configuration, and species composition of the harvested and discarded catch:

Data from 1994 through 2021 or 2017 through 2021 for these three programs were used to characterize the North Carolina striped mullet small mesh gill net fisheries depending on the analysis conducted. Using trip ticket data, trips where striped mullet were the species of highest abundance in landings were considered targeted striped mullet trips. These trips were then defined as either small mesh or large mesh. Basing analysis on trips where striped mullet are the presumed target species allows for results that describe the gear parameters associated with the directed striped mullet fishery (see NCDMF 2008 for further description of methodology). Once targeted mullet trips were identified, the method of fishing (set net, runaround gill net, or drift gill net), mesh size, and net length were characterized based on available fish house sampling data from 1994 through 2021 or 2017 through 2021 for each of the target species depending on the analysis conducted.

Regional analysis of the striped mullet small mesh gill net fishery was investigated by county of landing. The coastal counties were grouped into regions using distinct area boundaries or clear differences in fishing practices (Figure 1.2). All other counties within the state with landings were grouped into the "other" region.
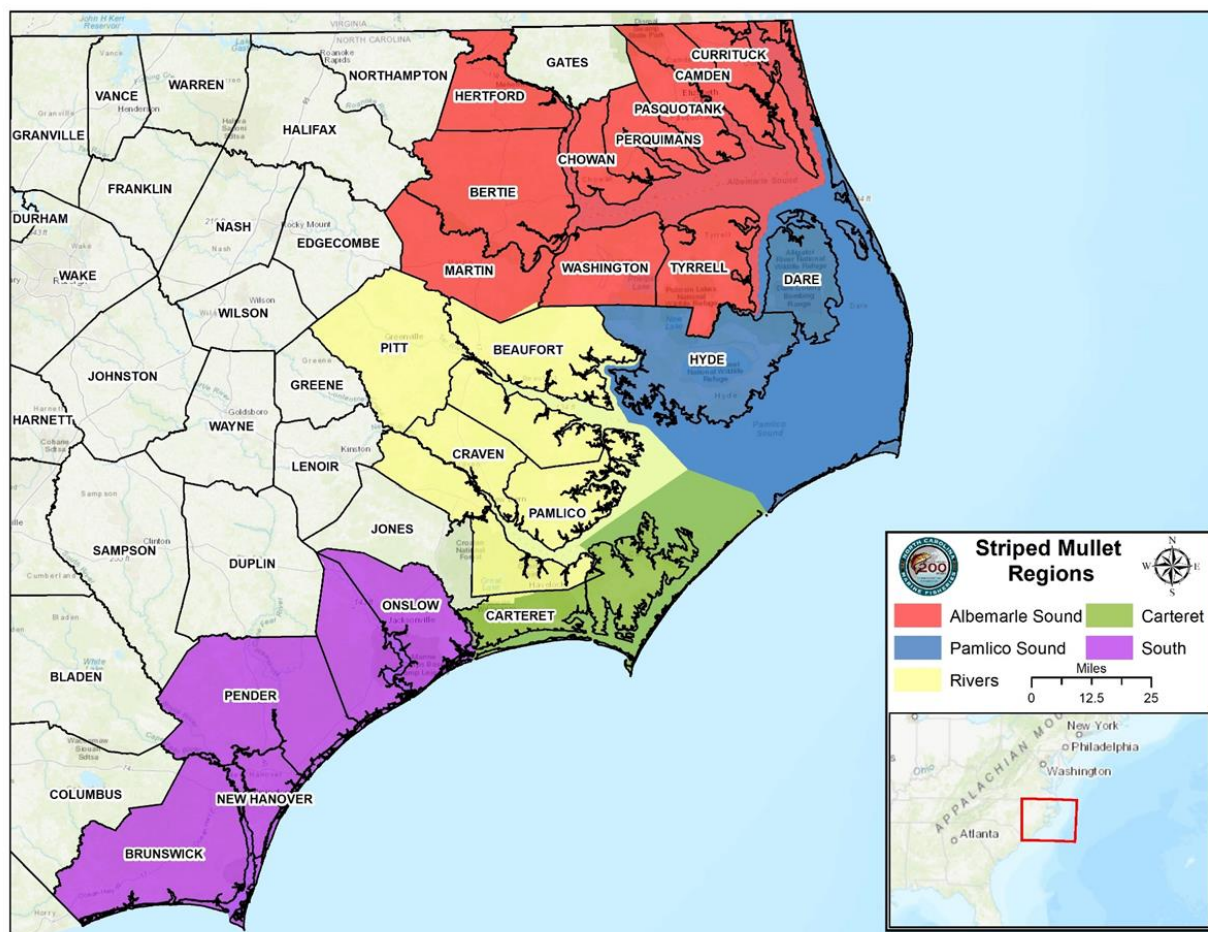
Figure 1.2. Map of defined regions used for regional characterization of the striped mullet small mesh gill net fishery.

RESULTS

For information regarding characterization of small mesh gill nets across all fisheries in North Carolina please refer to the Small Mesh Gill Net Rule Modifications Information Paper presented to the MFC at its August 2021 business meeting.

Striped Mullet Fishery General Characterization

Historically, beach seines and gill nets were the two primary gear types used in the striped mullet commercial fishery, with most commercial landings prior to 1978 coming from the beach seine fishery. Gill nets (runaround, set, and drift) replaced seines as the dominant commercial gear type in 1979 and since 2017 runaround gill nets have accounted for most (>70%) striped mullet commercial landings (Figure 1.3). Since the trip ticket program was initiated in 1994, the striped mullet fishery has shifted from a fairly even mix of set gill net and runaround gill net landings, to one strongly dominated by runaround gill net landings (Figure 1.4).

Because the commercial fishery primarily targets striped mullet for roe, the fishery is seasonal with the highest demand and landings occurring in October and November when large schools form during their spawning migration to the ocean and females are ripe with eggs (Figure 1.5). During this time, runaround gill nets are the primary gear used to harvest striped mullet. After the spawning migration striped mullet are no longer found in large aggregations, making runaround gill nets a less effective gear for harvest. Subsequently, from December through April set gill nets become a much more important gear used in the fishery (Figure 1.6). During this time, striped mullet may be harvested in set gill nets targeting the species, or as incidental catch in other targeted small mesh gill net fisheries such as white perch in the Albemarle Sound.

Mesh size is the most important gear parameter that affects the size of striped mullet caught in small mesh gill nets. As stretched mesh size increases, the average size of the striped mullet increases (Figure 1.7). Fishermen use stretched mesh sizes ranging from 2.75 ISM to 4.5 ISM to target striped mullet in North Carolina. This relationship between mesh size and size of striped mullet captured makes it feasible to use mesh size restrictions to protect or select for different sized striped mullet. Mesh size restrictions would be best used in conjunction with striped mullet size restrictions to ensure minimal discards. For more information on possible management applications of mesh size restrictions, see Appendix 2. Sustainable Harvest Issue Paper.
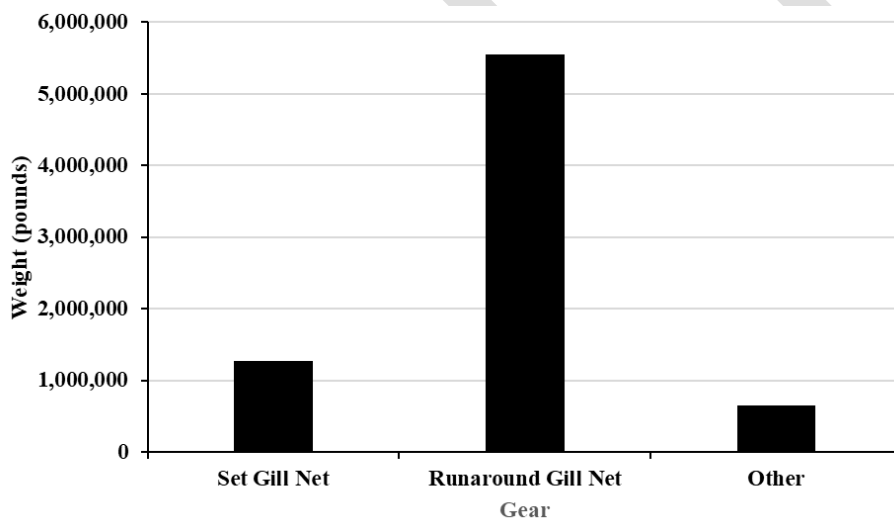
Figure 1.3. Percent of striped mullet commercial landings reported through the North Carolina Trip Ticket Program by gear, 2017–2021.

Figure 1.4. Percentage of striped mullet commercial landings by year and gear reported through the North Carolina Trip Ticket Program by gear, 1994–2021.
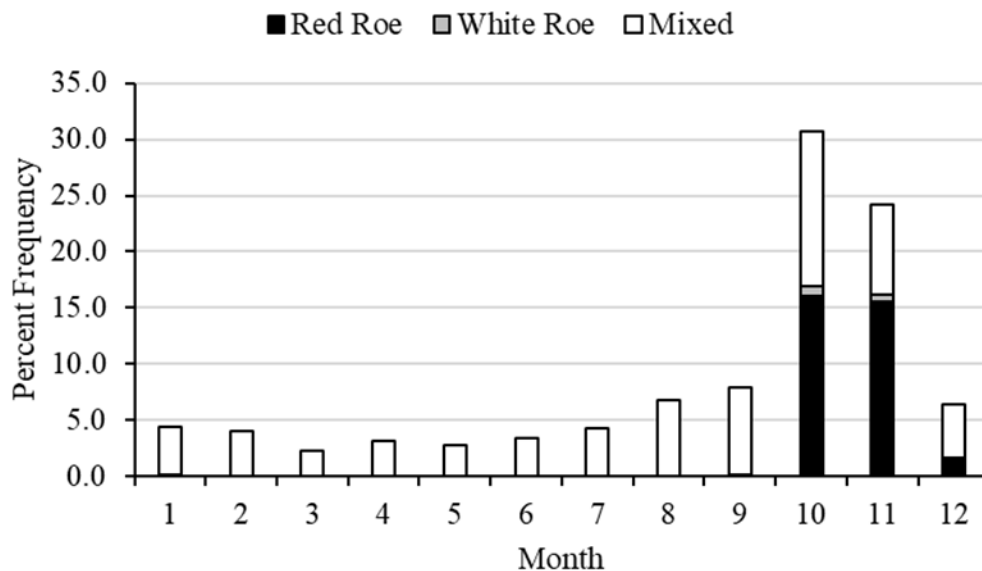
Figure 1.5. Percent frequency of striped mullet commercial landings by market grade and month, 2017-2021. Red Roe includes striped mullet graded as Red Roe and Roe. White Roe includes striped mullet graded as White Roe. Mixed includes striped mullet graded as Jumbo, Large, Medium, Mixed, Small, and X-Small.

Figure 1.6. Percentage of striped mullet commercial landings by month and gear reported through the North Carolina Trip Ticket Program by gear, 2017–2021.
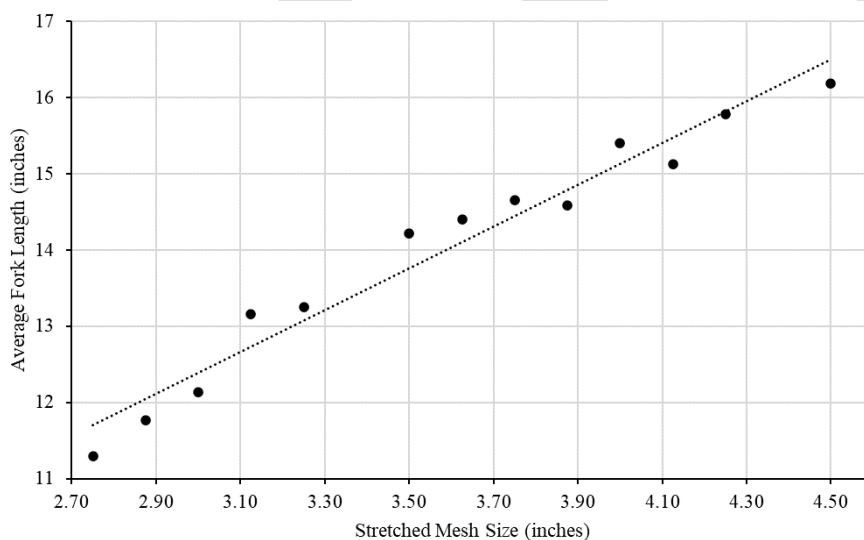
Figure 1.7. Relationship of stretched mesh size versus average fork length of striped mullet captured using data from the commercial fish house sampling program (1991-2021). A trendline and R squared value are provided for reference.

Regional Characterization

In the mid-1990s, the striped mullet small mesh gill net fishery was split between the Pamlico Sound, Carteret, and South regions (Figure 1.8). Since then, the fishery has experienced an expansion and retraction in the Rivers region, a contraction in the South region, and a small expansion in the Albemarle Sound region. These shifts in regional contribution have led to a fishery that is currently dominated by the Pamlico Sound and Carteret regions. These two regions have made up over 70% of the total striped mullet small mesh gill net fishery since 2017. The expansion of the fishery in the Albemarle region has been largely driven by the development of a

small mesh set gill net fishery for white perch where striped mullet are primarily captured incidentally. Set gill nets make up over 80% of striped mullet landings in this region (Figure 9). Runaround gill nets strongly dominate the fishery in the rest of the state.
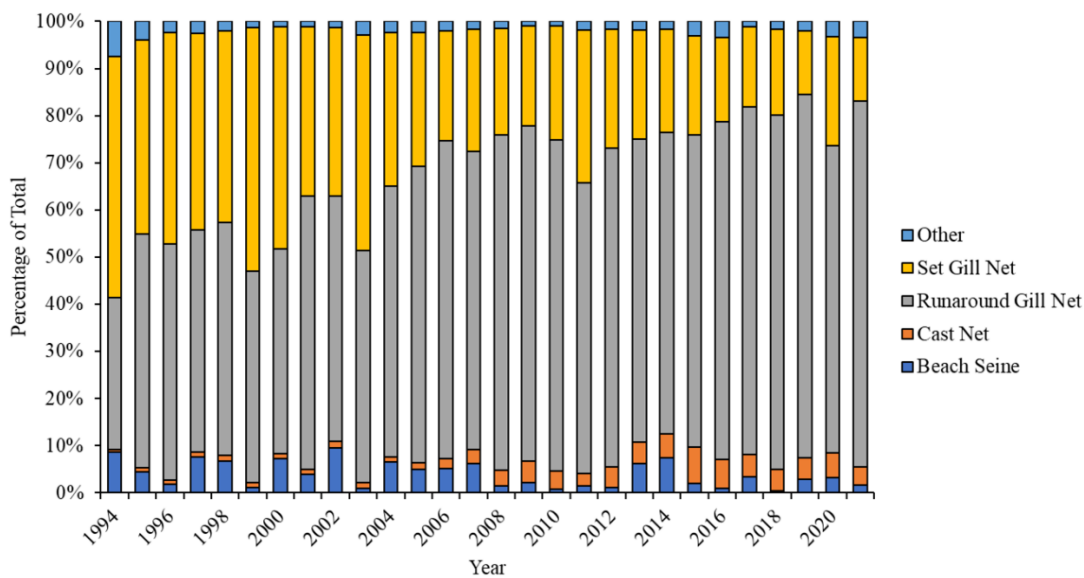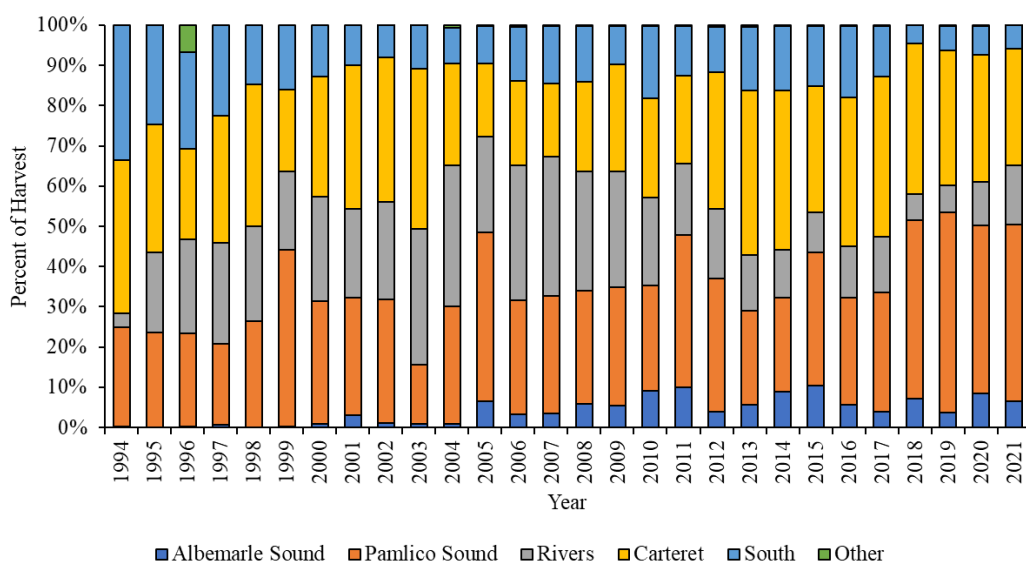

Figure 1.8. Percentage of striped mullet commercial landings by region and year reported through the North Carolina Trip Ticket Program, 1994–2021.

Set gill nets

Striped mullet are the third most important species targeted in the North Carolina small mesh set gill net fishery behind bluefish and spotted seatrout (Figure 1.9). They make up the largest proportion of monthly set gill net trips in November and December.

Set small mesh gill nets are the second most common gear used to capture striped mullet (Figures 1.3 - 1.4) in North Carolina and are the dominant gear in the Albemarle Sound region (Figure 1.10). Striped mullet are primarily landed incidentally in the set gill net fishery. They are typically not targeted with set gill nets as they move around in schools that are more easily targeted with runaround gill nets. Since 1994 use of set gill nets to target striped mullet has declined as both trips made and participants in the fishery have waned (Figure 1.11). This decline in participants and trips matches well with the decreased landings and increase in runaround gill net dominance in the striped mullet fishery over the same time period.

Set gill nets tend to be a low volume fishery for striped mullet. The average trip lands just over 76 pounds of striped mullet (Figure 1.12). Nearly 60% of set gill net trips that target striped mullet land less than 100 pounds. However, the 42% of trips that land more than 100 pounds account for over 80% of the total set gill net landings (Figure 1.13). The modal mesh size used to catch striped mullet in the set gill net fishery was 3.5 ISM (Table 1.2). Average total net length was 567 yards, with a maximum of 3,000 yards. Over 45% of all set gill net trips fished more than 500 yards (Figure 1.14). For reference, small mesh gill nets are currently restricted to a maximum of 800 yards. Yardage restriction could be an effective way to reduce harvest in this fishery. Yardage restrictions would be best used in conjunction with trip limits to ensure minimal discards. For more information on possible management applications of set gill net yardage restrictions, see Appendix 2.

Figure 1.9. Percentage of total set gill net trips for each of the 10 primary target species across months in N.C. waters during 2017-2021.
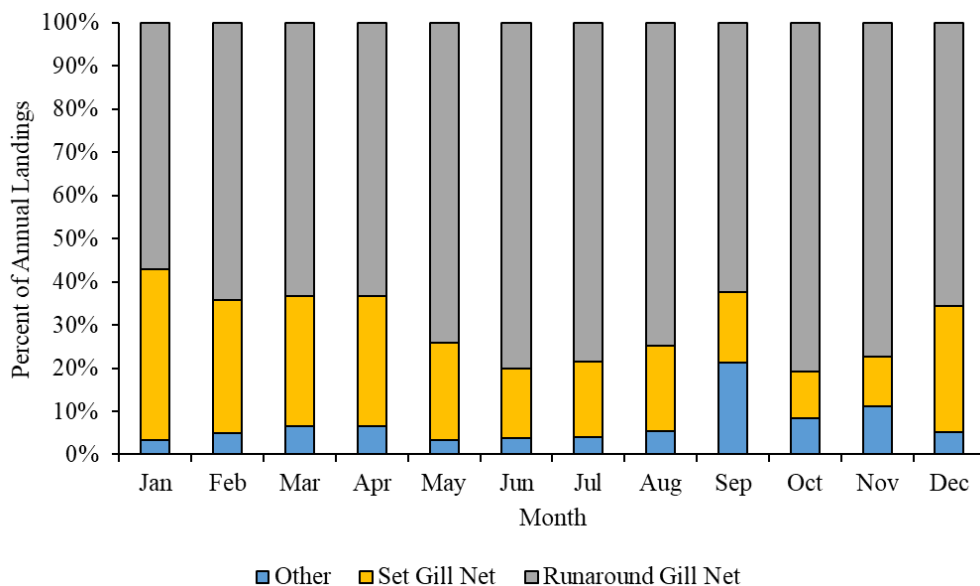

Figure 1.10. Percentage of annual striped mullet commercial landings by gear and area reported through the North Carolina Trip Ticket Program by gear, 2017–2021.

Figure 1.11. Targeted trips and participants in the set small mesh gill net striped mullet fishery by year reported through the North Carolina Trip Ticket Program by gear, 1994–2021.

Table 1.2. Small mesh (<5 inch ISM) set net trips in North Carolina using data from the N.C. Trip Ticket Program with associated gear characteristics from fish house, 2017-2021.

Species	Trips	Avg/Yr	Modal Mesh	Avg Yds	Max Yds
Striped mullet	14,282	2,856	3.5	567	3,000
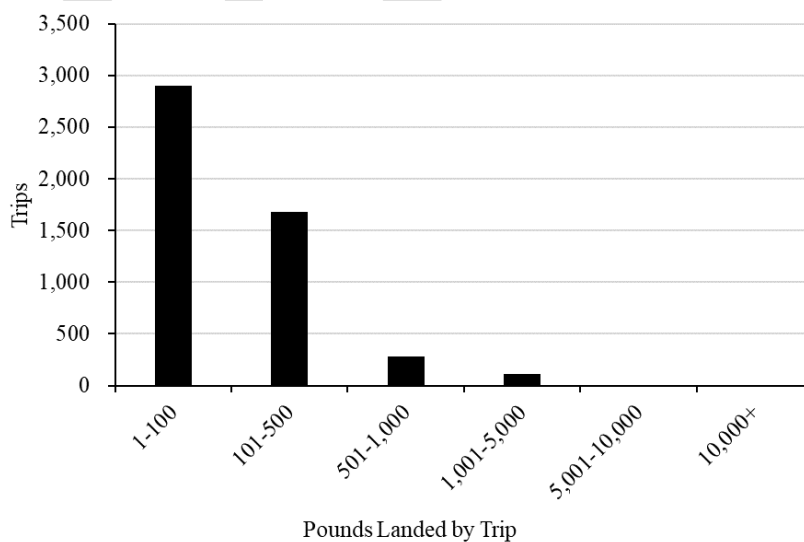
Figure 1.12. Number of targeted Trips grouped by pounds landed per trip in the set small mesh gill net striped mullet fishery reported through the North Carolina Trip Ticket Program by gear, 2017–2021.
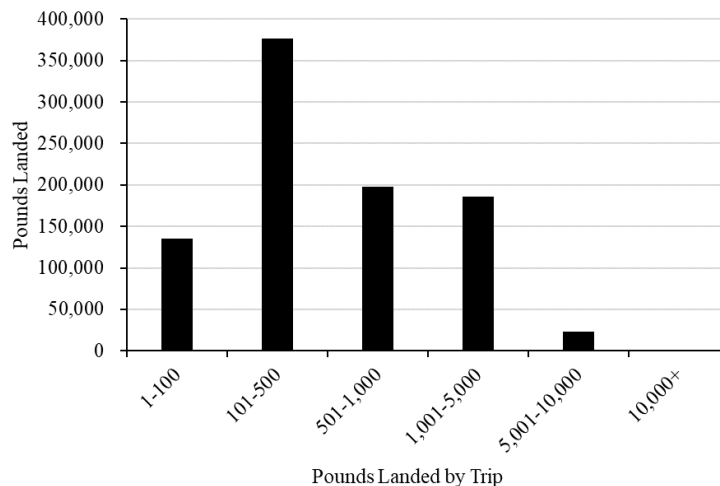
Figure 1.13. Total pounds landed grouped by pounds landed per targeted trip in the set small mesh gill net striped mullet fishery reported through the North Carolina Trip Ticket Program by gear, 2017–2021.
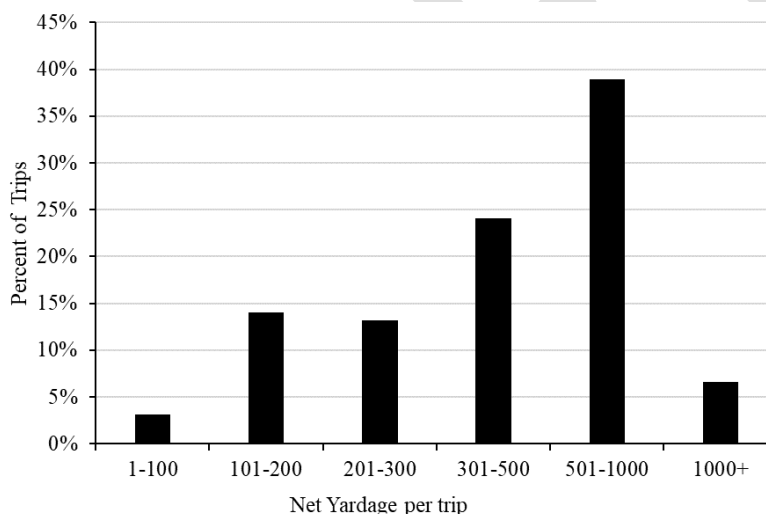
Figure 1.14. Percent of total trips grouped by yards fished per trip in the set small mesh gill net striped mullet fishery using data from the commercial fish house sampling program 2017–2021.

When targeting striped mullet with small mesh set gill nets, it is common to catch other species incidentally. The most common species landed incidentally when targeting striped mullet in set gill nets are spotted seatrout, red drum, catfish, bluefish, white perch, and gizzard shad (Figure 1.15). Conversely, striped mullet are most commonly caught incidentally when set gill net fishermen are targeting spotted seatrout, bluefish, and white perch (NC trip ticket data). This overlap between the striped mullet and spotted seatrout, bluefish, and white perch set gill net fisheries could have management implications for all these fisheries if gear restrictions are put in place to restrict striped mullet harvest.
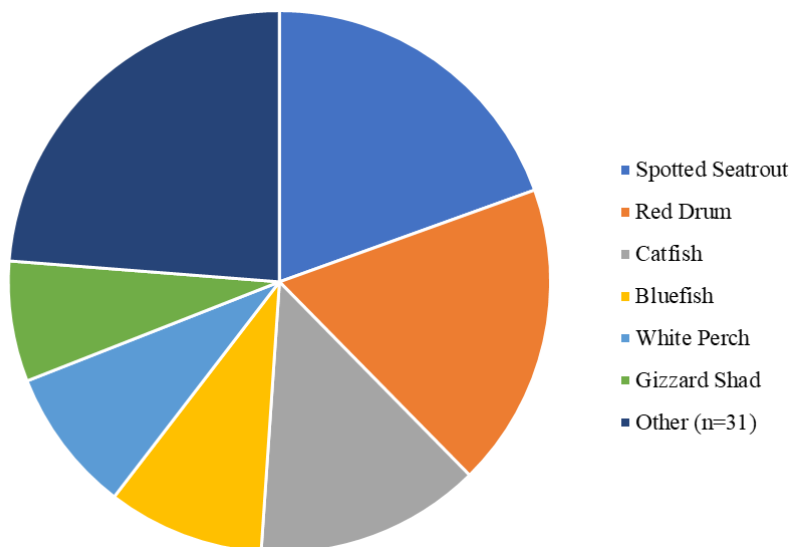
Figure 1.15. Proportion of incidental catch landed by species in the set small mesh gill net striped mullet fishery reported through the North Carolina Trip Ticket Program, 2017–2021.

Striped mullet discards in the set gill net fishery are difficult to characterize due to limited data but appear to be minimal based on observations from the commercial observer program. Of the over 9,500 striped mullet observed in set small mesh nets (2003-2021), only 49 fish were discarded. A discard rate of 0.5%. The low rate of striped mullet discards in the set small mesh fishery is likely due to there being no restrictions on their commercial harvest. Increased restrictions on striped mullet harvest could increase discards in this fishery. For more information on striped mullet bycatch in the set gill net fishery, please refer to the Striped Mullet Bycatch section of the Base Plane.

Discards of other species from striped mullet targeted small mesh set gill net trips could not be characterized due to limited data. Of the over 1,500 observed small mesh set net trips observed from the commercial observer program (2003-2021), only 35 striped mullet targeted trips have been observed. In those trips, eight managed species were discarded, including sheepshead, Atlantic menhaden, blue crab, horseshoe crab, croaker, bluefish, striped mullet, and red drum.

Runaround Gill Nets

Striped mullet are the most important species targeted in the North Carolina runaround gill net fishery (Figure 1.16). Striped mullet make up the largest proportion of monthly runaround gill net trips from April to November and are second to spotted sea trout the rest of the year.

Runaround gill nets are the predominant gear used to catch striped mullet in North Carolina (Figures 1.3 - 1.4) and the dominant gear in every region except the Albemarle Sound (Figure 1.9). The runaround gill net fishery is much more targeted than the set net fishery and is the main gear used to catch striped mullet when they form their spawning aggregations in October and November. During this time, catches from runaround gill nets can be very high as fishermen target striped mullet for their valuable roe. Over 50% of the average yearly landings of striped mullet come from this two-month period. Since 1994 effort and participation in this fishery have remained relatively consistent until 2021 when a significant spike in both trips and participants was observed (Figure 1.17). This sudden increase could be due to fishermen shifting to the fishery from other more restricted fisheries.
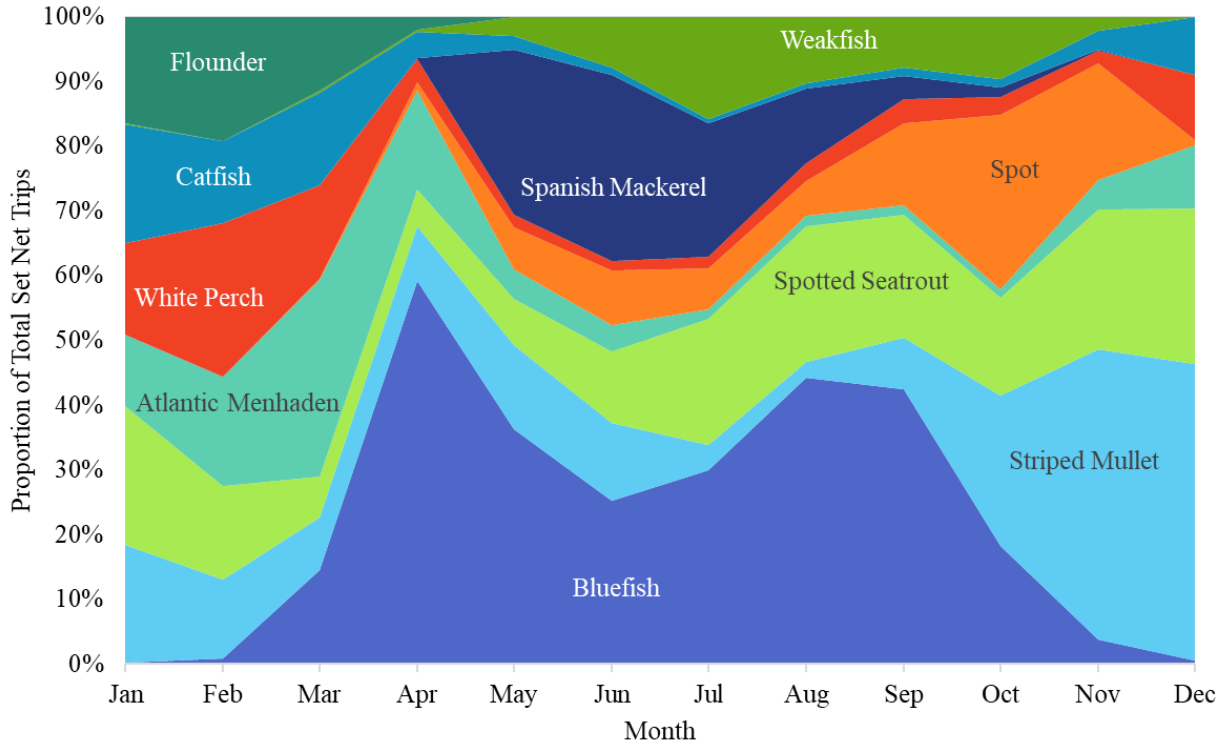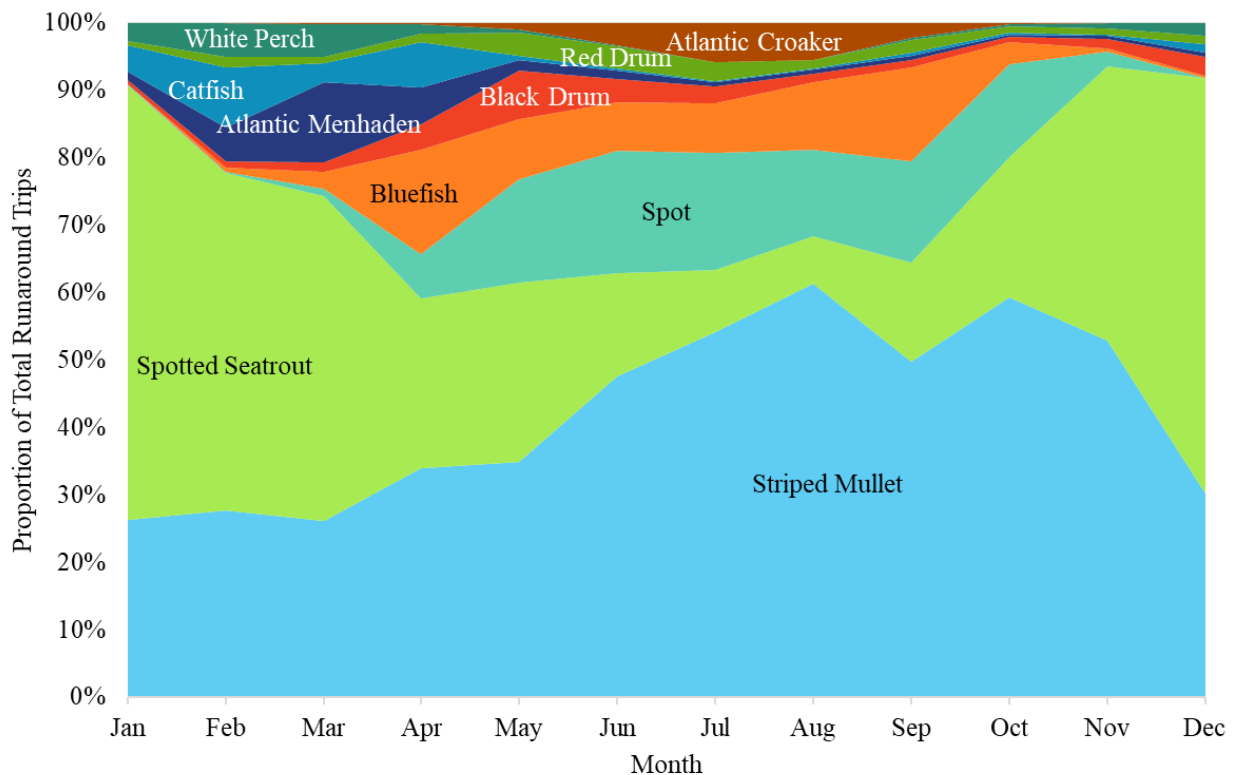
Figure 1.16. Percentage of total runaround gill net trips for each of the 10 primary target species across months in N.C. waters during 2017-2021.
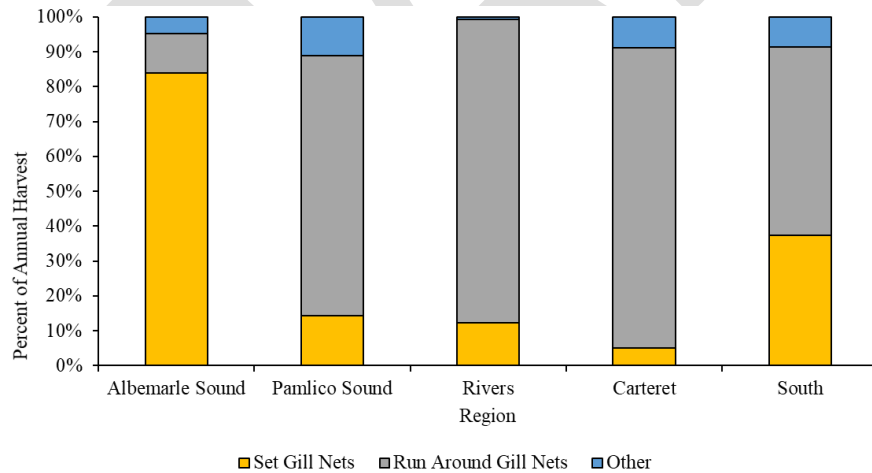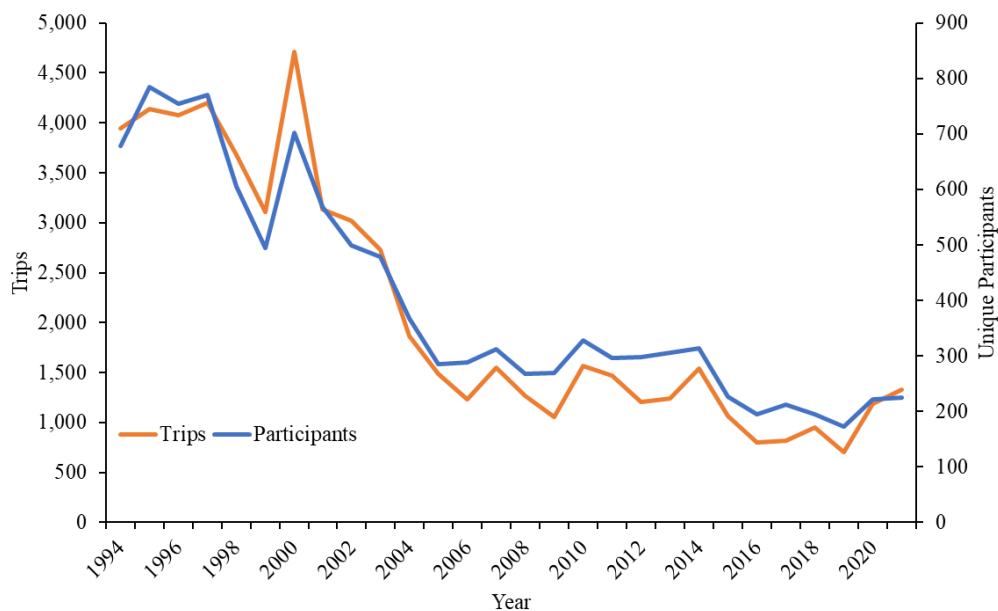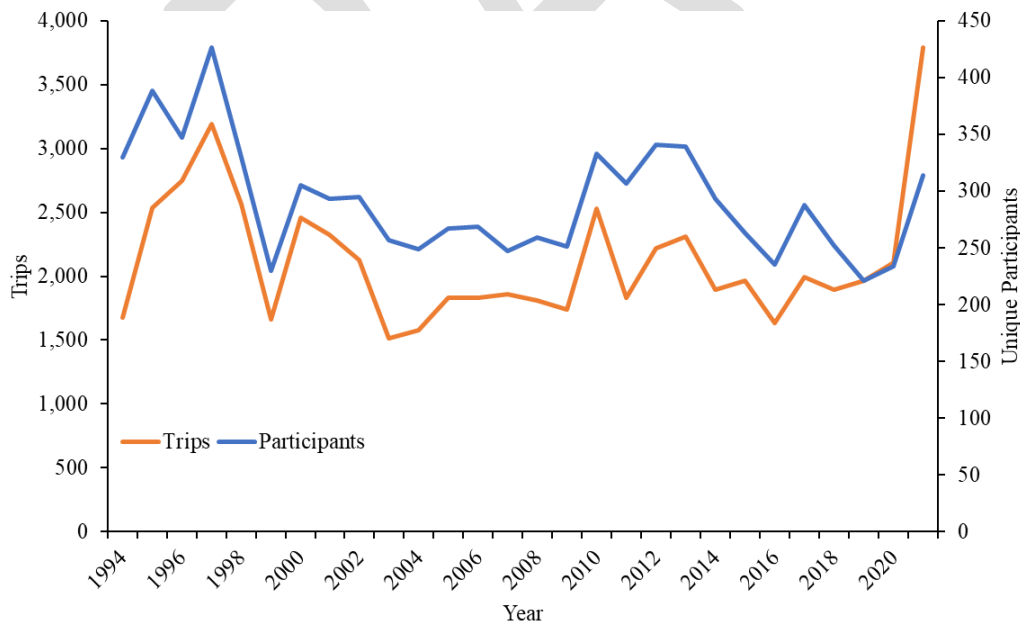

Figure 1.17. Targeted trips and participants in the runaround gill net striped mullet fishery by year reported through the North Carolina Trip Ticket Program by gear, 1994–2021.

Runaround gill nets are a higher volume fishery than set nets, with the average trip landing over 450 pounds (Figure 1.18). This is likely due to runaround gill nets being a more targeted gear for striped mullet. Most trips that target striped mullet land less than 500 pounds of mullet. However, the 12% of trips that catch over 1,000 pounds account for over 50% of total landings from runaround gill nets (Figure 1.19).
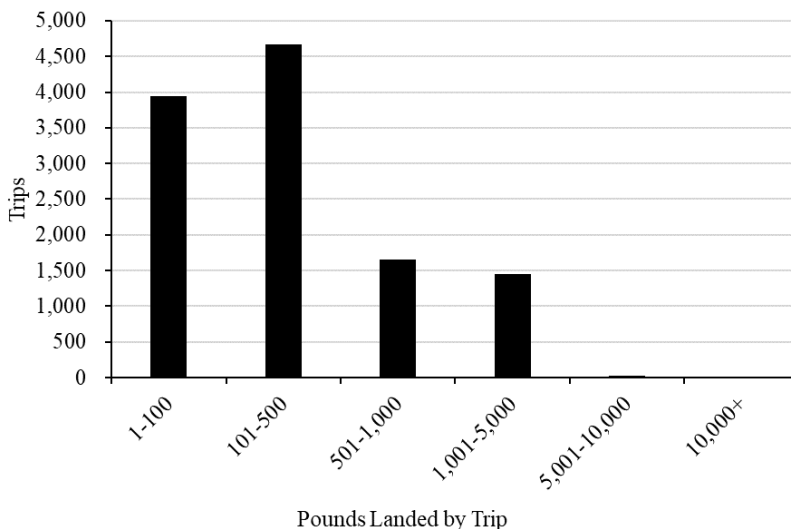
Figure 1.18. Number of targeted trips grouped by pounds landed per trip in the runaround gill net striped mullet fishery reported through the North Carolina Trip Ticket Program by gear, 2017–2021.
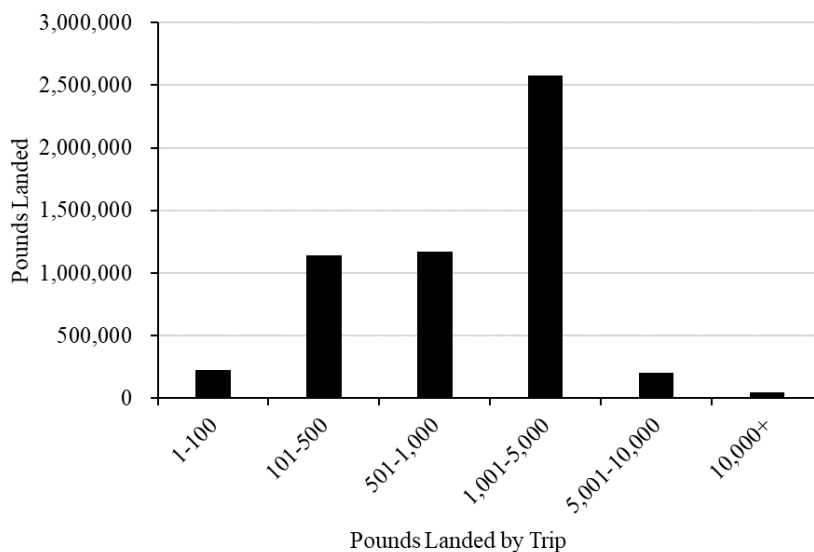
Figure 1.19. Total pounds landed grouped by pounds landed per targeted trip in the runaround gill net striped mullet fishery reported through the North Carolina Trip Ticket Program by gear, 2017–2021.

Runaround gill nets have a higher modal mesh size (3.75 ISM) than set small mesh gill nets (3.5 ISM; Table 1.3). This is likely due to most runaround gill net trips occurring in October and November during the roe season when fishermen are targeting larger females. The average net

length is 366 yards with a maximum of 1,000 yards, with nearly half of all trips setting less than 300 yards of net (Figure 1.20). Runaround gill nets tend to be much shorter than set gill nets because runaround gill nets are actively fished to encircle schools of striped mullet. This allows for much less yardage needed to catch the fish than the passively fished set gill nets. Since the gill nets are already significantly shorter, and nets can be fished several times consecutively, maximum yardage restrictions may not be effective in managing harvest in this fishery. For more information on possible management applications of runaround gill net yardage restrictions, see Appendix 2.

Table 1.3. Small mesh (<5 inch ISM) runaround gill net trips in North Carolina using data from the N.C. Trip Ticket Program with associated gear characteristics from fish house, 2017-2021.

Species	Trips	Avg/Yr	Modal Mesh	Avg Yds	Max Yds
Striped mullet	20,763	4,153	3.75	366	1,000
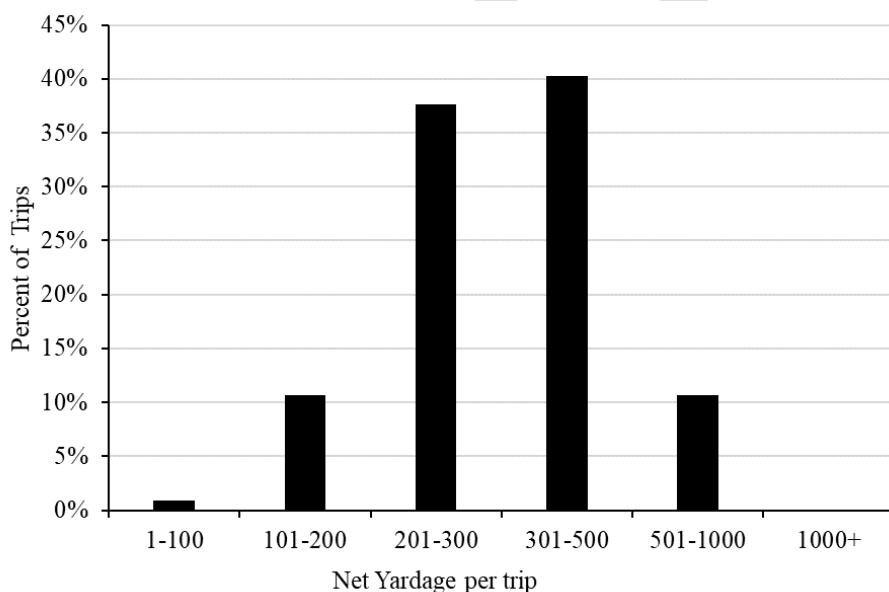
Figure 1.20. Percent of total trips grouped by yards fished per trip in the set small mesh gill net striped mullet fishery using data from the commercial fish house sampling program 2017–2021.

When targeting striped mullet with runaround gill nets, it is common to catch other species incidentally. The most common species landed incidentally when targeting striped mullet in set gill nets are spotted seatrout, red drum, bluefish, spot, black drum, and blue crab (Figure 1.21). Conversely, striped mullet are most commonly caught incidentally when runaround gill net fishermen are targeting spotted seatrout, bluefish, and spot (NC trip ticket data). This overlap between the striped mullet and spotted seatrout, bluefish, and spot runaround gill net fisheries could have management implications for all these fisheries if gear restrictions are put in place to restrict striped mullet harvest.

No data is available to characterize discards in this fishery because the commercial observer program does not observe runaround gill net trips.
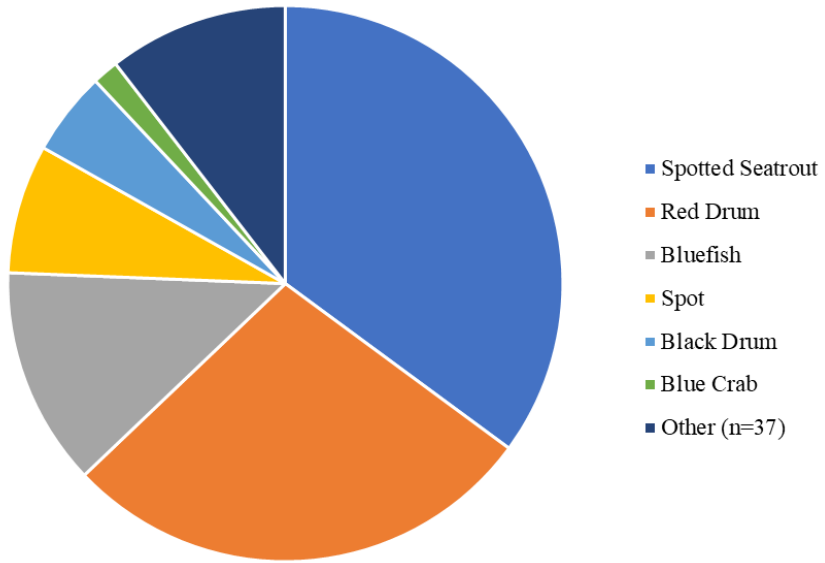
Figure 1.21. Proportion of incidental catch landed by species in the runaround net striped mullet fishery reported through the North Carolina Trip Ticket Program, 2017–2021.

Appendix 2: Achieving Sustainable Harvest in the North Carolina Striped Mullet Fishery

Issue

Implement management measures to achieve sustainable harvest in the North Carolina striped mullet fishery.

Origination

DMF

Background

The North Carolina striped mullet stock is overfished with overfishing occurring in 2019, the terminal year of the stock assessment (NCDMF 2022a). The observed data and model predictions suggest a decreased presence of larger, older striped mullet in the population. The model estimated declining trends in age-0 recruitment and female SSB over the last several decades. Model results also indicate consistent overestimation of biomass and the greatest risk for overfishing.

The stock assessment model estimated a value of 0.37 for the $F_{25\%}$ threshold and a value of 0.26 for the $F_{35\%}$ target. In 2019 F was 0.42, greater than the $F_{25\%}$ threshold, indicating overfishing is occurring (Figure 5). The model estimated a value of 1,364,895 pounds for the $SSB_{25\%}$ threshold and a value of 2,238,075 pounds for the $SSB_{35\%}$ target. Female SSB in 2019 was estimated at 579,915 pounds, lower than the $SSB_{25\%}$ threshold, indicating the stock is overfished (Figure 6).

North Carolina General Statute 113-182.1 states that fishery management plans shall: 1) specify a time period not to exceed two years from the date of adoption of the plan to end overfishing, 2) specify a time period not to exceed 10 years from the date of adoption of the plan for achieving sustainable harvest, and 3) must also include a standard of at least 50% probability of achieving sustainable harvest for the fishery. Sustainable harvest is defined in North Carolina General Statute 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".

Stock recovery is highly dependent on age-0 recruitment. The 2022 stock assessment indicates recruitment has not only declined but has been below average since 2009 (Figure 2.1). Stock projections based on the stock assessment indicate a conservative, 21.3-35.4% reduction in commercial removals is needed to rebuild spawning stock biomass to a sustainable level. If low recruitment continues, female SSB is never projected to reach the SSB target at a 21.3-35.4% harvest reduction. A 21.3-35.4% reduction in commercial removals is projected to, at a minimum, rebuild SSB to the threshold even if low recruitment continues (Figures 2.2-2.3). Assuming average recruitment, a 21.3% reduction in commercial removals rebuilds SSB to the target in eight years with a 78% probability of success and a 35.4% reduction in commercial removals rebuilds SSB to the target in four years with a 100% probability of success (Table 2.1). Either reduction scenario meets the statutory requirement to achieve sustainable harvest with at least a 50% probability of success. A 9.9% reduction in total removals reduces F to the F threshold and a 33% reduction reaches the F target.

In response to stock assessment results the MFC adopted Supplement A to Amendment 1 to the Striped Mullet FMP in May 2023 to end overfishing (NCDMF 2023). Supplement A established season closures for the striped mullet commercial and recreational fisheries with the goal of achieving a 21.7% reduction in harvest relative to 2019 commercial landings, ending overfishing and beginning to rebuild the stock (see Season Closure section of this issue paper for additional

information). Supplement A management will remain in place until adoption of Amendment 2 to the Striped Mullet FMP.
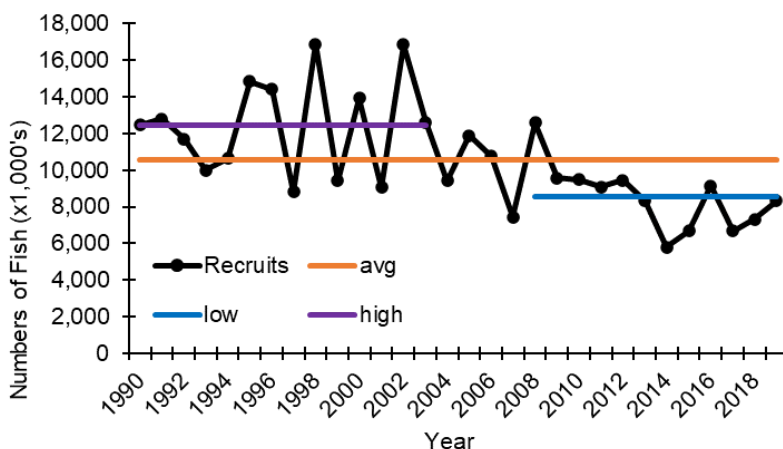
Figure 2.1. Estimates of striped mullet recruitment from the 2022 striped mullet stock assessment (NCDMF 2022). Average recruitment is the average number of recruits from 1990 to 2019, high recruitment is the average number of recruits from 1990 to 2003, and low recruitment is the average number of recruits from 2008 to 2019.

Table 2.1. Number of years to reach the SSB_{Target} and $SSB_{Threshold}$ with probability of success in parentheses at 21.3% and 35.4% reduction in commercial removals assuming low and average recruitment. Removals assumed are in comparison to removals in 2019. Both reduction scenarios end overfishing.

		number Years from 2024		
Reduction	Recruitment Assumption	Reach Target	Reach Threshold	Removals Assumed (lb)
21.3%	Low	Never (0%)	7 (68%)	1,072,538
	Average	8 (78%)	2 (100%)	1,072,538
35.4%	Low	Never (0%)	3 (99%)	880,418
	Average	4 (100%)	2 (100%)	880,418
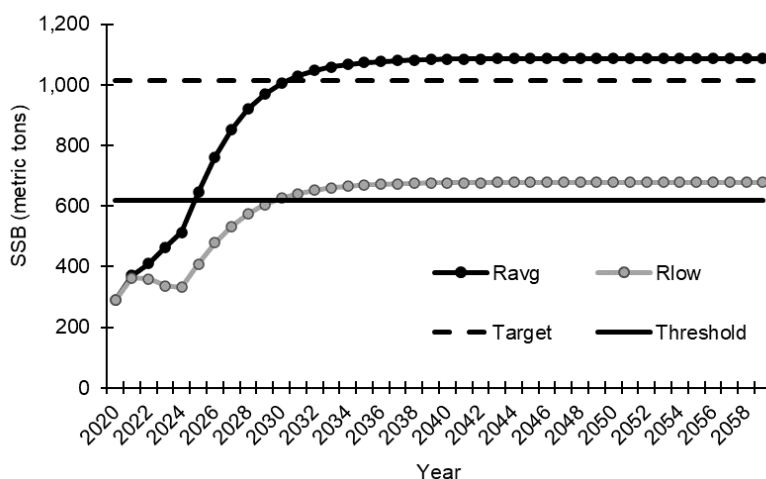
Figure 2.2. Projected striped mullet spawning stock biomass at various recruitment levels (average and low) compared to the SSB_{Target} (dashed line) and $SSB_{Threshold}$ (solid line) assuming a 21.3% reduction in commercial removals.
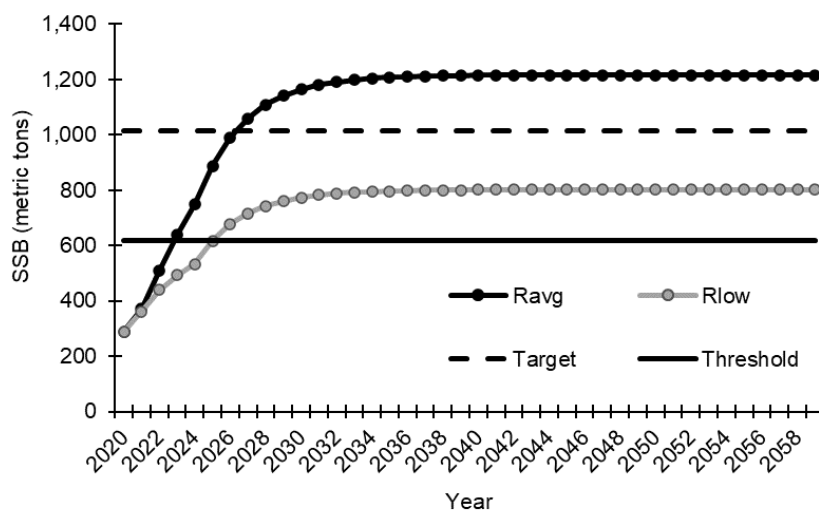
Figure 2.3. Projected striped mullet spawning stock biomass at various recruitment levels (average and low) compared to the SSB$_{Target}$ (dashed line) and SSB$_{Threshold}$ (solid line) assuming a 35.4% reduction in commercial removals.

Several management tools are available to achieve sustainable harvest in the striped mullet fishery. This discussion includes specific quantifiable management measures projected to meet the required harvest reductions to rebuild the striped mullet stock and fulfill the statutory requirements. Several management tools, including combinations of management measures, were explored including size limits, seasonal closures, day of week closures, trip/creel limits, gear restrictions, and seasonal catch limits. To establish context for small mesh gill net management options to support sustainable harvest options, Appendix 1: Small Mesh Gill Net Characterization in the North Carolina Striped Mullet Fishery provides a comprehensive review of the small mesh gill net fishery for striped mullet.

Discussion of sustainable harvest primarily focuses on reductions in the commercial fishery, where most striped mullet harvest occurs. Because of recreational harvest data limitations, harvest reductions from any specific management measure cannot be calculated. In 2019, recreational striped mullet harvest accounted for 1.7% of total harvest and accounted for 4.2% of total harvest from 1994-2019. While recreational harvest is not expected to have significant impacts on stock status (NCDMF 2022), management measures discussed in this issue paper could apply to the recreational sector. Additional information about the recreational fishery for striped mullet and potential recreational specific management measures can be found in the 2022 stock assessment (NCDMF 2022) and Appendix 3: Characterization and Management of the North Carolina Recreational Striped Mullet Fishery.

Because recreational harvest reductions cannot be quantified due to data limitations, sustainable harvest reduction calculations are based solely on commercial striped mullet landings (Table 2.2). All management options represent the percent reduction to commercial harvest relative to commercial landings in 2019 (terminal year of the stock assessment). While a 9.3% reduction does end overfishing, it does not rebuild SSB to the threshold and cannot be considered for long-term management of the stock.

Table 2.2. Commercial harvest reduction necessary to end overfishing and rebuild the stock. Target landings are 2019 commercial landings reduced by the given percentage. *Does not meet statutory requirement to rebuild stock.

Commercial Harvest Reduction (%)	Target Landings (pounds)
9.9*	1,227,358*
21.3	1,072,065
35.4	879,992

Authority

N.C. General Statute

G.S. 113-134 RULES

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

G.S. 113-182.1 FISHERY MANAGEMENT PLANS

G.S. 113-221.1. PROCLAMATIONS; EMERGENCY REVIEW

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

N.C. Rule

15A NCAC 03M .0502 MULLET

15A NCAC 03H .0103 PROCLAMATIONS, GENERAL

Discussion

The discussion below includes specific management measures that were both quantifiable and projected to meet the striped mullet harvest reduction. Reductions are based on the terminal year of the stock assessment (2019) and achieve sustainable harvest within 10 years with at least a 50% probability of success. Several management tools explored include: size limits, season closures, trip limits, day of week closures, combinations of measures, stop net management, seasonal catch limits, area closures, limited entry, and adaptive management.

Size Limits

Throughout this section, unless otherwise stated, all lengths are fork length (FL), which is a measurement of the fish from tip of snout to the fork in the tail.

Size limits are a common management tool to focus harvest on specific size and age classes of a fish stock. Management objectives and species life histories help managers determine what size limits should be implemented. By setting a minimum size limit based on length at maturity, managers can ensure a portion of the females in the stock have a chance to spawn at least once before harvest. In North Carolina, the length at 50% maturity (L50) for female striped mullet is 319 mm (12.6 inches; NCDMF 2021), and the length where 100% of the females are mature is 367 mm (14.4 inches; Bichy 2004). Striped mullet at 367 mm are as young as age-1 but more commonly are age-2. Other states with striped mullet fisheries, including Florida and Texas, use some form of a size limit to restrict harvest. Florida has an 11-inch minimum size in their commercial fishery with an allowance for 10% of the total weight possessed to be undersized. Texas has a 12-inch maximum size limit in both their recreational and commercial striped mullet fisheries during October, November, December, and January. A maximum size limit during the fall and early winter prevents harvest of the largest spawning fish.

Increasingly, minimum size limits are being re-evaluated as a conservation measure for fish stocks (Ahrens et al. 2019; Coggins et al. 2007; Garcia et al. 2012; Gwinn et al. 2013). While

minimum size limits are considered a good strategy for meeting some management objectives, sustainability may not be met through minimum size limits alone because minimum size limits often create additional discards and larger, older fish typically contribute disproportionately more to spawning success. For striped mullet, fish in the 300-350 mm size range (11.8-13.8 inches) are estimated to produce 551,105 to 984,000 eggs per individual whereas fish greater than 400 mm (15.7 inches) can produce upward of 2 million eggs (Table 2.3; Leard et al. 1995).

In North Carolina all sizes of striped mullet are targeted commercially and recreationally. Recreational and commercial fisheries use cast nets to target small striped mullet, or "finger mullet", for use as live bait. "Finger mullet" typically range from 70-140 mm (2.8-5.5 inches; NCDMF 2006, 2022a). Commercial fisheries harvest larger striped mullet ranging from 229-508 mm FL (9-20 inches; Figure 2.4). These fish are typically harvested for use as food, cut bait, or for roe. All sizes of striped mullet are targeted by commercial fisheries throughout the year to meet market demand for food and bait, but the size of striped mullet harvested begins to increase in September, with the largest striped mullet consistently captured in October and November as larger fish become available to the fishery and demand for roe increases (Tables 2.4-2.5; Figure 2.5). During October and November, the largest striped mullet are targeted by the roe fishery because larger fish have a higher roe content than smaller fish and a narrower size range of fish are harvested.

Table 2.3. Striped mullet fecundity estimates by size from Leard et al. (1995).

Fork Length (mm)	Fork Length (inches)	Average Fecundity (number of eggs)	
		Mahmoudi (1990)	J. Render (personal communication)
300-350	11.8-13.8	984,000	551,104
350-400	13.8-15.7	1,493,000	913,456
400-450	15.7-17.7	2,152,000	1,077,163
450-500	17.7-19.7	2,979,000	2,960,897[1]
500-550	19.7-21.7	3,992,000	2,269,251

[1]Figure may be overestimated because average was obtained from only two samples, 491 and 495 mm FL.
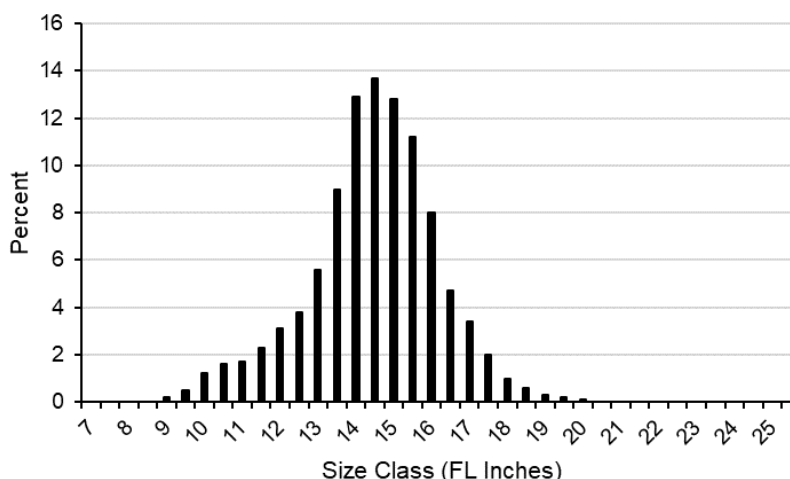
Figure 2.4. Length-frequency of striped mullet harvested in North Carolina commercial fisheries based on commercial fish house sampling, 2017-2021.

Figure 2.5. Length-frequency (inches) of striped mullet harvested in North Carolina commercial fisheries by month based on commercial fish house sampling, 2017-2021.

Table 2.4. Length-frequency (inches) of striped mullet harvested in North Carolina commercial fisheries by month based on commercial fish house sampling, 2017-2021. Shaded area represents modal length.

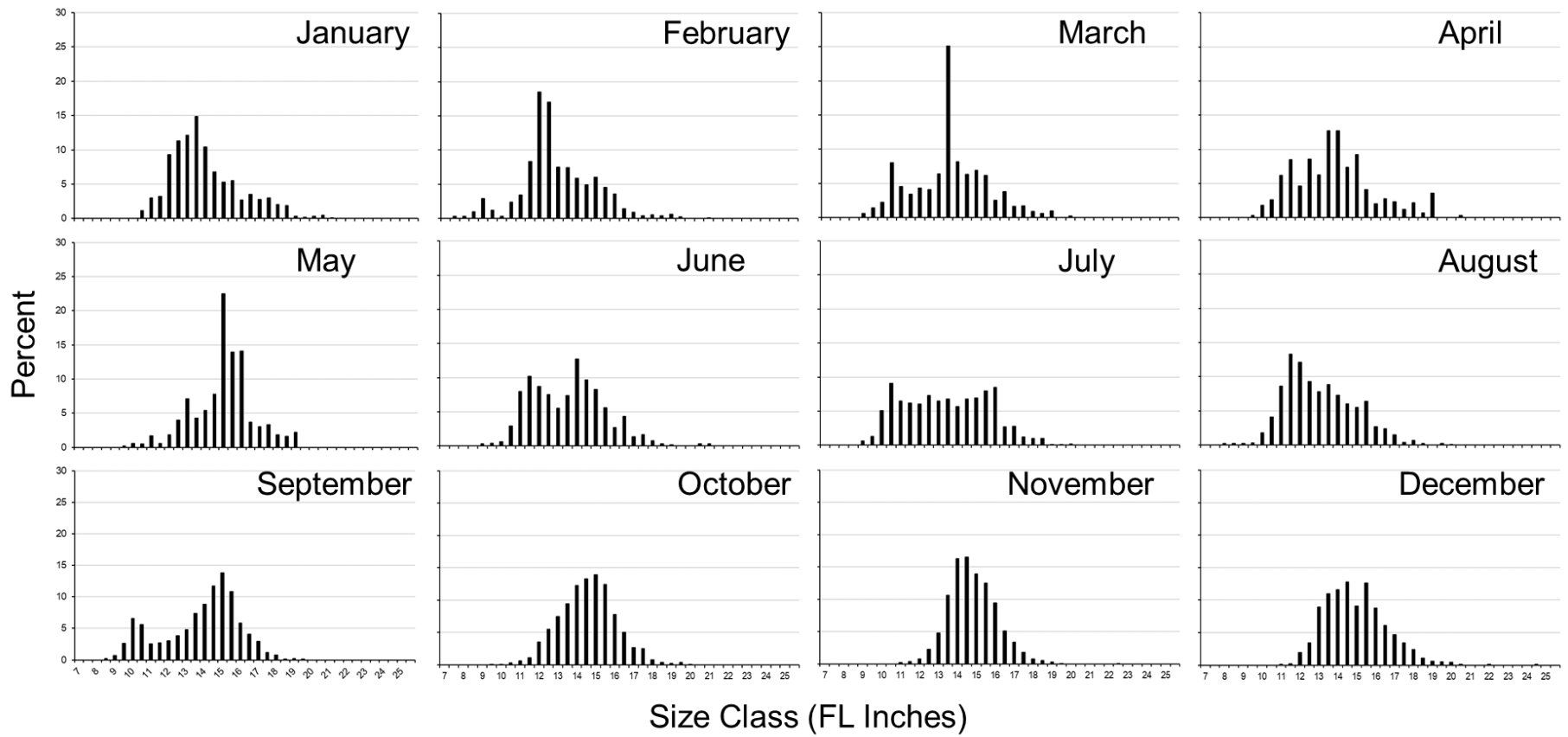| Size Class (inches)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.5	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
8.5	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.0
9.0	0.0	2.9	0.6	0.0	0.0	0.3	0.6	0.2	0.7	0.0	0.0	0.0
9.5	0.0	1.2	1.4	0.3	0.2	0.4	1.3	0.3	2.6	0.1	0.0	0.0
10.0	0.0	0.3	2.2	1.8	0.6	0.6	5.1	1.8	6.6	0.1	0.0	0.0
10.5	1.1	2.4	8.0	2.6	0.5	2.9	**9.1**	4.1	5.6	0.3	0.0	0.0
11.0	3.0	3.4	4.5	6.2	1.7	8.0	6.5	8.6	2.5	0.6	0.2	0.1
11.5	3.2	8.3	3.4	8.5	0.6	10.2	6.2	**13.3**	2.7	1.1	0.4	0.2
12.0	9.3	**18.5**	4.3	4.6	1.8	8.7	6.0	12.1	3.0	3.5	0.8	1.9
12.5	11.3	17.0	4.1	8.6	4.0	7.5	7.3	9.3	3.8	5.5	2.3	3.4
13.0	12.1	7.5	6.4	6.3	7.1	5.5	6.5	7.8	4.8	7.5	4.8	8.9
13.5	**14.9**	7.4	**25.1**	12.7	4.3	7.4	6.8	8.8	7.4	9.4	10.6	11.0
14.0	10.4	5.9	8.2	**12.7**	5.4	**12.7**	5.7	7.3	8.8	12.3	16.3	11.6
14.5	6.8	4.9	6.3	7.4	7.8	9.7	6.8	6.0	11.7	13.3	**16.5**	**12.8**
15.0	5.3	6.0	6.9	9.2	**22.5**	8.3	6.9	5.5	**13.8**	**13.9**	13.9	9.1
15.5	5.5	4.5	6.2	4.1	13.9	5.6	8.0	6.4	10.8	12.4	12.5	12.6
16.0	2.7	3.6	2.5	2.0	14.1	2.7	8.5	2.7	5.8	7.8	9.4	8.8
16.5	3.5	1.4	3.8	2.8	3.7	4.3	2.7	2.4	4.1	5.0	5.1	6.1
17.0	2.8	0.9	1.6	2.3	3.0	1.4	2.8	1.5	2.9	2.7	3.4	4.7
17.5	3.0	0.4	1.7	1.2	3.3	1.7	1.2	0.4	1.2	2.5	1.8	3.4
18.0	2.0	0.5	0.9	2.2	1.8	0.8	1.0	0.7	0.8	0.8	0.8	2.4
18.5	1.9	0.4	0.6	0.7	1.6	0.3	1.0	0.2	0.1	0.4	0.5	1.1
19.0	0.3	0.6	1.0	3.6	2.2	0.2	0.1	0.0	0.2	0.2	0.3	0.6
19.5	0.2	0.2	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.4	0.1	0.5
20.0	0.3	0.0	0.2	0.0	0.0	0.0	0.2	0.1	0.0	0.1	0.0	0.4
20.5	0.5	0.0	0.0	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.1
21.0	0.1	0.1	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
21.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
22.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
23.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
25.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 2.5. Length-frequency (inches FL) of striped mullet harvested in North Carolina commercial fisheries by month based on commercial fish house sampling, 2019. Shaded area represents modal length.

Size Class (inches)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9.5	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.1	0.2	0.0
10.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	0.2	0.3	0.0	0.0	0.0
10.5	0.0	0.0	0.0	0.0	0.0	0.0	3.9	4.0	0.1	0.0	0.0	0.0
11.0	0.0	0.0	0.0	0.1	0.0	0.0	3.0	12.7	0.5	0.1	0.0	0.0
11.5	0.0	0.0	0.0	0.5	0.0	0.0	6.9	22.3	0.1	0.1	0.1	0.0
12.0	0.0	0.0	0.0	1.0	0.0	0.5	3.5	21.5	1.9	0.2	0.1	0.6
12.5	0.0	0.0	0.0	2.7	0.0	4.2	9.2	14.0	6.6	1.0	1.4	0.7
13.0	2.3	0.0	0.0	6.1	0.0	0.9	6.8	6.6	7.6	4.0	3.7	8.7
13.5	19.7	4.1	100.0	15.2	0.0	9.1	11.9	2.1	10.5	8.4	7.8	9.4
14.0	30.2	16.9	0.0	11.4	0.0	11.0	8.8	2.7	10.7	15.4	15.4	12.0
14.5	12.9	8.7	0.0	9.3	0.0	19.8	5.6	1.0	14.0	14.9	15.1	12.3
15.0	9.1	33.1	0.0	18.0	50.0	9.7	5.7	2.4	22.0	13.1	15.4	16.6
15.5	6.1	20.7	0.0	7.6	25.0	10.3	11.6	2.4	14.3	15.7	15.9	12.9
16.0	2.7	8.3	0.0	3.1	25.0	4.0	9.4	2.2	4.2	8.6	11.1	10.6
16.5	1.5	8.3	0.0	7.9	0.0	20.3	3.7	2.0	5.0	8.2	6.0	4.5
17.0	1.5	0.0	0.0	4.7	0.0	3.1	2.1	2.0	0.9	3.7	2.8	1.6
17.5	2.7	0.0	0.0	4.4	0.0	3.9	3.6	1.1	0.0	3.4	2.5	3.1
18.0	2.7	0.0	0.0	4.0	0.0	3.1	0.0	0.4	0.7	1.4	0.7	1.4
18.5	3.1	0.0	0.0	3.1	0.0	0.0	0.0	0.2	0.0	0.6	0.8	2.4
19.0	1.1	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.5	0.4	0.8
19.5	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.7	0.6	0.1	1.2
20.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1
20.5	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
21.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
22.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
22.5	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
23.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

On its own, implementation of a minimum size limit set at the L50 for striped mullet would be unlikely to meet sustainability objectives and would eliminate the bait fishery for finger mullet. Striped mullet less than L50 size (12.6 inches) are captured in commercial fisheries during every month, and in some months make up significant portions of the commercial catch. Generally, striped mullet reach length at maturity in the estuary before migrating offshore to spawn. If a minimum size limit based on the L50 was implemented, striped mullet would reach harvestable size before spawning, resulting in little conservation benefit. As an example, implementing a minimum size limit of 12.5 inches would appear to reduce harvest by around 14.5% (Table 2.6). However, overall harvest would likely not be reduced by that amount because harvest would likely be delayed until those fish reach harvestable size, preventing achieved harvest reductions and

minimizing conservation benefit. In addition, minimum size limits would likely increase discards if gear modifications and changes in fishery behavior did not also occur.

Implementing a maximum size limit or seasonal maximum size limit, like what is done in Texas, would reduce harvest and provide additional non-quantifiable benefits to the stock. Unlike minimum size limits, a maximum size limit would not cause delayed harvest or recoupment of catch, once a fish reached the maximum size limit it could not be harvested. While there is little information to inform an ideal maximum size limit (Texas has a 12-inch maximum size limit during October-January), as an example, a 15-inch maximum size limit could reduce harvest by 39.8% compared to commercial landings from 2017-2021 (Table 2.6) and would have reduced commercial landings by 49% in 2019.

A maximum size limit, focused on the spawning season (October-December), would have a more direct impact on the spawning stock. As an example, implementing a 15-inch maximum size limit during the spawning season could reduce overall commercial harvest by 27.0% compared to landings from 2017-2021, while continuing to allow significant harvest of smaller roe size striped mullet (Table 2.6). An October-November 15-inch maximum size limit would have reduced harvest up to 33% in 2019. This type of harvest control would likely result in quantifiable harvest reductions and have nonquantifiable benefits to the stock by allowing larger females, that produce more eggs, to spawn while allowing the roe fishery to occur. While discards would likely occur during the spawning season, discards would be lower outside of the spawning season. In addition, because of market demands the largest striped mullet are generally not targeted outside of the spawning season so it is unlikely effort would shift to larger fish earlier in the season. However, a seasonal maximum size limit during the fall would negatively affect the roe fishery, which targets large fish with a high roe content.

Slot limits should not be considered in the striped mullet fishery. Implementation of a harvest slot would exclude "finger mullet" and large roe mullet from harvest. This type of measure would not allow for the fish to be used in the same way they are used currently and may have little conservation benefit because peak harvest already occurs on a narrow range of sizes. A protected slot would direct more harvest to larger fish and would likely prevent significant amounts of harvest resulting in excessive discards.

Implementing a minimum or maximum size limit would need to be accompanied by corresponding changes to minimum or maximum mesh sizes used in gill nets to reduce dead discards. As illustrated in Appendix 1, the primary method for harvesting striped mullet is runaround gill nets with the most common mesh size of 3.75 inches stretched mesh (ISM; Table 1.3), but mesh sizes ranging from less than 3.0 ISM up to 4.5 ISM are used in the fishery. As an example, if a minimum size limit of 12.5 inches was implemented, a minimum mesh size of around 3.25 ISM would need to be adopted to minimize discards (Figure 1.7). If a maximum size limit of 15 inches was implemented, a maximum mesh size of around 4.0 ISM or 3.75 ISM would need to be adopted to minimize discards. If a maximum size limit is seasonal, the associated mesh size restrictions could also be seasonal and could apply to runaround gill nets only, all small mesh gill nets, or just gill net trips landing mullet. However, if additional mesh size restrictions are adopted there would likely be some impact to small mesh gill net fisheries targeting other species.

The striped mullet FMP Advisory Committee (AC) was not supportive of any type of size limit because striped mullet of all sizes are marketable. In addition, the AC cautioned that setting minimum or maximum mesh sizes in response to a size limit may increase overall harvest because of annual, seasonal, and regional variation in the size of striped mullet available to the fishery.

Table 2.6. Example minimum, maximum and seasonal maximum size limit options (inches) and associated percent commercial harvest reduction based on fish house sampling, 2017-2021. Options that meet the needed 21.3-35.4% reduction in commercial harvest on their own are shaded in gray.

Size Limit Options (Inches FL)	
Minimum	Percent Reduction
12.5	14.5
13.0	20.4
13.5	27.2
14.0	37.2
Maximum	Percent Reduction
15.0	39.8
15.5	28.4
16.0	18.2
16.5	11.4
17.0	7.1
17.5	4.4
18.0	2.5
18.5	1.5
19.0	0.9
19.5	0.4
Oct-Dec Maximum	Percent Reduction
14.5	51.4
15.0	27.0
15.5	19.3
16.0	12.2
16.5	7.4
17.0	4.5
17.5	2.6
18.0	1.3
18.5	0.8
19.0	0.4
19.5	0.3

Option 1: Size Limit Options
   a. *Status Quo – Manage fishery without minimum or maximum size limits*
      + Allows for continued use of all striped mullet size classes
      + Does not increase discards
      − No preferential protection for largest fish

   b. *Minimum Size Limit and 3.25 ISM Minimum Gill Net Mesh Size*
      + Could benefit the roe fishery later in the year
      − Prevents use of smaller mullet as bait
      − Unlikely to meet sustainability objectives
      − Allows for recoupment of catch
      − Directs harvest to biggest fish
      − Would need to implement corresponding minimum mesh size requirements
      − May increase harvest

   c. *Maximum Size Limit and 3.75 or 4.0 ISM Maximum Gill Net Mesh Size*
      + Preferential protection for largest fish

+ Would result in quantifiable harvest reductions
+ No recoupment of catch
– Prevents harvest of valuable larger fish
– Increased discards
– Would need to implement corresponding maximum mesh size requirements
– May increase harvest

d. *Seasonal Maximum Size Limit and 3.75 or 4.0 ISM Maximum Gill Net Mesh Size*
+ Preferential protection for largest fish
+ Would result in quantifiable harvest reductions
+ No recoupment of catch
+ More directly protects the spawning stock
+ Increased discards would not occur prior to the spawning season
– Prevents harvest of valuable larger fish
– Increased discards
– Would need to implement corresponding seasonal maximum mesh size requirements
– May increase harvest

Seasonal Closures

Season closures, specifically end of year season closures, are considered an effective and efficient management option to end overfishing of the striped mullet stock and rebuild SSB. In May 2023, the MFC adopted Supplement A to Amendment 1 to the North Carolina Striped Mullet FMP. The intent of Supplement A is to end overfishing of the striped mullet stock. The Supplement implements regional season closures to reduce harvest by 21.7% in 2023 to end overfishing by reducing F to a level between the threshold and target. The anticipated harvest reduction from the season closures also begins to rebuild the stock to the target assuming average recruitment occurs. Additional information about season closures can be found in Supplement A. Options from the supplement are presented in this paper. Only options that meet the statutory requirement to end overfishing and rebuild the stock (21.3%-35.4%) are presented.

Statewide Season Closures

Options 2.b and 2.c (Table 2.7) reduce commercial harvest enough to end overfishing and recover the stock. Any statewide season closure must occur no sooner than October 29 and continue through the end of the year to meet needed reductions.

Region Specific Season Closures

To better account for the difference in management impact between the two regions, options for region specific season closures were developed. Options for region specific seasons are shown in Table 2.8. The split between the northern and southern regions was designated as the Highway 58 Bridge to Emerald Isle, including a line extending from the bridge to a point three miles offshore.

Table 2.7. End of year season closure options that reduce harvest to end overfishing and recover the stock. Supplement A included a third option which cannot be considered for Amendment 2 management since it does not recover the stock.

Option	Season Closure	Reduction	End Overfishing?	Recover Stock?
2.b*	October 29 - December 31	33.7	Yes, Target	Yes
2.c	November 7 - December 31	22.1	Yes, *F* Below Threshold	Yes

*Adding one more closure day exceeds 35.4% statutory reduction requirement

Table 2.8. Management options to reduce commercial harvest to end overfishing and recover the stock by splitting the seasons between north and south. All reductions are calculated from 2019 commercial harvest levels (terminal year of stock assessment).

| Option | Season Closure | | Reduction | End Overfishing? | Recover Stock? |
	North	South			
2.d	Oct. 28-Dec. 31	Oct. 30-Dec.31	35.6	Yes, Target	Yes
2.e	Nov. 7-Dec. 31	Nov. 10-Dec. 31	21.7	Yes, *F* Below Threshold	Yes

Options 2.d and 2.e (Table 2.8), which meet the reduction needed to end overfishing and recover the stock, provide up to three additional fishing days in the south without substantially reducing fishing days in the north. In 2019, there appeared to be minimal overlap in participation between the northern and southern regions. However, under a split season, where the north closes earlier than the south, effort could shift from north to south and expected harvest reductions may not be realized. The Striped Mullet FMP AC indicated the striped mullet fishery has highly mobile participants who move between regions following the fish and suggested it would be beneficial for management measures to be consistent statewide. In addition, AC members questioned the accuracy of waterbody locations recorded on trip tickets and expressed concern about using waterbody fished or county of landing to set regional specific seasons. While this concern is valid, the NC Trip Ticket Program continues to provide outreach and education to dealers about the importance of accurate trip tickets for fair and effective management. These season closure options assume an equal reduction for each region. However, additional options could be developed for scenarios where the amount of reduction is different between regions to allow the season to be extended in one region or the other.

Region specific closures were not considered using other regional splits because other splits are more likely to have overlap in participation and there is no clear delineation for different areas where the striped mullet commercial fishery operates in a different manner. The one exception may be the Albemarle Sound area, where low landings of striped mullet occur throughout the year but increase slightly in the winter. These landings occur incidentally to other small mesh gill net fisheries in the region, primarily the white perch fishery (see Appendix 1). However, most of these landings occur in January and February, months which are not being considered for striped mullet season closures. Because there is not a large directed striped mullet fishery in the Albemarle Sound region, creating a region-specific season closure in this area would likely be ineffective unless other fisheries were significantly impacted. No additional regional closure options were suggested or discussed by the AC.

The Striped Mullet FMP AC strongly disagreed with the use of statewide or regional season closures as a management measure to reduce harvest in the striped mullet fishery. AC members suggested putting a hard closure date on the fishery would result in effort shifts and participants trying to catch as much as they can before the closure. AC members also expressed concern that if the fishery were to close, roe buyers may not come to the state, eliminating the most profitable segment of the fishery. In addition, AC members felt having a complete closure would result in striped mullet discards occurring in other fisheries and suggested having a small bycatch allowance during the closed season may help prevent discards.

Option 2. Season Closure Options
a. No Season Closure
   +   Short season closures
   +   Does not have significant impacts on roe fishery
   +   Does not have significant impacts on bait fishery
   +   Landings less likely to be impacted by extreme weather events

- Other measures may be more complicated to monitor and enforce
- Other measures may be less effective

b. Statewide Season Closure – October 29 - December 31
c. Statewide Season Closure – November 7 - December 31
  + No additional resources required to implement
  + No additional reporting burden on fishermen or dealers
  + Reduces effort from current level
  + High likelihood of ending overfishing and recovering stock
  - Weather may prevent fishing during open periods
  - Effort may increase during the open period reducing the effectiveness of the closure
  - Reduction in fishing mortality may not be achieved
  - Overfishing may still occur if recruitment is low
  - May adversely impact some fisheries and more than others
  - Create discards in the closed period

d. Regional, North/South, Season Closure – North Oct. 28-Dec. 31 South Oct. 30-Dec.31
e. Regional, North/South, Season Closure – North Nov. 7-Dec. 31 South Nov. 10-Dec. 31
  + No additional resources required to implement
  + No additional reporting burden on fishermen or dealers
  + Reduces effort from current level
  + High likelihood of ending overfishing and recovering stock
  - Weather may prevent fishing during open periods
  - Effort may increase during the open period or open regions 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 more than others Create discards in the closed period

Additional Options

Several management options could be used in place of season closures or in conjunction with season closures to extend the open season, prevent excessive harvest during the open season, or prevent excessive discards. Many options, like trip limits, would likely need to be implemented in conjunction with small mesh gill net restrictions. See Appendix 1 for a comprehensive review of the small mesh gill net fishery for striped mullet and information about small mesh gill net restrictions that could be implemented to support sustainable harvest.

Trip Limits

Applying a daily trip limit or seasonal daily trip limit to striped mullet commercial catches could be used to limit harvest during the open season. Early in the year, commercial catches are smaller, but during the peak season in October and November landings per trip increase substantially (Tables 2.9 and 2.10). Striped mullet are primarily targeted with actively fished gear, like runaround gill nets, with smaller landings amounts coming from anchored gill nets (see Appendix 1). In high volume fisheries, daily trip limits would typically be expected to result in higher levels of discards. However, in a fishery like striped mullet where landings volume is seasonal, and trips are highly targeted, daily trip limits could be used to limit landings by discouraging participants from targeting large numbers of fish. The Striped Mullet FMP AC expressed some concern with using daily trip limits as a management tool, particularly when catch volume is high, but did suggest participant behavior would likely change to reduce effort and waste if daily trips limits are implemented. A lower daily trip limit could be applied early in the year when the fishery lands less and a larger daily trip limit could be applied during the peak fall season to allow for the typical

high-volume trips during the peak of landings. Restrictive daily trip limits may cause increased discards if participant behavior does not change, and trips continue to target the highest volume of striped mullet possible. It is also possible implementation of daily trip limits, particularly early season daily trip limits, may just delay harvest and necessary harvest reductions may not be realized. For this reason, combining daily trips limits with other management measures may be beneficial for reducing total harvest.

Table 2.9. Percentage of commercial trips landing striped mullet by landings bin (lb), 2017-2021.

Month	0-100	101-500	501-1,000	1,001-5,000	5,001-10,000	10,000+
Jan	75.3	18.2	4.4	2.1	<0.1	.
Feb	81.3	13.6	3.2	1.9	.	.
Mar	83.5	13.8	1.9	0.8	.	.
Apr	81.5	14.3	3.2	1.0	.	.
May	78.4	17.2	2.8	1.6	.	.
Jun	75.9	19.0	3.3	1.8	.	.
Jul	70.8	23.5	4.0	1.7	.	.
Aug	68.5	23.7	5.5	2.3	.	.
Sep	70.9	21.2	5.1	2.8	.	.
Oct	63.8	23.4	6.4	6.2	0.2	.
Nov	66.7	22.4	5.6	5.0	0.2	<0.1
Dec	76.5	17.4	4.4	1.7	.	<0.1
Total	71.7	20.2	4.8	3.3	0.1	<0.1

Table 2.10. Percent harvest reduction from 2019 commercial landings based on various daily trip limits and time periods.

Trip Limit (lb)	Reduction (%)		
	Jan-Sept, Dec	Oct-Nov	Total
50	33.1	50.4	83.4
75	30.3	47.8	78.1
100	27.9	45.5	73.5
150	24.3	41.7	66.0
200	21.3	38.5	59.8
300	16.8	33.3	50.2
400	13.6	29.4	42.9
500	11.0	26.1	37.2
600	9.0	23.4	32.4
1,000	3.8	15.5	19.3
1,100	3.0	14.1	17.1
1,250	2.1	12.3	14.4
1,500	1.2	10.0	11.2
1,750	0.7	8.2	9.0
2,000	0.4	6.8	7.2
2,500	0.1	4.8	4.9

Any daily trip limit option would need to be implemented in tandem with yardage limits on runaround gill nets. Appendix 1 provides a review of gear characteristics in the small mesh gill net fishery. To effectively limit landings and prevent excessive discards, daily trip limit options should be implemented with restrictions limiting runaround gill nets to 300-500 yards. Members of the Striped Mullet FMP AC were not in favor of reducing the maximum yardage allowed for small mesh gill nets and thought the 800-yard maximum currently in place was restrictive enough.

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However, AC members also suggested commercial fishery participants would likely reduce the yardage they used to limit landings within a lower daily trip limit, essentially self-regulating. They did not suggest what a likely yardage reduction might be.

Option 3: Trip limits
+ No additional resources required to implement
+ No additional reporting burden on fishermen or dealers
+ Reduces length of season closures
+ Limits impacts on roe fishery
+ Limits impacts on bait fishery
− Unlikely to meet sustainability objectives
− Increased discards

Day of Week Closures

Day of week closures could be used to reduce effort and harvest. Generally, the highest landings occur early in the week (Monday and Tuesday) and drop as the week goes on (Table 2.11). However, late in the summer, a higher percentage of landings occur on Friday, likely to supply bait markets, and early in the roe season a higher percentage of landings occur on Saturday (Table 2.12). Typically, the lowest landings occur on Saturday and Sunday.

Table 2.11. Percent of harvest by day of week or combination of days, 2019 and 2017-2021.

Day(s) of Week	2019 Landings	Landings (%)	2017-2021 Landings	Landings (%)
Sunday	162,709	11.9	780,061	10.4
Monday	209,707	15.4	1,201,290	16.1
Tuesday	247,756	18.2	1,273,991	17.0
Wednesday	190,343	14.0	1,148,997	15.4
Thursday	191,313	14.0	1,038,243	13.9
Friday	173,090	12.7	1,048,743	14.0
Saturday	187,294	13.7	984,763	13.2
Saturday-Sunday	350,003	25.7	1,764,823	23.6
Friday-Sunday	523,093	38.4	2,813,566	37.6
Saturday-Monday	559,710	41.1	2,966,113	39.7
Friday-Monday	732,800	53.8	4,014,856	53.7

Table 2.12. Percent of commercial landings by day of week for each month, 2017-2021.

Month	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
January	8.5	18.2	18.7	16.4	15.2	13.5	9.5
February	8.6	14.7	20.6	13.8	15.2	14.1	13.1
March	9.7	20.2	15.8	15.8	17.1	14.2	7.1
April	11.0	13.7	15.1	17.6	16.2	12.0	14.4
May	11.7	10.4	17.4	19.0	14.0	13.1	14.3
June	10.9	16.3	15.4	14.4	12.8	17.0	13.2
July	10.1	16.0	15.5	15.9	16.8	15.3	10.4
August	9.1	19.6	14.4	13.4	15.4	17.4	10.7
September	14.3	14.3	14.2	15.1	13.2	12.5	16.4
October	10.8	16.7	19.1	15.0	11.4	11.4	15.5
November	9.7	14.7	17.9	16.0	15.1	15.3	11.4
December	10.2	18.1	10.0	14.8	15.2	19.3	12.5

Striped mullet are most available to the fishery during the fall as they aggregate in schools and migrate through the estuary to the ocean to spawn. Conventional thinking suggests striped mullet migration increases, and they become most susceptible to the fishery ahead of cold fronts. Day

of week closures could be effective at reducing harvest by preventing fishing during periods of ideal fishing conditions, particularly given the runaround gill net fishery is largely dependent on good weather days. For example, prohibiting fishing for striped mullet on Saturday and Sunday would have reduced 2019 landings by 25.7% (Table 2.11). This percentage reduction is relatively consistent from 2017-2019. There is the possibility prohibiting fishing on one day shifts effort to other days or that potential catch from one day can be recouped another day. However, given most of the striped mullet commercial landings occur during a brief period from October 15-November 15 limiting the number of days participants can fish is likely to reduce landings. The Striped Mullet FMP AC shared concerns about recoupment of catch but generally supported day of week closures, particularly weekend closures, as a method to reduce harvest. AC members further suggested allowing some limited bycatch on closed days as a method to reduce discards. In addition, the AC members felt weekend closures may reduce user group conflict and preferentially benefit full-time fishery participants.

<u>Option 4: Day of week closures</u>

- + No additional resources required to implement
- + No additional reporting burden on fishermen or dealers
- **+** Reduces length of season closures
- **+** Limits impacts on roe fishery
- **+** Limits impacts on bait fishery
- **+** Could meet sustainability objectives
- **+** May prevent user group conflicts
- +/- May preferentially benefit full time participants
- +/- Weather could prevent fishing on open days
- − Possibility for recoupment of catch
- − Landings reduction highly dependent on external factors

Combination of Measures

Fisheries are commonly managed using a combination of management measures rather than relying on a single, all-encompassing measure. Using a combination of management measures allows for more comprehensive management to address multiple objectives in addition to sustainability. From 1990-1992, the state of Florida required gill nets to have a minimum mesh size of three inches and striped mullet fishery weekend closures of 36 hours and 54 hours from October-January (Leard et al. 1995). In 1993, in response to a stock assessment indicating overfishing was occurring on the Florida striped mullet stock, the state adopted additional management measures including an extension of the 54-hour weekend closure to 72 hours from July to January, a pre-roe season (July-September) trip limit of 500 pounds, and a reduction of the maximum gill net yardage allowed to 600 yards. These additional measures were intended to reduce catch, increase escapement of spawners during the roe season, increase SPR to the 35% target in 5-7 years, and increase SSB by 90%. However, before success of these measures could be evaluated the state implemented a ban on gill nets, the primary gear used to harvest striped mullet, significantly reducing harvest in an absolute manner that did not preserve traditional fisheries and precluded determination of the effectiveness of the combination of management measures initially implemented.

Management measures directly limiting commercial harvest of striped mullet have never been implemented in North Carolina. Stock assessment results suggest some stock-recruit relationship for striped mullet, and projections indicate if average or higher recruitment occurs the stock recovers quickly even at moderate harvest reduction levels. A combination of management measures including end of season closures, day of week closures, and daily trip limits may be suitable to reduce harvest while allowing traditional fisheries and uses to continue. Some form of

all these measures, except for end of season closures, were supported by the Striped Mullet FMP AC. However, given the life history of striped mullet and nature of the fishery, management measures should focus on reducing harvest during the peak of the fishery in the fall. The fall fishery accounts for most striped mullet commercial landings and is primarily composed of females because the fishery specifically targets roe mullet during their spawning migration. As an example, implementing a December closure, a year-round weekend closure (Saturday-Sunday), and a 1,000 lb daily trip limit from January-September would result in a 31.8% reduction (Option 5.i; Table 2.13). In this example there would be minimal discarding of fish from the daily trip limit early in the season allowing for catch to supply bait markets, the roe fishery would remain relatively unaffected except for the weekend closure, and the December closure would prevent expansion of the roe fishery later in the year.

The Striped Mullet FMP AC supported the combination management measure strategy to reduce striped mullet harvest. Specifically, the AC supported using a combination of day of week closures and daily trip limits to reduce harvest and minimize discards while avoiding extended end of year closures. The FMP AC recommended options 5.a, c, and f which would reduce harvest by 24.0% to 27.7% using combinations of seasonal daily trip limits, day of week daily trip limits, and day of week closures (Table 2.13). All options supported by the FMP AC meet statutory requirements by, at a minimum, rebuilding SSB to the threshold with a 50% probability of success. The FMP AC also supported an option that would implement a 1,000 lb daily trip limit from January 1 to September 30 and a year-round Saturday and Sunday daily trip limit of 100 lb. (22.1% reduction) and an option that would implement a 1,000 lb daily trip limit from January 1 to October 15 and a year-round Saturday and Sunday daily trip limit of 100 lb. (22.9% reduction). However, when a 30,000 lb stop net catch cap is factored into these options; they do not meet statutory requirements for recovering the stock and were not considered further (see stop net section of this paper for additional details).

Following examples endorsed by the FMP AC, the DMF initially supported option 5.p which would implement seasonal and day of week daily trip limits to achieve a 35.5% commercial harvest reduction after accounting for a 30,000 lb stop net catch cap. This option is projected to rebuild SSB to the target with a 99% probability of success and prevents any complete closure which might result in excessive discards. The seasonal and day of week daily trip limits are low enough that targeting high volumes of striped mullet should be prevented during these times. Implementing a 500 lb daily trip limit from February 1 through October 15 prevents high volume harvest early in the roe season and implementing a November 16 through January 31 50 lb daily trip limit essentially "freezes the footprint" of the roe fishery not allowing for expansion of the roe mullet season which historically occurs from approximately October 15 through November 15. The year-round 50 lb weekend trip limit serves a similar purpose to day of the week closures while still allowing a small incidental catch allowance to minimize discards. While complete end of year season closures are considered an effective conservation measure, the DMF took into consideration the request of the FMP AC to minimize discards and avoid extended end of season closures when making a recommendation. Recommending a higher reduction level than the FMP AC recommendation creates a buffer to account for uncertainty in behavior changes by participants in the fishery and allows for a greater probability of the stock rebuilding to the target.

During MFC AC and public review of the FMP, a strong preference was expressed for a year-round weekend closure (Option 5.a), with no management specific to the stop-net fishery, to achieve a 25.7% reduction (Table 2.13). MFC advisors and commenters cited unusually high landings in the stop net fishery in 2023 and wanting to avoid creating high levels of dead discards in that fishery as reasons to not implement a stop net catch cap.

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Considering comments and preferences expressed by MFC ACs and public comment, the DMF recommendation is Option 5.n. This option is calculated to result in a 34.9% commercial harvest reduction relative to 2019 commercial landings. This option applies to harvest, not possession, allowing seafood dealers to sell mullet and commercial operations to use mullet as bait during days closed to harvest. This option extends the weekend closure by 24 hours for three months of the year, during roe season, when landings and effort peak. This addition is projected to reduce commercial harvest closer to a level projected to rebuild SSB to the target allowing for some buffer to account for variability in fishing effort and availability of fish. Additionally, this option preferentially protects spawning fish and potentially benefits full-time commercial participants while reducing user group conflict. For implementation and enforcement purposes, the closures will start at 6 pm Friday and end at 6 am the day the fishery reopens (Monday from January 1 to September 30; or Tuesday from October 1 to December 31). The DMF recommends not implementing a stop net fishery catch cap due to the fishery's highly variable landings, unusually high landings in 2023, and the potential for high volumes of dead discards. While options to limit nighttime fishing were discussed, because of the potential to increase user group conflict, and the disproportionate effect they may have on certain segments of the fishery, they are not recommended.

Option 5: Combination of Measures
  See Table 2.13 for all options

Table 2.13. Management measure combinations to end overfishing and achieve sustainable harvest, compared to 2019 commercial landings. Unless otherwise specified all options for day of week closures or day of week reduced trip limits are applied year-round. All trip limit options are applied to a commercial fishing operation regardless of the number of persons, license holders, or vessels involved.

Option	Season Closure	Daily Trip Limit (lb.)	Day of Week Closure	% Reduction	% Reduction with 30k Stop Net Cap
5.a*	.	.	Sat-Sun	25.7	24.0
5.b	Dec 1-Dec 31	Jan-Sep 1,000; Sat-Sun 50 lb	.	28.1	26.4
5.c*	.	Jan-Sep 1,000	Sat-Sun	28.5	26.9
5.d	Dec 1-Dec 31	Jan-Oct 15 1,000; Sat-Sun 50 lb	.	28.9	27.3
5.e	Nov 12-Dec 31	1,000	.	29.1	27.5
5.f*	.	Jan-Oct 15 1,000 lb	Sat-Sun	29.3	27.7
5.g	.	.	Jan-Oct Sat-Sun; Nov-Dec Sat-Mon	30.0	28.5
5.h	.	Jan-Oct 15 and Dec 500; Sat-Sun 50 lb	.	31.3	29.8
5.i	Dec 1-Dec 31	Jan-Sep 1,000	Sat-Sun	31.8	30.2
5.j	.	Jan and Dec 100 lb; Feb-Sep 500 lb; Sat-Sun 50 lb	.	32.4	30.9
5.k	Dec 1-Dec 31	Jan-Oct 15 1,000	Sat-Sun	32.6	31.1
5.l	Nov 8-Dec 31	1,000	.	34.6	33.1
5.m	.	Jan and Dec 50 lb; Sat-Sun 50 lb; Feb-Oct 15 500 lb	.	34.6	33.2
5.n[+]	.	.	Jan-Sept Sat-Sun; Oct-Dec Sat-Mon	34.9	33.4
5.o	.	Jan-Oct 15 and Dec 500	Sat-Sun	35.4	33.9
5.p	.	Jan1-31 and Nov16-Dec31 50 lb., Sat-Sun 50 lb, Feb1-Oct15 500lb	.	36.9	35.5
5.q	.	Jan and Dec 100 lb; Feb-Sep 500 lb	Sat-Sun	36.5	36.0
5.r	Nov 12-Dec 31	1,000	Sat	38.6	37.2

*Endorsed by Striped Mullet FMP AC
[+]DMF Recommendation

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Stop Nets

The striped mullet beach seine fishery is a historically and culturally important fishery occurring primarily in conjunction with the Bogue Banks stop net fishery (See Striped Mullet FMP and Amendment 1 for review of historical significance of stop net fishery). The stop net fishery has operated under fixed seasons and net and area restrictions since 1993. Currently, stop nets are limited to 4 nets, 400 yards in length, and minimum mesh size of eight inches outside panels and six inches middle section. Stop nets have typically been allowed along Bogue Banks (Carteret County) in the Atlantic Ocean from October 1 to November 30. However, the stop net season was extended to include December 3 to December 17 in 2015 due to minimal landings of striped mullet (Proclamation M-28-2015). In 2020, 2021, and 2022 the stop net fishery was open from October 15 through December 31 (Proclamations M-17-2020, M-21-2021, and M-23-2022). Due to the schooling nature of striped mullet, the beach seine fishery is a high-volume fishery with the ability to land thousands of pounds during a single trip.

From 2017 to 2021 the beach seine/stop net fishery accounted for 2.1% of the total commercial striped mullet harvest. In these years the fishery has primarily operated in November with a few trips occurring in October and December, and minimal landings after November 15.

Current management of the stop net fishery has focused on limiting interactions with protected species, primarily bottlenose dolphins, and limiting conflict with the ocean gill net fishery and recreational pier fisheries. There are no management measures in the stop net fishery to directly limit harvest of striped mullet. A detailed review of current stop net management measures can be found in the Striped Mullet FMP (NCDMF 2006). Additional management of the stop net fishery is addressed in the Spotted Seatrout FMP (NCDMF 2012). The spotted seatrout management strategy grants the DMF Director latitude to reconcile the potentially high-volume catch of spotted seatrout with the 75 fish commercial trip limit. An agreement was reached between the Director, the Fisheries Management Section Chief, and the stop net fishery participants to manage the fishery at a 4,595 lb season quota for spotted seatrout. The agreement required the stop net fishery participants to report spotted seatrout harvest daily and remove the stop nets from the water when the quota is met.

Because commercial harvest reductions are necessary to end overfishing and recover the striped mullet stock, it may be necessary to consider additional stop net management measures. Stop nets could be considered with all other commercial gears and have the same restrictions applied as any other sector of the fishery. However, given the limited extent and seasonality of the fishery some restrictions may disproportionately impact the stop net fishery. For example, extended season closures would likely eliminate all harvest from stop nets (Table 2.14). In addition, restrictive trip limits may create excessive discards in the fishery. Setting a specific season resulting in proportional harvest reductions may be a more equitable management option. Alternatively, the stop net fishery could operate on a sector specific striped mullet catch cap, as is done with spotted seatrout. Given minimal participation and effort in the stop net fishery, along with the already required daily reporting of spotted seatrout landings, requiring additional daily reporting of striped mullet landings could be accomplished.

The Striped Mullet FMP AC supported the strategy to manage the stop net fishery under a sector specific catch cap but did not suggest any specific harvest or reduction level to achieve. After reviewing recent striped mullet commercial landings from stop nets, DMF initially recommended an annual catch cap for the stop net fishery of 30,000 lb. This harvest level is in line with recent landings and prevents increasing harvest above those recent levels. However, following MFC AC and public review, where managing the stop net fishery with the same regulations as the rest of the striped mullet commercial fishery was strongly supported, the DMF revised its

recommendation to not manage stop nets with a catch cap. DMF recommends Option 6.a, manage the stop net fishery with management measures applied to the rest of the commercial fishery. To maintain consistency, the stop net season will open annually no sooner than October 15 and close no later than December 31 and all other stop net and associated gill net regulations will be set by proclamation consistent with, but not limited to, previous management. See proclamations M-17-2020, M-21-2021, and M-23-2022 for stop net season, setting and net restrictions and proclamations M-18-2020, M-20-2021 and, M-22-2022 for associated gill net restrictions.

Table 2.14. Percent reduction of striped mullet landings in the stop net fishery at various season closure options, 2017-2021.

Season Closure	Percent Reduction				
	2017	2018	2019	2020	2021
October 28-December 31	100.0	100.0	100.0	100.0	69.1
October 29-December 31	100.0	100.0	100.0	100.0	69.1
November 6-December 31	88.3	100.0	100.0	98.4	35.9
November 7-December 31	88.3	100.0	100.0	98.4	35.9
November 13-December 31	81.6	99.2	45.1	98.4	1.5

Option 6: Stop net fishery management
a. Status Quo – Manage stop net fishery with management measures applied to the rest of the commercial fishery
     + Prevents confusion
     + Minimizes user group conflict
     − Some measures may completely eliminate stop net fishery
     − May not meet sustainability objectives
     − Could increase discards

b. Stop Net Specific Catch Cap
     + Allows continuation of fishery
     + Likely to meet sustainability objectives
     + Easy to monitor and enforce with minimal participation
     + Already being done in fishery for other species
     − Could create user group conflict
     − Daily reporting necessary

Seasonal Catch Limits

Seasonal catch limits, otherwise known as a harvest quota or total allowable landings (TAL), is a management measure used to set harvest levels for a stock to end overfishing, recover the stock, or to maintain F and SSB at a specified management target. The intent of implementing a seasonal catch limit on any fishery is to prevent expansion and reduce or stabilize harvest. The benefit of managing harvest through a seasonal catch limit is the harvest level is directly set and controlled.

To calculate the seasonal catch limit, a reduction percentage must be established (21.3-35.4%). The selected reduction percentage is calculated based on 2019 commercial landings (1,362,212 pounds). The simplest method for seasonal catch limit implementation is a single statewide seasonal catch limit starting at the beginning of the year and running until the limit is met. The

seasonal catch limit would be between 879,992 and 1,072,065 pounds depending on the reduction percentage. On average, from 2017 to 2021, the season would close between October 23 (35.4% reduction) and November 6 (21.3% reduction).

While implementing a seasonal catch limit with multiple allocations makes monitoring and enforcement more difficult, allocations could be divided by region, gear, or fishery segment. Most commercial landings come from the northern part of the state (north of the Highway 58 Bridge to Emerald Isle) with minimal contributions from the southern part of the state. More specifically, most commercial landings come from Dare and Carteret counties. From 1994 to 2021, 88.5% of commercial striped mullet landings have come from the northern region, and 11.5% of commercial landings have come from the southern region (Onslow, Pender, New Hanover, Brunswick). If this historical allocation is maintained, an example of a region-specific seasonal catch limit, at various reduction levels that end overfishing and recover the stock, is shown in Table 2.15. A region-specific seasonal catch limit could also be implemented using allocations from a more recent period to better reflect the current fishery, for example 2017-2021 (Table 2.16), or use allocations from 2019 which is the year reductions are calculated from (Table 2.17).

Table 2.15. Regional seasonal catch limit, split at the Highway 58 bridge to Emerald Isle, based on 1994 - 2021 allocation.

Region	1994-2021 Contribution	2019 Landings Contribution	Reduction and TAL	
			21.3	35.4
North	88.5	1,205,558	948,774	778,790
South	11.5	156,654	123,287	101,199
Total	100	1,362,212	1,072,061	879,989

Table 2.16. Regional seasonal catch limit, split at the Highway 58 bridge to Emerald Isle, based on 2017 - 2021 allocation.

Region	2017-2021 Contribution	2019 Landings Contribution	Reduction and TAL	
			21.3	35.4
North	92.8	1,264,133	994,872	816,630
South	7.2	98,079	77,188	63,359
Total	100	1,362,212	1,072,061	879,989

Table 2.17. Regional seasonal catch limit, split at the Highway 58 bridge to Emerald Isle, based on 2019 allocation.

Region	2019	2019 Landings	Reduction and TAL	
			21.3	35.4
North	94.1	1,281,870	1,008,832	828,088
South	5.9	80,342	63,229	51,901
Total	100	1,362,212	1,072,061	879,989

Most striped mullet commercial landings come from gill nets, specifically runaround gill nets. Minimal contributions come from other gears, but the stop net fishery has the potential to be a high-volume fishery. If a seasonal catch limit is implemented, it is possible the limit could be reached before the stop net fishery has a chance to operate. Accounting for stop net landings separately may be necessary to allow the fishery the chance to operate. See the stop net section of this issue paper for additional information and discussion.

A seasonal catch limit could be implemented specifically for the striped mullet roe fishery. This fishery occurs predominantly in October and November and typically accounts for up to 50% of the striped mullet commercial landings each year. This fishery is the most valuable portion of the striped mullet fishery and specifically targets large female striped mullet during the spawning migration. A seasonal catch limit could be developed and applied to October-November commercial landings and other measures could be used to limit harvest early in the year (e.g., trip limits, day of week closures, etc., see additional discussion in this paper). Once the roe fishery seasonal catch limit was met, the fishery would be closed through the end of the year. This would allow the most valuable segment of the fishery to operate independent of other fishery segments and have direct conservation benefits to the stock. However, shortening the fishery in this manner would likely create a "derby" fishery, where intensive fishing effort is focused during a short period, which is unpopular with the fishing industry and may create conflict.

To successfully manage harvest using a seasonal catch limit, the ability to accurately monitor harvest in a timely manner and have the flexibility to quickly implement management changes or close fishing sectors when the seasonal catch limit is being approached is essential. Currently, striped mullet commercial landings are reported by the North Carolina Trip Ticket Program, a fishery-dependent program initiated by NCDMF in 1994. A trip ticket is the form used by fish dealers to report commercial landings information. Trip tickets collect information about the fisherman, the dealer purchasing the product, the transaction date, crew number, area fished, gear used, and the quantity of each species landed for each trip. Each month dealers are required to send these forms to the NCDMF for processing.

If a seasonal catch limit is used to manage striped mullet harvest, changes to reporting requirements would need to occur. Daily striped mullet harvest reporting by dealers would be necessary during at least part of the year. Because the striped mullet fishery is highly seasonal, requiring daily reporting during the peak season in October-November until the seasonal catch limit is reached would be necessary. Prior to daily reporting, regular monthly, or weekly, reporting could be sufficient, but an accurate accounting of commercial landings would need to be finalized prior to a period of daily reporting. Implementation of daily or weekly reporting would require development of a permit with conditions requiring time of reporting.

If a seasonal catch limit is implemented, the use of other management measures to limit harvest would likely still be necessary to either extend the fishing season or ensure the catch limit is not exceeded. Specifically, trip limits and gill net yardage limits have been used to constrain harvest for fisheries managed using seasonal catch limits, but day of week closures may also have the same effect. See discussion about trip limits and day of week closures (this paper) for additional information.

If a seasonal catch limit were implemented for striped mullet, restrictions on the use of small mesh gill nets may be needed to prevent excessive discards. The use of anchored small mesh gill nets has been extensively reviewed as part of North Carolina FMPs for red drum (NCDMF 2001; 2008) and striped bass (NCDMF 2004; 2013a). Further restrictions would add additional management complexity to a gear that is already heavily regulated. Appendix 1 summarizes the small mesh gill net fishery in North Carolina including seasonality, gear characteristics and species targeted. If the use of small mesh gill nets is restricted to prevent excessive discards of striped mullet, other fisheries like spotted seatrout (*Cynoscion nebulosus*), bluefish (*Pomatomus saltatrix*), kingfish/sea mullet (*Menticirrhus* spp.), white perch (*Morone americana*), and spot (*Leiostomus xanthurus*) would likely be impacted.

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It should be noted previous management has not directly limited the commercial harvest of striped mullet in North Carolina. In many cases, implementation of a seasonal catch limit has been a "last resort" measure when other methods of controlling harvest have been ineffective. At this point, there are no clear models for how participant behavior may change under various management scenarios. Implementation of seasonal catch limits in other fisheries has resulted in "derby fisheries" which are unpopular with participants. Implementation of a seasonal catch limit is the most definitive and blunt method for directly limiting harvest because if the limit is effectively monitored and enforced landings cannot exceed a set level even if variable fishery or stock conditions occur. However, seasonal catch limits are also the most resource intensive to monitor and enforce because of the necessity of daily reporting. Stock projections indicate if average or above average recruitment occurs the striped mullet stock recovers quickly even at moderate harvest reduction levels. If a seasonal catch limit is implemented, updates to the limit could only occur following stock assessment updates, which may constrain harvest excessively even when it is no longer necessary.

While the Striped Mullet FMP AC felt a seasonal catch limit would effectively limit harvest, members were concerned about how low the limit would be set initially, lack of flexibility in adjusting the limit, the potential of a "derby" fishery, the potential for a short season, and the need for a complete closure once the limit is reached. AC members did suggest using a seasonal catch limit but allowing some bycatch limit after the limit was reached. While this could be done, it would require lowering the catch limit to account for limited bycatch, further reducing the limit. While implementing a seasonal catch limit for striped mullet would be effective, given the characteristics of the striped mullet fishery, management objectives could be met using other management strategies that are much less resource intensive for monitoring and that would be less restrictive or constraining to this multi-faceted fishery.

Option 7: Seasonal Catch Limit
a. Status Quo – Manage fishery without Seasonal Catch Limit
  + Other measures may be effective in reducing harvest
  + Less impact to other fisheries
  + No derby fishery
  − No hard cap on commercial landings

b. Implement Statewide Seasonal Catch Limit
  + Hard cap on landings
  + Should meet sustainability objectives
  − As stock grows, TAL cannot be adjusted without stock assessment update
  − Will likely impact other fisheries
  − Increased discards
  − Unpopular with fishery participants
  − Resource intensive to monitor and enforce
  − Would need to establish new reporting requirements
  − Could disadvantage certain areas of the state

c. Implement Regional (North/South) Seasonal Catch Limit
  + Hard cap on landings
  + Should meet sustainability objectives
  + Equitable between areas of the state
  − As stock grows, TAL cannot be adjusted without stock assessment update
  − Will likely impact other fisheries
  − Increased discards
  − Unpopular with fishery participants

- Resource intensive to monitor and enforce
- Would need to establish new reporting requirements

Area Closures

Area closures are a management measure that could be used to achieve nonquantifiable harvest reductions in the striped mullet fishery in support of sustainability objectives. From 1997 to 2001, DMF conducted a striped mullet tagging study to examine movements and migration of striped mullet in North Carolina (Wong 2001). Of approximately 15,000 tagged fish, 384 were recaptured, indicating limited movement prior to the spawning season in October and November (Bacheler et al. 2005). Other than a generally southward movement, tag returns provide little information to inform potential area closures (Figure 2.6). Striped mullet are catadromous, migrating from freshwater to offshore marine waters in the fall to spawn. Because of this life history, striped mullet can be found in nearly all common habitat types including the water column, wetlands, submerged aquatic vegetation, soft bottom, and shell bottom with variation in preference due to location, season, and life stage (see base plan Biological Profile and Ecosystem Protection and Impact sections for further description and NCDMF 2022a). In addition, striped mullet nursery areas and spawning locations, habitats that would benefit most directly from area closures, are considered at a broad level (e.g., estuarine areas serve as nursery areas, spawning occurs in the ocean), therefore, identifying discrete areas for potential closures is difficult.

One recent example of an area closure impacting the striped mullet commercial fishery is the prohibition of all gill nets above the ferry lines in the Pamlico and Neuse rivers (Proclamation M-6-2019; Figure 2.7). During an emergency meeting on March 13, 2019, the N.C. Marine Fisheries Commission directed the DMF Director to issue proclamation M-6-2019 pursuant to N.C. General Statute 113-221.1 (d). The Director has no legal authority to modify or change a proclamation when the proclamation is specifically directed by the Commission under this statute. The intent of the proclamation was to reduce dead discards of striped bass (*Morone saxitilis*) in support of a striped bass harvest moratorium in these rivers. The gill net closure was implemented with little supporting data and potential benefits to striped bass stocks will be evaluated in the future (NCDMF 2022b). However, recreational fishing groups have touted the gill net closure as a conservation success, particularly for striped mullet. Striped mullet are common above the ferry lines in each river and commercial fishery participants have expressed frustration that the closure prevents harvest of striped mullet, particularly early in the year and during the summer. However, because striped mullet migrate from estuarine waters to the ocean to spawn in the fall, the gill net closures in these rivers are not considered an effective conservation measure for striped mullet. Essentially, the gill net closure acts as a harvest delay measure, where striped mullet become available to the fishery when they cross the ferry line while moving down river to spawn.

While there may be fishery benefits to this harvest delay because harvest is delayed until the fall when demand and prices are higher, the closure prevents other components of the fishery (i.e., bait and food) from occurring in the area. Given seasonal migration patterns of striped mullet and characteristics of the fishery, area closures to effectively address sustainability objectives would likely need to be so large the fishery would have limited ability to operate. In this sense, season closures accomplish the same result as area closures with more clearly defined and obtainable objectives.
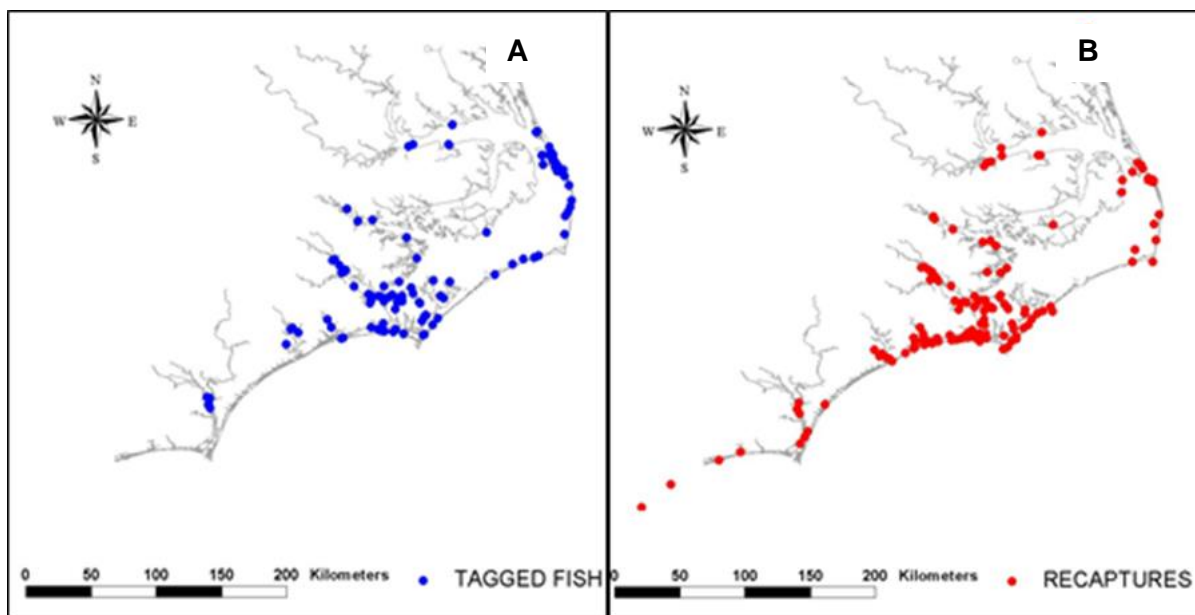
Figure 2.6. Tagging location of recaptured striped mullet (A) and recapture location for all striped mullet tag returns (B). A single dot may indicate multiple fish. From Wong (2001).

Option 8: Area Closures
+   No additional resources required to implement
+   No additional reporting burden on fishermen or dealers
+   Limits impacts on roe fishery
+   Limits impacts on bait fishery
−   Unlikely to meet sustainability objectives
−   Increased discards

Limited Entry

North Carolina General Statute 113-182.1 states the MFC can only recommend the General Assembly limit participation in a fishery if the commission determines sustainable harvest in the fishery cannot otherwise be achieved. The North Carolina striped mullet stock is overfished and overfishing is occurring so sustainability is a concern. However, there have never been any regulations directly limiting harvest of striped mullet in North Carolina, therefore it would be difficult to conclude limiting participation is the only way to achieve sustainable harvest. Supplement A to Amendment 1 implemented the first management measures directly limiting harvest of striped mullet in North Carolina and Amendment 2 will introduce more comprehensive measures. Success of Amendment 2 management measures can be used to gauge the need for limited entry in the future.

Option 9: Limited Entry
+   Likely to meet sustainability objectives
+   Limits impacts on roe fishery
+   Limits impacts on bait fishery
−   Statutory requirements not met
−   Additional resources required to implement
−   Additional reporting burden on fishermen or dealers
−   Increased discards

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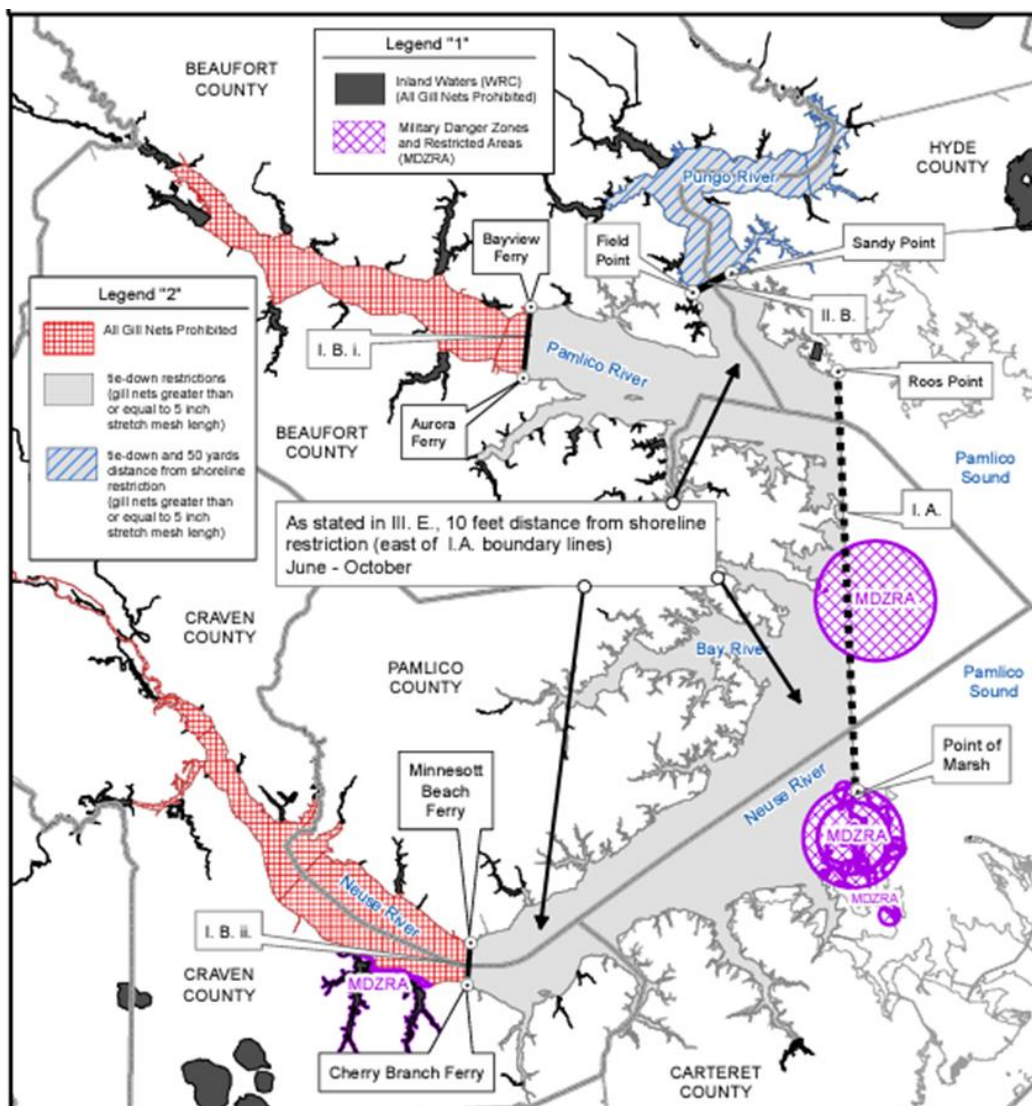
Figure 2.7. Map of the Pamlico and Neuse rivers showing existing gill net restrictions and the prohibition on the use of gill nets above the ferry line in each river.

Adaptive Management

The current striped mullet adaptive management framework and trigger needs to be updated. Adaptive management is a structured decision-making process when uncertainty exists, with the objective to reduce uncertainty through time with monitoring. Adaptive management provides flexibility to incorporate new information and accommodate alternative and/or additional actions. The original FMP established minimum and maximum commercial landings triggers of 1.3 and 3.1 million pounds (NCDMF 2006). Amendment 1 updated the commercial landings triggers to 1.13 and 2.76 million pounds (NCDMF 2015). The triggers were set two standard deviations above or below the average commercial landings from 1994 to 2002 in the original FMP and the average commercial landings from 1994 to 2011 in Amendment 1. If annual landings fall below the minimum trigger, the DMF would investigate whether the decrease in landings is attributed to stock decline, decreased fishing effort, or both. If annual landings exceed the maximum trigger, the DMF would determine whether harvest is sustainable and what factors are driving the increase in harvest.

The commercial landings trigger has only tripped once since its adoption in 2006, when commercial landings fell below the minimum landings trigger in 2016 (Figure 2.8). Commercial landings are a poor indicator of stock abundance because they can be impacted by many factors including fishing effort and market demand. In addition, fishery efficiency could maintain higher, or consistent, commercial landings even as the stock declines. The adaptive management language in Amendment 1 was also vague, providing no specifics for determining stock status or the degree to which management measures should impact the fishery or reduce harvest. Updating the adaptive management framework for striped mullet is necessary to eliminate ambiguity and provide guidance for decision making processes.

Success or failure of any given management strategy to rebuild and sustain the stock is assessed relative to the established biological reference points and can only be determined through a stock assessment. Failure to achieve projected harvest reductions does not necessarily indicate failure of a management measure. It could indicate improving stock conditions but can only be measured with an updated stock assessment. Peer reviewed stock assessments and stock assessment updates should continue to be used to guide management decisions for the North Carolina striped mullet stock. The 2022 peer reviewed stock assessment (NCDMF 2022) should be updated, at least once between full reviews of the plan to gauge success in stock rebuilding and to monitor changes in *F*. The 2022 stock assessment had a terminal year of 2019; Supplement A management measures will be implemented in 2023, and Amendment 2 management measures will be implemented, at the earliest, in 2024. Given this timeline, the earliest a stock assessment update should be completed is during 2025 with the inclusion of data from 2024, though timing of a stock assessment update is at the discretion of the division. An update will determine if management targets are being met and allow for any adjustments to management measures via adaptive management if needed.
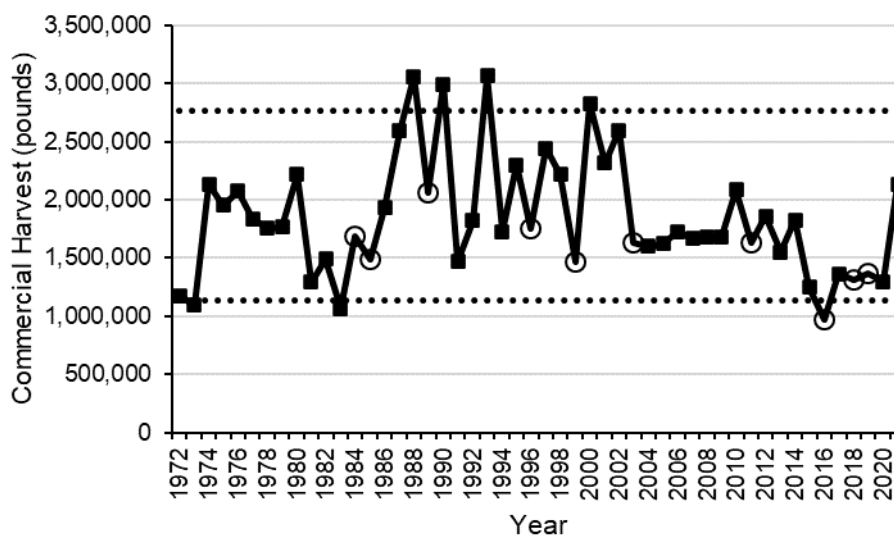
Figure 8. Striped mullet commercial landings (pounds) reported through the North Carolina Trip Ticket Program, 1972–2021 Lower dashed line (1.13 million lb.) and upper dashed line (2.76 million lb.) represent landings limits that trigger closer examination of data. Open circles represent years with significant hurricanes or storms.

The existing mullet rule, 15A NCAC 03M .0502, provides the Fisheries Director proclamation authority pursuant to 15A NCAC 03H .0103 to impose any of the following restrictions on the taking of mullet:

1) Specify time;
2) Specify area;
3) Specify means and methods
4) Specify seasons
5) Specify size; and
6) Specify quantity, except as provided in Paragraph (a) of the rule.

Upon adoption of Amendment 2, the adaptive management framework will consist of the following:

Option 10: Adaptive Management Framework

Parts 1-3 of the adaptive management framework are explicitly tied to an updated stock assessment and implementation of management measures intended to reduce or allow for additional harvest to meet or maintain management targets (as defined in part 1.a).

5) Update the stock assessment at least once in between full reviews of the FMP, timing at discretion of the division
   a. If current management is not projected to meet management targets (management targets are minimum SSB between $SSB_{Threshold}$ and SSB_{Target}, and maximum F between $F_{Threshold}$ and F_{Target}), then management measures shall be adjusted via an adaptive management update and implemented using the Fisheries Director's proclamation authority to reduce harvest to a level that is projected to meet the F_{Target} and SSB_{Target}.
   b. If management targets (as defined in 1.a above) are being met, then new management measures would not be needed, or current management measures could possibly be relaxed provided projections still meet management targets. When management targets are met, a striped mullet industry workgroup will be convened to discuss the possibility of "guard rail management" to maintain a sustainable harvest for the striped mullet stock.
6) Management measures that may be adjusted using adaptive management include:
   a. Season closures
   b. Day of week closures
   c. Trip limits
   d. Gill net yardage or mesh size restrictions in support of the measures listed in a-c
7) Use of the Director's proclamation authority for adaptive management to meet management targets is contingent on:
   c. Consultation with the MFC Northern, Southern, and Finfish advisory committees
   d. Approval by the Marine Fisheries Commission

Part 4 of the adaptive management framework allows for adjustment of management measures outside of an updated stock assessment. Part 4 is intended to allow for adjustment of management measures to ensure compliance with and effectiveness of management strategies adopted in Amendment 2 and would be a tool to respond to concerns with stock conditions and fishery trends.

8) Upon evaluation by the division, if a management measure implemented to achieve sustainable harvest (either through Amendment 2 or a subsequent revision) is not achieving its intended purpose, it may be revised or removed and replaced using the Director's proclamation authority; provided it conforms to part 2 above and provides similar protections to the striped mullet stock. If a revised management measure is anticipated to reduce or increase harvest compared to measures implemented through Amendment 2, it must conform to parts 2 and 3 above.

Table 2.18. Management measures to achieve sustainable harvest in the striped mullet fishery

Topic	Option	Description
Size Limit	1.a	Status quo – no size limit
	1.b	Minimum size limit and 3.25 ISM minimum gill net mesh size
	1.c	Minimum size limit and 3.75 or 4.0 ISM maximum gill net mesh size
	1.d	Seasonal maximum size limit and 3.75 or 4.0 ISM maximum gill net mesh size
Season Closure	2.a	No season closure
	2.b	Statewide season closure October 29–December 31
	2.c	Statewide season closure November 7–December 31
	2.d	Regional, North/South, season closure North Oct. 28–Dec. 31 South Oct. 30–Dec. 31
	2.e	Regional, North/South, season closure North Nov. 7–Dec. 31 South Nov. 10–Dec. 31
Trip Limit	3	
Day of Week Closure	4	
Combinations	5.a–r	See Table 2.13
Stop Net Fishery Management	6.a	Manage stop net fishery with same management measures applied as the rest of the fishery
	6.b	Stop Net specific catch cap
Seasonal Catch Limit	7.a	Status quo – no seasonal catch limit
	7.b	Statewide seasonal catch limit
	7.c	Regional, North/South, seasonal catch limit
Area Closures	8	
Limited Entry	9	
Adaptive Management	10	

RECOMMENDATION

DMF Recommendation:

The DMF recommends the following options that are projected to rebuild the striped mullet spawning stock biomass (SSB) to a level between the threshold and target:

Option 5.n Combination of Measures

- Saturday-Sunday closure (Jan. 1-Sept. 30) (Table 2.18)
- Saturday-Monday closure (Oct. 1-Dec. 31) (Table 2.18)

Option 6.a Manage stop net fishery with same management measures applied as the rest of the fishery

Option 10: Adaptive Management Framework

Advisory Committees Recommendations and Public Comment: see Appendix 4

NCMFC Selected Management Options:

Option 5.n Combination of Measures
- Saturday-Sunday closure (Jan. 1-Sept. 30) (Table 2.18)
- Saturday-Monday closure (Oct. 1-Dec. 31) (Table 2.18)

Option 6.a Manage stop net fishery with same management measures applied as the rest of the fishery

Option 10: Adaptive Management Framework

APPENDIX 3. CHARACTERIZATION AND MANAGEMENT OF THE NORTH CAROLINA RECREATIONAL STRIPED MULLET FISHERY

ISSUE

Review available data and characterize the North Carolina recreational striped mullet fishery. Recommend potential non-quantifiable management measures in support of sustainable harvest objectives.

ORIGINATION

DMF

BACKGROUND

Striped mullet are not typically targeted by recreational anglers using hook and line though, striped mullet (*Mugil cephalus*) and white mullet (*M. curema*) are commonly used as bait fish by recreational anglers targeting a wide variety of inshore and offshore species (Nickerson 1984; NCDMF 2020). Juvenile mullet, referred to as finger mullet, caught by cast net are commonly used for bait by recreational anglers and are generally available in the summer and fall with the majority caught in July, August, September, and October (NCDMF 2020). Larger mullet are used as cut bait by anglers fishing from boats, piers, and the beach and are a popular bait used for targeting red drum (*Sciaenops ocellatus*).

The 2006 Striped Mullet FMP (NCDMF 2006) characterized the cast net fishery for bait mullet and examined management measures to reduce discarding of bait mullet and prevent recreational cast netters from harvesting large amounts of bait mullet in North Carolina to sell in other states. The FMP established a possession limit of 200 mullets (white and striped in aggregate) per person per day for recreational purposes. A possession limit in the recreational fishery allows Marine Patrol to distinguish between commercial and recreational fishing operations and enforce accordingly. Marine Fisheries Commission Rule 15A NCAC 03M .0502 was amended to include section (a) "it is unlawful to possess more than 200 mullet per person per day for recreational purposes" and went into effect July 1, 2006. There are no other measures directly limiting the recreational harvest of striped mullet.

The 2022 stock assessment concluded the striped mullet stock was overfished and overfishing is occurring. Development of recreational harvest estimates are described in the stock assessment report (NCDMF 2022). Briefly, annual estimates of recreational harvest (A, B1, A + B1) and associated percent standard error (PSE) values for striped mullet, white mullet, and mullet genus (striped or white mullet not identified to species) were obtained from the Marine Recreational Information Program (MRIP). Annual estimates of the average individual weight of harvested striped mullet were also obtained from MRIP. Estimates of live releases were not considered for inclusion in the stock assessment because mullet are primarily captured by recreational anglers for use as live bait and releases are assumed to have no associated post-release mortality and the assessment model only considers dead fish.

This paper further characterizes the recreational striped mullet fishery, available data, and data needs. Because estimates of recreational harvest are highly uncertain, management measures resulting in quantifiable harvest reductions cannot be recommended. Non-quantifiable management measures to support sustainable harvest and allow for recreational access to meet fishery needs are discussed.

DRAFT

AUTHORITY

N.C. General Statute
G.S. 113-134 RULES
G.S. 113-182 REGULATION OF FISHING AND FISHERIES
G.S. 113-182.1 FISHERY MANAGEMENT PLANS
G.S. 113-221.1. PROCLAMATIONS; EMERGENCY REVIEW
G.S. 143B-289.52 MARINE FISHERIES COMMISSION-POWERS AND DUTIES

N.C. Rule
15A NCAC 03M .0502 MULLET
15A NCAC 03M .0101 MUTILATED FINFISH
15A NCAC 03H .0103 PROCLAMATIONS, GENERAL

DISCUSSION

Collection of Recreational Data

North Carolina conducts three fishery-dependent surveys to collect recreational harvest data. 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 border south to the South Carolina border, excluding the Albemarle Sound. The Recreational Commercial Gear License (RCGL) Survey was conducted from 2002-2008 by the DMF to collect data from recreational fishermen who are licensed to harvest recreational limits of finfish using commercial gears. 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 who fish using cast nets and seines.

Marine Recreational Information Program

The MRIP is a national program administered through NOAA Fisheries that uses several surveys to estimate catch and effort data at a regional level. The Access Point Angler Intercept Survey (APAIS) provides the catch rates and species composition from anglers fishing in estuarine or marine waters (not freshwater). Anglers who have completed a fishing trip are intercepted and interviewed to gather catch and demographic data, including fishing mode (charter boat, private/rental boat, beach/bank, and man-made structures), area fished, and wave (each two-month sampling period). The MRIP implemented the Fishing Effort Survey (FES) in 2018, an improved methodology of the prior effort survey (Coastal Household Telephone Survey). The data from the APAIS and FES are combined to provide estimates of the total number of fish caught, released, and harvested. Additionally, information is collected on the weight of the harvest, total number of trips, and the number of people participating in marine recreational fishing. Additional information on MRIP is available through the [NOAA MRIP Website](#).

Striped mullet landings reported through MRIP are available at the species level through direct observation; however, releases are not observed and therefore are only available at the genus level, which includes both striped mullet and white mullet. Juvenile striped mullet and white mullet are not easily distinguished by recreational anglers, and harvest levels reported through MRIP at the species level are imprecise for both striped mullet and white mullet. To estimate species-level recreational harvest of striped mullet more accurately, the sum of recreational harvest reported for striped mullet and a proportion (29%) of the recreational harvest reported at the mullet genus level are used. This proportion was derived from a study by the DMF, indicating that about 29% of mullet harvested using cast nets are striped mullet (NCDMF 2006). The option to record harvest at the genus level for unobserved harvest of mullet only became available in 2002, therefore, MRIP estimates for recreational striped mullet harvest prior to 2002 are unreliable. Additionally,

recreational harvest is estimated by the number of fish harvested rather than in pounds because most mullet reported by anglers are not observed or weighed.

Estimates for recreational harvest of striped mullet peaked in 2002 and 2003 at about six million and four million fish harvested, respectively (Table 3.1). This increase coincides with an increase in commercial harvest (see Commercial Fishery section) and appears to be the result of increased striped mullet abundance. From 2004 to 2017, recreational harvest fluctuated between roughly 1 million and 1.8 million fish, then dropped to around 500 thousand fish harvested per year until 2021 when harvest increased to about 1.5 million fish (Table 3.1). The decline in harvest from 2018-2020 was likely the result of decreased striped mullet abundance and management measures that significantly shortend the recreational fishing season for southern flounder (*Paralichthys lethostigma)*, a fishery where live finger mullet are a popular bait.

Table 3.1. Recreational harvest (number of fish landed) of striped mullet and mullet genus estimated from MRIP sampling for 2002 to 2021. Type A harvest is observed while Type B1 harvest is reported by the angler and never observed. Proportional standard error (PSE) values greater than 50 indicate an imprecise estimate (highlighted gray).

Year	Striped Mullet		Mullet Genus		Striped Mullet from Mullet Genus (29%)	Striped Mullet + Mullet Genus
	Harvest (A+B1)	PSE	Harvest (B1)	PSE	Harvest (B1)	Striped Mullet Total Harvest
2002	4,668,427	18.0	4,480,197	36.3	1,299,257	5,967,684
2003	3,368,881	29.6	2,487,885	20.4	721,487	4,090,368
2004	5,496	101.7	4,790,382	16.1	1,389,211	1,394,707
2005	10,795	61.5	4,487,719	21.4	1,301,439	1,312,234
2006	15,706	63.5	3,599,098	21.4	1,043,738	1,059,444
2007	301,004	81.3	5,052,995	22.3	1,465,369	1,766,373
2008	3,458	65.0	4,097,156	14.4	1,188,175	1,191,633
2009	83,480	90.6	3,736,571	14.3	1,083,606	1,167,086
2010	126,250	44.7	4,113,171	14.3	1,192,820	1,319,070
2011	80,267	28.6	3,653,514	14.3	1,059,519	1,139,786
2012	351,960	79.5	3,510,395	16.3	1,018,015	1,369,975
2013	150,020	53.9	4,493,166	20.5	1,303,018	1,453,038
2014	50,381	67.0	4,490,722	26.2	1,302,309	1,352,690
2015	142,696	64.5	4,405,800	21.5	1,277,682	1,420,378
2016	29,965	50.6	5,039,891	55.6	1,461,568	1,491,533
2017	37,791	43.9	5,170,318	55.2	1,499,392	1,537,183
2018	35,565	59.3	1,564,676	31.7	453,756	489,321
2019	324,986	52.0	817,596	25.3	237,103	562,089
2020	323,102	43.2	719,908	23.2	208,773	531,875
2021	1,194,213	73.6	1,002,195	31.6	290,637	1,484,850

Recreational striped mullet harvest increases begginning in May and June, coinciding with increasing recreational fishing effort, and peaks in September and October (Table 3.2, Figure 3.1). A cast net study conducted by the DMF in 2002 and 2003 found the composition of cast net catches was primarily white mullet but in November, striped mullet were 74% of the catch (NCDMF 2006). White mullet were a higher proportion of the catch at ocean or inlet stations compared to estuarine stations which had a higher percentage of striped mullet.

Table 3.2. Recreational harvest (number of fish landed) of striped mullet and mullet genus by wave estimated from MRIP sampling, 2002-2021. Striped mullet assumed as 29% of mullet genus.

Year	Wave	Striped Mullet Harvest (A+B1)	Mullet Genus Harvest (B1)	Striped Mullet from Mullet Genus (29%) Harvest (B1)	Striped Mullet + Mullet Genus Striped Mullet Total Harvest
2017	Jan/Feb	.	.	.	.
2017	Mar/Apr	.	82,931	24,050	24,050
2017	May/Jun	27,708	284,430	82,485	110,193
2017	Jul/Aug	8,505	354,629	102,842	111,347
2017	Sep/Oct	1,579	4,432,737	1,285,494	1,287,073
2017	Nov/Dec	.	15,590	4,521	4,521
2018	Jan/Feb	.	.	.	.
2018	Mar/Apr	.	.	.	.
2018	May/Jun	2,239	136,595	39,613	41,852
2018	Jul/Aug	18,993	750,891	217,758	236,751
2018	Sep/Oct	13,505	457,709	132,736	146,241
2018	Nov/Dec	828	219,480	63,649	64,477
2019	Jan/Feb	.	.	.	.
2019	Mar/Apr	.	32,700	9,483	9,483
2019	May/Jun	11,773	86,637	25,125	36,898
2019	Jul/Aug	82,801	280,921	81,467	164,268
2019	Sep/Oct	217,317	367,020	106,436	323,753
2019	Nov/Dec	13,096	50,318	14,592	27,688
2020	Jan/Feb	1,648	1,540	447	2,095
2020	Mar/Apr	.	21,050	6,105	6,105
2020	May/Jun	6,308	78,303	22,708	29,016
2020	Jul/Aug	40,470	239,694	69,511	109,981
2020	Sep/Oct	274,675	370,617	107,479	382,154
2020	Nov/Dec	.	8,704	2,524	2,524
2021	Jan/Feb	.	6,340	1,839	1,839
2021	Mar/Apr	7,087	.	.	7,087
2021	May/Jun	1,336	144,319	41,853	43,189
2021	Jul/Aug	21,670	292,846	84,925	106,595
2021	Sep/Oct	1,164,119	558,690	162,020	1,326,139
2021	Nov/Dec	.	.	.	.
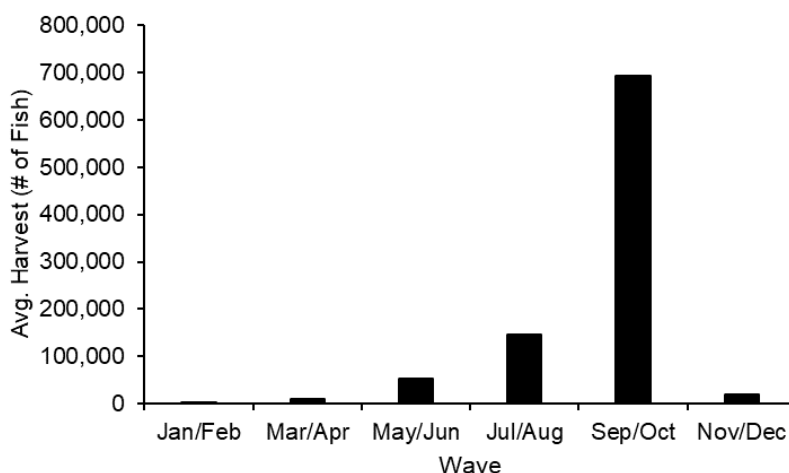
Figure 3.1. Average number of striped mullet harvested by the recreational fishery by wave based on MRIP estimates for 2017 to 2021.

The average length of striped mullet encountered in the North Carolina MRIP survey has ranged from a minimum of 7.2 inches (182 mm) in 2009 to a maximum of 13.6 inches (345 mm) in 2005 (Table 3.3). Because of small sample sizes, average lengths in almost all years of the time series are associated with high degrees of imprecision and are not considered reliable for characterizing recreational mullet harvest. Typically, only the largest mullet harvested by anglers are available to be sampled by MRIP staff. Most mullet harvested for use as bait are released prior to returning to the dock. The cast net survey conducted by DMF found striped mullet in cast net samples ranging from 1.9-15.3 inches FL (50-390 mm) with 76% of the fish from 2.8-5.5 inches FL (70-140 mm; NCDMF 2006; Figure 3.2). White mullet from cast net samples ranged from 1.6-7.4 inches FL (40-190 mm) with 98% of the fish between 2.4-5.9 inches FL (60-50 mm). Sub-adult and adult striped mullet were occasionally caught in the independent samples, but no sub-adult or adult white mullet were captured.

Table 3.3. Average length and weight of individual striped mullet intercepted by APAIS interviewers in North Carolina, 2002–2021. Proportional standard error (PSE) values greater than 50 indicate an imprecise estimate (highlighted gray).

Year	Avg Length (in)	PSE	Avg Weight (lb)	PSE
2002	8.2	26.0	0.4	30.2
2003	9.2	44.9	0.4	48.8
2004	10.0	143.8	0.4	143.8
2005	13.6	87.2	1.3	88.1
2006	11.9	86.4	0.9	83.1
2007	10.6	113.5	0.7	110.4
2008	10.8	90.9	0.7	90.6
2009	7.2	122.9	0.2	110.1
2010	10.4	63.7	0.9	73.2
2011	10.7	41.4	0.7	48.0
2012	10.5	112.5	0.7	112.8
2013	10.8	74.9	0.9	76.8
2014	12.9	96.4	1.1	97.0
2015	12.4	91.7	1.3	94.9
2016	11.9	71.7	0.9	72.3
2017	10.8	62.3	0.7	61.8
2018	10.9	83.3	0.7	82.0
2019	12.5	73.9	1.1	77.0
2020	13.4	63.1	1.5	67.8
2021	7.8	100.6	0.2	92.1
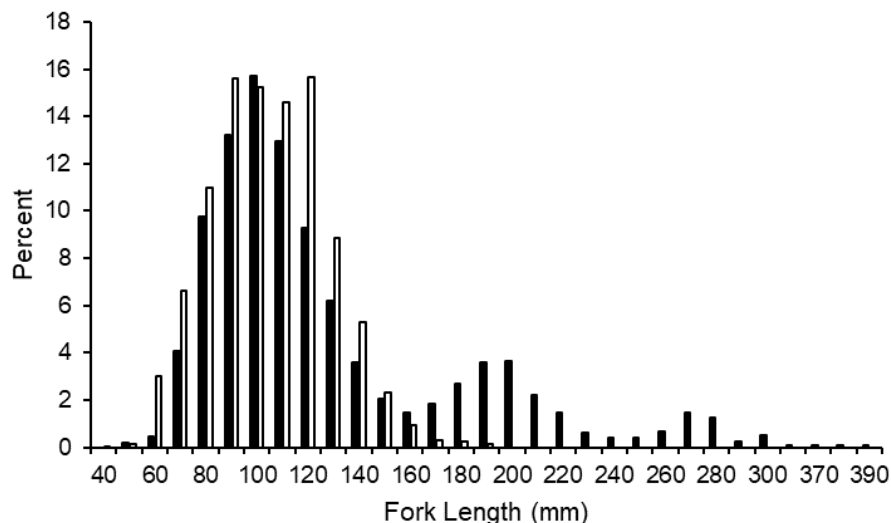
Figure 3.2. Length-frequency distributions of striped mullet (black bars) and white mullet (white bars) collected in the DMF fisheries-independent cast net study, 2002-2003.

Recreational Commercial Gear Landings

Harvest data from the Recreational Commercial Gear License (RCGL) survey were collected from 2002 to 2008. The program was discontinued in 2009 due to a lack of funding and the minimal contributions from RCGL to overall harvest. From 2002 to 2008, it is estimated that RCGL holders harvested an average of 41,512 pounds per year (Table 3.4). Estimated landings of striped mullet by RCGL holders peaked in 2002 and 2008, the first and final years of the survey. See Amendment 1 to the Striped Mullet Fishery Management Plan for a detailed summary of RCGL landings and effort (NCDMF 2015). Since the discontinuation of the RCGL survey in 2008, the number of RCGL issued each year has declined. In 2008, 5,503 RCGL were issued and in 2021, 2,143 RCGL were issued (NCDMF 2022a). It is unlikely harvest from this license type has increased substantially, particularly as additional restrictions have been placed on the use of gill nets.

Table 3.4. North Carolina RCGL number of striped mullet harvested, pounds harvested, number released, and total number caught. Estimates are from a RCGL survey conducted from 2002-2008.

Year	Number Harvested	Pounds Harvested	Number Released	Total Number
2002	66,305	64,213	6,549	72,854
2003	28,757	24,774	3,514	32,270
2004	34,736	35,947	2,875	37,611
2005	35,888	36,314	3,492	39,380
2006	38,175	37,385	5,352	43,527
2007	35,472	40,168	7,449	42,921
2008	51,465	51,785	9,207	60,672

Coastal Recreational Fishing License Survey

In October 2011, the DMF began a mail survey to develop catch and effort estimates for recreational cast net and seine use. The mail survey was established as a direct response to a lack of precision in MRIP estimates for difficult to sample or overlooked recreational fisheries and activities. The survey does not distinguish between striped and white mullet and all data should

be interpreted with caution because the ratio of striped mullet to white mullet in the recreational catch differs between seasons and areas of the state. Estimates from the DMF CRFL mail survey vary by month but generally peak between July and October, consistent with MRIP harvest estimates. The mail survey is a good source of recreational mullet effort, catch, and harvest information because of the relatively high precision of estimates.

Between 2012 and 2021, estimated annual harvest by cast nets of striped and white mullet from the mail survey ranged from 347,187 fish in 2018 to 942,521 fish in 2015 and the estimated number of trips that harvested mullet ranged from 88,939 trips in 2018 to 206,876 trips in 2015 (Table 3.5).

Additional sampling effort should focus on better characterizing the recreational fishery for striped mullet by contextualizing data collected by the CRFL Mail Survey through fishery-independent sampling. Characterization of cast net fishery catch composition was completed by the DMF in 2002-2003. While these data have been important for understanding the recreational fishery, particularly the proportion of striped mullet in the cast net harvest, updating the study in the context of the current recreational fishery, should be completed. Further sampling should be stratified based on effort, timing and locations reported in the CRFL Mail Survey and, in addition to collecting species composition information, should focus on collecting length and age data.

Table 3.5. Total mullet (striped and white) harvest (numbers of fish), releases, catch and effort from the Coastal Recreational Fishing License Survey by wave, 2012-2021. Proportional standard error (PSE) values greater than 50 indicate an imprecise estimate (highlighted gray).

Year	Wave	Total Effort	PSE	Total Mullet Harvest	PSE	Total Mullet Release	PSE	Total Mullet Catch	PSE
2021	Jan/Feb	10,518	27.9	15,365	61.1	4,615	56.7	19,980	57.7
	Mar/Apr	50,726	29.9	52,766	42.7	14,592	46.4	67,358	42.0
	May/Jun	45,681	11.8	133,646	26.9	34,978	50.6	168,624	26.9
	Jul/Aug	41,346	15.3	254,681	22.8	69,914	24.5	324,594	20.7
	Sep/Oct	65,736	11.4	582,176	24.5	169,786	25.5	751,961	21.1
	Nov/Dec	36,335	14.6	183,488	27.2	57,966	29.4	241,453	26.9
	Total	250,379	9.3	1,222,120	14.2	351,850	15.9	1,573,970	12.8
2020	Jan/Feb	11,690	23.9	8,878	37.9	1,077	53.3	9,955	36.8
	Mar/Apr	11,799	17.5	25,426	29.9	4,549	47.5	29,975	29.7
	May/Jun	24,586	16.9	51,327	21.1	19,058	31.5	70,385	20.6
	Jul/Aug	64,789	14.8	152,144	21.3	78,864	25.8	231,008	19.8
	Sep/Oct	34,501	13.0	254,362	18.0	56,512	18.5	310,874	16.8
	Nov/Dec	26,203	14.9	136,348	19.6	46,406	22.1	182,754	18.7
	Total	173,568	7.6	628,485	10.5	206,466	13.0	834,951	9.9
2019	Jan/Feb	12,139	18.4	27,088	35.1	7,351	33.7	34,439	32.7
	Mar/Apr	9,674	21.4	11,023	37.4	3,517	47.8	14,540	34.7
	May/Jun	44,262	14.5	143,824	21.9	35,856	25.0	179,680	20.9
	Jul/Aug	39,904	14.5	210,967	20.3	122,890	33.6	333,857	20.8
	Sep/Oct	40,143	13.3	219,358	14.8	124,146	22.7	343,504	15.3
	Nov/Dec	16,819	20.1	76,555	30.7	27,125	33.3	103,680	30.0
	Total	162,941	7.1	688,815	10.0	320,885	16.5	1,009,700	10.2
2018	Jan/Feb	4,121	30.4	3,935	65.2	450	70.5	4,385	62.1
	Mar/Apr	8,950	20.8	16,051	41.4	4,560	43.2	20,611	39.5
	May/Jun	32,021	14.3	58,694	25.2	12,577	29.5	71,271	24.8
	Jul/Aug	11,125	20.3	43,317	24.2	13,418	33.4	56,735	24.5
	Sep/Oct	11,832	71.1	139,578	72.5	56,912	85.8	196,490	76.1
	Nov/Dec	20,890	16.3	85,612	18.4	20,987	23.6	106,599	18.4
	Total	88,939	12.1	347,187	30.1	108,904	45.4	456,091	33.5
2017	Jan/Feb	6,178	25.3	7,047	55.9	994	70.9	8,042	56.7
	Mar/Apr	16,513	15.9	36,630	25.7	13,572	30.5	50,202	26.3

Year	Wave	Total Effort	PSE	Total Mullet Harvest	PSE	Total Mullet Release	PSE	Total Mullet Catch	PSE
	May/Jun	37,371	13.2	175,562	20.3	56,093	21.8	231,656	19.4
	Jul/Aug	54,353	13.8	218,395	15.6	89,636	19.3	308,031	15.0
	Sep/Oct	41,186	13.8	195,901	15.9	54,855	24.7	250,756	16.1
	Nov/Dec	27,259	14.4	89,393	18.6	24,847	28.1	114,240	18.9
	Total	182,861	6.7	722,929	8.8	239,998	11.3	962,927	8.7
2016	Jan/Feb	11,910	27.1	6,927	51.1	3,283	73.2	10,210	55.4
	Mar/Apr	13,803	20.5	17,333	44.5	1,238	63.5	18,571	42.0
	May/Jun	39,127	13.7	141,203	25.2	47,699	29.9	188,903	23.6
	Jul/Aug	51,085	11.8	306,614	18.3	109,938	22.3	416,552	17.7
	Sep/Oct	41,325	12.1	173,517	18.6	26,096	21.3	199,613	17.2
	Nov/Dec	34,673	16.3	102,800	26.5	31,637	33.1	134,437	27.0
	Total	191,922	6.4	748,394	10.9	219,892	14.3	968,286	10.7
2015	Jan/Feb	6,730	25.4	19,540	38.2	3,060	52.0	22,600	37.0
	Mar/Apr	13,981	18.5	25,446	28.2	5,880	33.6	31,326	27.9
	May/Jun	50,315	12.1	147,726	17.8	50,052	25.7	197,778	16.9
	Jul/Aug	71,656	10.7	400,123	13.9	156,696	19.1	556,819	14.1
	Sep/Oct	40,078	10.6	232,037	15.4	43,801	19.1	275,837	15.1
	Nov/Dec	24,116	17.8	117,650	21.6	36,550	26.2	154,200	21.9
	Total	206,876	6.0	942,521	8.4	296,039	12.2	1,238,561	8.5
2014	Jan/Feb	5,206	25.0	12,023	46.3	1076	57.9	13,099	44.3
	Mar/Apr	16,131	19.0	13,949	45.0	1,859	60.3	15,807	43.0
	May/Jun	35,945	13.5	110,839	20.8	28,262	22.4	139,101	19.5
	Jul/Aug	52,883	13.7	208,730	18.1	63,626	19.8	272,356	16.8
	Sep/Oct	63,224	12.7	362,912	14.6	136,337	16.4	499,250	13.5
	Nov/Dec	23,867	14.5	74,605	19.7	20,344	26.7	94,949	19.2
	Total	197,257	6.8	783,058	9.4	251,504	11.1	1,034,561	8.9
2013	Jan/Feb	13,053	18.3	57,047	30.0	7,862	36.4	64,909	29.7
	Mar/Apr	9,079	23.4	20,839	41.4	4,021	49.4	24,860	41.4
	May/Jun	24,541	11.8	65,072	24.4	21,957	30.5	87,030	24.8
	Jul/Aug	41,197	11.3	324,616	16.2	121,012	21.7	445,628	15.9
	Sep/Oct	25,872	16.3	159,790	20.9	39,065	26.1	198,855	19.8
	Nov/Dec	25,544	15.3	83,943	21.1	35,592	31.0	119,534	21.5
	Total	139,286	6.3	711,307	10.1	229,509	13.9	940,816	9.9
2012	Jan/Feb	10,484	22.1	23,346	32.8	9,050	42.3	32,395	32.4
	Mar/Apr	9,734	19.8	17,055	32.0	3,931	57.2	20,986	31.8
	May/Jun	20,903	12.5	84,180	25.7	26,845	32.9	111,025	23.9
	Jul/Aug	32,810	13.3	181,667	19.6	76,701	26.0	258,368	18.3
	Sep/Oct	30,377	11.2	292,859	13.0	72,004	16.1	364,862	12.6
	Nov/Dec	21,315	15.8	94,155	21.1	31,676	26.7	125,831	20.7
	Total	125,623	6.2	693,262	8.9	220,205	12.2	913,467	8.6

Non-Quantifiable Management Options

Because of uncertainty in recreational harvest estimates, it is not possible to calculate harvest reductions from any specific management measure. Assumptions about species composition and imprecision of harvest estimates at the wave (two month) level prevent quantifying harvest reductions from season closures and bag limits. A lack of length composition information prevents calculation of harvest reductions from size limits. However, stock assessment sensitivity runs using alternative proportions of striped mullet in recreational landings had very little effect on model outputs and stock status (NCDMF 2022b). Regardless of recreational fishery magnitude or importance, implementing management on the commercial fishery without limiting recreational harvest could shift effort and have the potential to complicate enforcement. For example, the commercial striped mullet fishery supplies significant amounts of live and dead mullet to bait shops, which are purchased by recreational anglers for use as bait. If limits are put on commercial

harvest, recreational anglers could increase directed effort for mullet to continue meeting the need for bait.

Whether recreational harvest reductions are quantifiable or not, sustainability objectives should be consistent between commercial and recreational fisheries management. Management options can be developed for the recreational fishery allowing for traditional resource use while supporting sustainability objectives.

If management measures like size limits, season closures, or day of week closures are adopted for the commercial fishery the same measures could be applied equally to the recreational fishery. However, given differing resource uses and fishery characteristics between the commercial and recreational fisheries, it is likely unnecessary to manage the sectors jointly. Using available data for guidance, specific management measures for the recreational fishery should be considered allowing for traditional use while supporting sustainability objectives.

Bag and Size Limits

The 200 fish bag limit established in the Striped Mullet FMP does little to limit recreational harvest (Table 3.6). Most recreational trips that harvest mullet harvest fewer than 25 fish (Table 3.6). Reducing the bag limit further could prevent excessive recreational harvest of finger mullet while continuing to meet fishery demands. In addition, a vessel limit could be implemented in addition to an individual bag limit to prevent excessive harvest and waste. Cast net sampling indicates most finger mullet captured in cast nets are white mullet, and sub-adult and adult white mullet are rarely encountered in North Carolina waters (NCDMF 2006). A recreational bag limit of 50 fish and vessel limit of 100 fish would be sufficient to meet the needs of 97% of anglers who harvest mullet recreationally (Table 3.6) and most of the harvest would likely be white mullet. Members of the Striped Mullet FMP AC were in favor of managing the recreational striped mullet fishery separate from the commercial fishery and suggested reducing the bag limit as a good approach. Specifically, members of the AC supported reducing the bag limit somewhere in the range of 50-100 fish per person per day and expressed support for measures similar to those used to manage the Florida recreational mullet fishery including a 50 fish bag limit and vessel limit of 100 fish per vessel from February 1 through August 31 and 50 fish per vessel from September 1 through January 31.

Implementing a reduced bag limit for mullet over a certain size would specifically prevent excessive harvest of striped mullet and could be implemented specifically during the spawning season to reduce harvest on the spawning stock while allowing continued harvest of finger mullet. For example, implementing a bag limit on mullet greater than 8-inches (Figure 3.2), would still allow harvest of finger mullet, which are primarily white mullet and prevent excessive recreational harvest of larger mullet. A bag limit, somewhere in the range of 10-25 mullet greater than 8-inches would allow continued use of striped mullet as cut bait. There was not strong support for size specific bag limits from members of the FMP AC. Because of difficulty catching larger mullet in cast nets, AC members felt minimal harvest of these larger fish occurred but wanted to be able to catch these fish in large quantities when they were available for use as cut bait.

Table 3.6. Frequency and percentage of recreational trips harvesting mullet by harvest bin, 2002-2021.

Number Harvested	Frequency	Percent
1-25	2,644	85
26-50	386	12
51-75	34	1
56-100	19	1
101-150	8	<0.1
151-200	5	<0.1
200+	7	<0.1
Total	3,103	100

Option 1. Recreational Vessel and Bag Limit
    a. Status Quo
        +   No new regulations
        +   Allows continuation of fishery that mostly harvests white mullet
        −   Does not reduce harvest of striped mullet
        −   No preferential protection for largest fish

    b. Reduce Recreational Bag Limit (100 fish)
        +   Limits striped mullet harvest
        +   Allows continuation of fishery that mostly harvests white mullet
        −   No preferential protection for largest fish
        −   Discarding could occur

    c. Reduce Recreational Bag Limit (100 fish) and Implement Vessel Limit (400 fish)
        +   Limits striped mullet harvest
        +   Allows continuation of fishery that mostly harvests white mullet
        −   No preferential protection for largest fish
        −   Discarding could occur

    d. Bag Limit (10, 15, 20, 25, etc.) for Fish Over 8-Inches
        +   Provides some reduction in striped mullet harvest
        +   Allows continuation of fishery that mostly harvests white mullet
        +   Directs harvest to finger mullet which may experience high natural mortality
        +   Provides preferential protection for largest fish
        +   Allow larger mullet to be harvested for personal consumption or cut bait
        −   Limits use of larger mullet for personal consumption and cut bait
        −   Discarding could occur

    e. Seasonal (October-December) Bag Limit (10, 15, 20, 25, etc.) for Fish Over 8-Inches
        +   Provides some reduction in striped mullet harvest
        +   Allows continuation of fishery that mostly harvests white mullet
        +   Directs harvest to finger mullet which may experience high natural mortality
        +   Provides preferential protection for largest fish
        +   Allow larger mullet to be harvested for personal consumption or cut bait
        +   Limits harvest during spawning season
        −   Limits use of larger mullet for personal consumption and cut bait
        −   Discarding could occur

For Hire Vessel operations often harvest mullet ahead of time for their customers to use as bait during charter and head boat trips. Because For Hire licenses allow vessels in North Carolina to carry six or more passengers, For Hire Vessel operations may use more mullet as bait during fishing trips than typical recreational fishing vessels. If a vessel limit for mullet is implemented, it could be applied equally to both private vessel trips and For Hire Vessel trips; however, this would not allow for traditional use of mullet in the For Hire fishery. Implementing a vessel limit specific to For Hire Vessels (as defined in G.S. § 113-174) while engaged in For-Hire Vessel operations, would limit excessive recreational harvest of striped mullet while continuing to meet fishery demands. A similar strategy is currently used to manage the For Hire cobia fishery in North Carolina.

Alternatively, the individual bag limit could be applied to all passengers on board and the vessel limit could be suspended during For Hire Vessel operations, allowing for traditional use of the fishery while limiting harvest. In this scenario, the maximum number of mullet allowed to be held onboard for use as bait prior to the beginning of a trip, during a trip, or after a trip is completed would be the individual bag limit multiplied by the number of customers allowed on the vessel. During a trip, the number of mullet in possession to be harvested could not exceed the individual bag limit multiplied by the number of anglers onboard the vessel during the trip. The For Hire Vessel trip would be defined as a period of time in which fishing is conducted, beginning when the vessel leaves port and ending when the vessel returns to port. A similar strategy has been implemented by the Atlantic States Marine Fisheries Commission's Addendum III to Amendment 1 to the Interstate Fishery Management Plan for Atlantic Croaker to allow For Hire Vessel operations to use live Atlantic croaker as bait.

The DMF initially recommended a 50 fish individual recreational bag limit with an exception for For Hire Vessel Operations to possess a bag limit for the number of anglers they are licensed to carry, including in advance of a trip. Input from the ACs suggested there was not strong support for reducing the 200 fish bag limit; however, a reduced bag limit would limit effort shifting from the commercial bait fishery to the recreational fishery because of management measures that may reduce commercial bait harvest. Reducing the recreational bag limit also creates consistency in meeting sustainability objectives across sectors. In consideration of input from the regional ACs, the Division changed its recommendation to options 1.c and 2.c, which would implement a 100 fish individual bag limit and a 400 fish vessel limit with an exception for For Hire Vessel Operations to possess a bag limit for the number of anglers fishing up to the 400-fish maximum, including in advance of a trip (Table 3.7). This option limits effort from expanding into the recreational fishery while continuing to allow traditional use of the resource.

Option 2. For Hire Vessel and Bag limit
    a. For Hire Vessel Limit (500 fish, etc.)
        + Provides some reduction in striped mullet harvest
        + Allows continuation of fishery that mostly harvests white mullet
        + Allows for traditional use of fishery while engaged in For Hire Vessel operation
        − No preferential protection for largest fish
        − Discarding could occur

    b. Exception for For Hire Vessel Operations to Possess a Bag Limit for the Number of Anglers They are Licensed to Carry (Including in Advance of a Trip).
        + Provides some reduction in striped mullet harvest
        + Allows continuation of fishery that mostly harvests white mullet
        + Allows for traditional use of fishery while engaged in For-Hire Vessel operation
        − No preferential protection for largest fish

− Discarding could occur

c. Exception for For Hire Vessel Operations to Possess a Bag Limit for the Number of Anglers Fishing Up to the 400-fish Maximum (Including in Advance of a Trip).
- **+** Provides some reduction in striped mullet harvest
- **+** Allows continuation of fishery that mostly harvests white mullet
- **+** Allows for traditional use of fishery while engaged in For-Hire Vessel operation
- − No preferential protection for largest fish
- − Discarding could occur

d. Mirror Option 1 management decision

Adaptive Management

See Appendix 2. If adaptive management is adopted as part of Amendment 2, the specifications would apply to the commercial and recreational fisheries for mullet.

Table 3.7. Management options for recreational harvest of striped mullet.

Topic	Option	Description
Vessel and Bag Limit Options	1.a	Status Quo
	1.b	Reduce Recreational Bag Limit (100 fish)
	1.c*	Reduce Recreational Bag Limit (100 fish) and Implement Vessel Limit (400 fish)
	1.d	Bag limit (10, 15, 20, 25, etc.) for Fish Over 8-inches
	1.e	Seasonal (October-December) Bag Limit (10, 15, 20, 25, etc.) for Fish Over 8-inches
For Hire Vessel Operations Options	2.a	For Hire Vessel Limit (500 fish, etc.)
	2.b	Exception for For Hire Vessel Operations to Possess a Bag Limit for the Number of Anglers They are Licensed to Carry (Including in Advance of a Trip)
	2.c*	Exception for For Hire Vessel Operations to Possess a Bag Limit for the Number of Anglers Fishing Up to the 400-fish maximum (Including in Advance of a Trip)
	2.d	Mirror Option 1 Management Decision

*DMF recommendation

PROPOSED RULE(S)

No rule changes are necessary. Existing MFC rule 15A NCAC 03M .0502(b) delegates authority to the Fisheries Director to issue a proclamation to implement any of the management options proposed in Amendment 2.

"Mullet" Rule (15A NCAC 03M .0502)
Existing MFC rule 15A NCAC 03M .0502(b), "Mullet", delegates authority to the Fisheries Director to issue a proclamation to implement any of the management options proposed in Amendment 2. The Fisheries Director, consistent with the variable conditions provided in 15A NCAC 03H .0103 including compliance with FMPs, may impose any of the following restrictions on the taking of mullet:

(1) specify time;
(2) specify area;
(3) specify means and methods;
(4) specify season;
(5) specify size; and
(6) specify quantity, except as provided in Paragraph (a) of this Rule.

Paragraph (a) of the rule sets a fixed maximum possession limit of 200 mullet per person per day for recreational purposes. However, given the current stock status this rule will likely be amended in the second round of the periodic review of rules (G.S. § 150B-21.3A) in the late 2020s, to remove the recreational bag limit of 200 mullet. If changes to the bag limit are needed before that time, the Fisheries Director has authority to suspend this portion of the rule (15A NCAC 03I .0102). Potentially amending the rule to remove the bag limit during the next periodic review of the rule would simplify the process for implementing management measures for the Striped Mullet FMP.

"Mutilated Finfish" Rule (15A NCAC 03M .0101)

The MFC originally adopted the "Mutilated Finfish" rule (15A NCAC 03M .0101) in 1991 with the intent of providing added resource protection for finfish species subject to a size or bag limit. In response to the 200 fish bag limit for mullet, in July 2006, the rule was amended to add mullet as an exception, otherwise the use of mullet as cut bait would not have been allowed to continue. At that time, overfishing of the striped mullet stock was not occurring and the 200 fish bag limit was high enough there was little concern about enforceability.

However, the rule did not provide flexibility to manage variable conditions for species commonly used as cut bait, particularly when new regulations implemented to meet sustainability objectives (i.e., size or bag limits) make species subject to this rule. The MFC proposed amendments to the April 1, 2019 version of the rule in August 2022 to read:

15A NCAC 03M .0101   MUTILATED FINFISH
It shall be unlawful to possess aboard a vessel or while engaged in fishing any species of finfish that is subject to a ~~size or harvest restriction~~ possession limit, including size limit, recreational bag limit, commercial trip limit, or season, without having head and tail attached, unless otherwise specified in a rule of the Marine Fisheries Commission or a proclamation issued pursuant to a rule of the Marine Fisheries Commission. except:
    ~~(1)~~   ~~mullet when used for bait;~~
    ~~(2)~~   ~~hickory shad when used for bait, provided that not more than two hickory shad per vessel or fishing operation may be cut for bait at any one time; and~~
    ~~(3)~~   ~~tuna possessed in a commercial fishing operation as provided in rule .0520 of this Subchapter.~~

The use of mullet as cut bait is an enforcement issue, not a conservation issue but given the updated stock status for striped mullet and the need to implement conservation measures to rebuild the striped mullet stock, removing the mullet exception from the "Mutilated Finfish" rule is justified to support enforcement of sustainability measures like bag or size limits within the context of the "Mullet" rule and any proclamation issued under its authority. The use of mullet as cut bait should continue, to allow for traditional use and to meet stakeholder preferences.

In June 2023, the N.C. Rules Review Commission (RRC) objected to the amendments proposed to the "Mutilated Finfish" rule for unclear or ambiguous language (G.S. § 150B-21.9(a)(2)). In

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October 2023, the RRC returned the "Mutilated Finfish" rule to the MFC in accordance with the requirements of Section 21.2.(m) of Session Law 2023-134. The law change resulted in a situation where the MFC was unable to address the RRC's earlier objection within the prescribed time limit. Nothing from that action would prevent a new proposed amendment to be pursued.

The amended "Mutilated Finfish" rule would have allowed the Fisheries Director to use proclamation authority that is set forth in other MFC rules (like the "Mullet" rule) to allow the use of any species as cut bait, subject to the Fisheries Director's discretion consistent with the variable conditions provided in 15A NCAC 03H .0103, including compliance with FMPs. This option would simplify the rule by including all requirements for a specific species within the same rule or proclamation.

RECOMMENDATION

DMF Recommendation:

> Option 1.c: Recreational Individual Bag Limit of 100 Fish and Vessel Limit of 400 Fish

> Option 2.c: Exception for For Hire Vessel Operations to Possess a Bag Limit for the Number of Anglers Fishing Up to the 400-fish Maximum (Including in Advance of a Trip)

Advisory Committees Recommendations and Public Comment: see Appendix 4

NCMFC Selected Management Options:

> Option 1.c: Recreational Individual Bag Limit of 100 Fish and Vessel Limit of 400 Fish

> Option 2.c: Exception for For Hire Vessel Operations to Possess a Bag Limit for the Number of Anglers Fishing Up to the 400-fish Maximum (Including in Advance of a Trip)

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Appendix 4: Summary of management recommendations and comment

Issue Paper	DMF	Northern Regional Advisory Committee	Southern Regional Advisory Committee	Finfish Standing Advisory Committee	Public
2: Appendix Sustainable Harvest	Option 5.n Option 6.a Option 10	Option 5.a Option 6.a Abstain from making any motion regarding adaptive management	Approve DMF recommendation 5.n, 6.b and 10 for the commercial fishery. With the staff looking to adjust the roe season north and south for equitable reduction	Option 5.a with no catch cap for stop net (Option 6.a Approve division recommendation for adaptive management (Option 10)	Concerns about overfishing. General support for gill net restrictions, seasonal closures, and trip limits to provide protection to the spawning stock. Some support for region specific regulations. Suggestions to account for economic impacts of regulation.
3: Appendix Recreational Fishery	Option 1.c Option 2.c	Abstain from making any motion regarding recreational fishery management	Approve options 1.b and 2.b for the recreational fishery	Option 1.a	Support for managing recreational and commercial fisheries separately. General questions related to the need to manage the recreational fishery at all.

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April 26, 2024

MEMORANDUM

TO: N.C. Marine Fisheries Commission

FROM: Charlton Godwin, N.C. Estuarine Striped Bass FMP Co-Lead

SUBJECT: 2024 Revision to the N.C. Estuarine Striped Bass FMP Amendment 2

Issue

Update the N.C. Marine Fisheries Commission (MFC) on the 2024 Revision to the N.C. Estuarine Striped Bass FMP Amendment 2. This Revision applies only to management of the Albemarle-Roanoke (A-R) striped bass stock in the Albemarle Sound and Roanoke River Management Areas.

Action Needed

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

Overview

This memo provides an **update on the status of the 2024 Revision to the N.C. Estuarine Striped Bass FMP Amendment 2, A-R striped bass stocking, and ongoing A-R striped bass research.**

2024 Revision to the N.C. Estuarine Striped Bass FMP Amendment 2

The 2024 Revision to Amendment 2 documents the authority and rationale for implementing a harvest moratorium in the Albemarle Sound and Roanoke River Striped Bass Management Areas, effective January 1, 2024. The 2022 update to the A-R striped bass benchmark stock assessment requires a 75% reduction in total removals relative to total removals allowed in 2021 (the last year of data in the stock assessment update) to reduce F to the F_{Target}. After accounting for recreational and commercial dead discards (estimate was 9,833 pounds of dead discards for 2021) the new Total Allowable Landings (TAL) is 8,349 pounds. A TAL of 8,349 pounds divided among three harvest sectors is too low to effectively manage and emphasizes the need to prioritize stock recovery over a very limited recreational fishery and commercial bycatch fishery. At such a low TAL, either sector would have the potential to harvest their entire TAL in less than one day.

While a moratorium is in place, all DMF and WRC juvenile and adult fishery-independent surveys continue to be monitored for the A-R striped bass stock and results will continue to be updated annually. This annual monitoring is provided to the public and MFC through the Division's annual Fishery Management Plan Review. These annual reports are provided to the MFC at the August

business meeting each year and are also available on the Division's website. Monitoring surveys include the WRC's electrofishing spawning stock survey and the DMF's fall/winter overwintering gill net survey, spring spawning stock gill net survey, and the juvenile abundance survey. Through these surveys, the relative abundance of year classes and the age and length structure of the stock will be evaluated annually to determine if improvements in the stock condition are occurring.

Albemarle-Roanoke Striped Bass Stocking Strategy
To address the concern with consecutive years of recruitment failure since 2017 and to bolster stock rebuilding, stocking will be used to supplement natural production. The A-R striped bass broodstock progeny will be raised at hatcheries and stocked into the western Albemarle Sound nursery area during at least 2023–2025. Success of stocked fish will be evaluated using genetic markers unique to the broodstock of the stocked individuals. Results of the A-R stocking strategy will be evaluated annually through a cooperative effort of the DMF, WRC and the Edenton National Fish Hatchery, U.S. Fish and Wildlife Service. Genetic samples used to determine the contribution of hatchery fish to natural production from the wild stock will be collected through at least 2030. The nonprofit North Carolina Marine & Estuary Foundation is also providing funding to support these restoration efforts.

Additional Ongoing Albemarle-Roanoke Striped Bass Research
Division of Marine Fisheries staff, in conjunction with university researchers, are conducting sampling in the lower Roanoke River and western Albemarle Sound for larval striped bass and the zooplankton prey they eat. Results from sampling in 2023 and 2024 will be compared to previous studies to determine trends in larval striped bass abundance and if there is adequate zooplankton prey available for proper larval striped bass development and growth. If the desired food source is not readily available, larval striped bass will starve, leading to a potential recruitment failure.

Wildlife Resources Commission staff, in conjunction with university researchers, are conducting research to determine if organic chemicals possessing fluorinated-carbon molecules (e.g. PFAS) are present in striped bass ovaries, and if so, are those chemicals being transferred from the mother to her offspring, and are these chemicals having adverse effects on larval fish survival.

2024 Revision

to the

North Carolina Estuarine Striped Bass
Fishery Management Plan
Amendment 2

Prepared By The

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2024 Revision

to the

North Carolina Estuarine Striped Bass
Fishery Management Plan
Amendment 2

I.   ISSUE

The striped bass total allowable landings (TAL) in the Albemarle Sound Management Area (ASMA) and Roanoke River Management Area (RRMA) must be reduced to meet compliance with the North Carolina Estuarine Striped Bass Fishery Management Plan (FMP) Amendment 2 and the Atlantic States Marine Fisheries Commission (ASMFC) Amendment 7 to the Interstate FMP for Atlantic Striped Bass. The required TAL reduction is based on results of the 2022 update to the Albemarle-Roanoke (A-R) striped bass benchmark stock assessment that indicates overfishing is still occurring in the terminal year (2021) of the assessment and the stock continues to be overfished. (Lee et al. 2022). An additional concern is the seven consecutive years (2017–2023) of very poor A-R stock spawning success. The North Carolina Division of Marine Fisheries (DMF) and an external peer review panel of experts concluded the stock assessment update is suitable for management use and represents the current stock status. The peer review panel recognized factors in addition to fishing mortality are likely contributing to the chronic poor recruitment observed since the early 2000s and the current low abundance of the stock. Contributing factors may include river flow, water quality, water temperatures, habitat conditions, predation (i.e. blue catfish), and competition for food. This Revision applies only to management of the A-R striped bass stock in the Albemarle Sound and Roanoke River Management Areas.

II.   ORIGINATION

North Carolina Division of Marine Fisheries, Wildlife Resources Commission (WRC), Inland Fisheries Division, and results of the 2022 update to the 2020 A-R striped bass benchmark stock assessment.

III.   BACKGROUND

Atlantic striped bass from Maine through North Carolina are managed under the jurisdiction of the ASMFC since Congress passed the Atlantic Striped Bass Conservation Act in 1984. The A-R striped bass stock is migratory at older ages but contributes minimally to the overall Atlantic striped bass migratory stock complex compared to the Chesapeake Bay, Delaware River, and Hudson River stocks (ASMFC 2022; Berggren and Lieberman 1978; Callihan et al. 2014). Due to the non-migratory behavior of striped bass stocks south of the ASMA, the striped bass stocks within the Central Southern Management Area (CSMA) are not included in the management program for ASMFC's Interstate FMP for Atlantic Striped Bass.

The ASMFC Atlantic Striped Bass Management Board approved Amendment 7 to the Interstate FMP for Atlantic Striped Bass in May 2022. Amendment 7 maintains the provision to use DMF A-R stock assessments to determine fishing mortality (F) and spawning stock biomass (SSB) biological reference points (BRPs) specifically for the A-R stock. The ASMFC Striped Bass

Technical Committee (TC) continues to monitor the contribution of the A-R stock to the coastal migratory population and make recommendations to the Board regarding future management.

In the fall of 2022, the 2020 A-R striped bass benchmark stock assessment (last year of data was 2017) was updated with data through 2021 This update to the 2020 stock assessment was completed to determine if management action taken through the November 2020 Revision to the North Carolina Striped Bass FMP Amendment 1 had the intended effect of ending overfishing and achieving F equal to or below the F_{Target} (NCDMF 2020). Results of the stock assessment update indicate that the F_{Target} was not achieved; the stock remained in an overfished condition and overfishing was still occurring (Table 1).

Table 1. Biological reference points for the Albemarle Sound-Roanoke River striped bass stock and the point estimate from the terminal year (2021) of the assessment. Source: Lee et al. 2022.

Metric	Target	Threshold	2021 Value	Status
Fishing Mortality	0.14	0.20	0.77	Overfishing
Female Spawning Stock Biomass	163.62 metric tons (mt) (360,720 lb)	124.87 mt (275,286 lb)	16.13 mt (35,566 lb)	Overfished

Under Amendment 2, adaptive management requires a reduction in the TAL to a level that is projected to lower F to the F_{Target} (NCDMF 2022). A reduction in total removals of 75% relative to total removals in 2021 is needed to reduce F to the F_{Target}. The new TAL of 8,349 pounds (Table 2) was calculated after accounting for anticipated recreational and commercial dead discards (estimate was 9,833 pounds of dead discards for 2021). This action of reducing the TAL maintains compliance with Amendment 2 to the North Carolina Estuarine Striped Bass FMP and ASMFC's Amendment 7 to the Interstate FMP for Atlantic Striped Bass.

Table 2. Total allowable landings (lb) for the Albemarle Sound-Roanoke River striped bass stock, 1991–2024.

Years	Total Allowable Landings	ASMA Commercial	ASMA Recreational	RRMA Recreational
1991–1997	156,800	98,000	29,400	29,400
1998	250,800	125,400	62,700	62,700
1999	275,880	137,940	68,970	68,970
2000–2002	450,000	225,000	112,500	112,500
2003–2014	550,000	275,000	137,500	137,500
2015–2020	275,000	137,500	68,750	68,750
2021–2023	51,216	25,608	12,804	12,804
2024–	8,349	4,175	2,087	2,087

Strategies for the Albemarle Sound-Roanoke River stock currently in place under Amendment 2 to the North Carolina Estuarine Striped Bass FMP:

Sustainable harvest: Albemarle Sound-Roanoke River Stock
1.   Manage for sustainable harvest through harvest restrictions
     A.   Continue to use stock assessments and stock assessment projections to determine the TAL that achieves a sustainable harvest for the A-R stock.

2. Management of striped bass harvest in the commercial fishery as a bycatch fishery
   A. Status quo: continue managing the ASMA striped bass fishery as a bycatch fishery.
3. Accountability Measures to Address TAL Overages
   D. If the landings in any one of the management areas' three fisheries (RRMA recreational, ASMA recreational, and ASMA commercial) exceeds their allocated TAL in a calendar year, any landings in excess of their allocated TAL will be deducted from that fisheries' allocated TAL the next calendar year.
   If paybacks to a fishery exceed the next year's allocated TAL for that fishery, paybacks will be required in subsequent years to meet the full reduction amount; in situations where a fisheries allocated TAL has been reduced from a previous year's overage, if the reduced TAL is exceeded, any required paybacks the subsequent year are reduced from the fisheries' original allocated TAL, not from the reduced TAL.
4. Size limits to expand the age structure of the stock
   C. In the ASMA, implement a harvest slot of a minimum size of 18-inches TL to not greater than 25-inches TL in the commercial and recreational sectors.
   E. In the RRMA, maintain current harvest slot limit of a minimum size of 18-inches TL to not greater than 22-inches TL with no harvest allowed on fish greater than 22 inches TL.
5. Gear modifications and area closures to reduce striped bass discard mortality.
   A. Status quo-continue to allow commercial harvest of striped bass with gill nets in joint and coastal waters of the ASMA and continue recreational harvest and catch-and-release fishing in the ASMA and RRMA, including striped bass spawning grounds in the Roanoke River. The requirement that from April 1 through June 30, only a single barbless hook or lure with single barbless hook (or hook with barb bent down) may be used in the inland waters of the Roanoke River upstream of U.S. Highway 258 Bridge will remain in effect.
   E. Implement a requirement to use non-offset barbless circle hooks when fishing with live or natural bait in the inland waters of the Roanoke River (upstream of Hwy 258 bridge) from May 1* through June 30.
6. Adaptive management
   • Use peer reviewed stock assessments and updates to recalculate the BRPs and/or TAL. The current TAL of 51,216 lb remains in place until a new TAL is determined. Stock assessments will be updated at least once between benchmarks. Increases or decreases in the TAL will be implemented through Adaptive Management. A harvest moratorium could be necessary if stock assessment results calculate a TAL that is too low to effectively manage, and/or the stock continues to experience spawning failures.
   • Use estimates of F from stock assessments to compare to the F BRP and if F exceeds the F_{Target} reduce the TAL to achieve the F_{Target} through Adaptive Management.

The management strategy contained in Amendment 2 and approved by the MFC in November of 2022 stated May 1 through June 30 (5. E.). However, the WRC approved a more restrictive time frame to coincide with the existing barbless hook requirement in 5. A., which is April 1 through June 30.

IV. AUTHORITY

The existing North Carolina fisheries management system grants rule-making authority over estuarine striped bass to the North Carolina Marine Fisheries Commission (MFC) and the North Carolina Wildlife Resources Commission within their respective jurisdictions. Further, the MFC, in rule, has delegated specified proclamation authority to the DMF Director. The WRC has

authority to issue limited proclamations for striped bass harvest seasons and has delegated this authority to the WRC Executive Director.

<u>*N.C. General Statutes*</u>
G.S. 113-134.	RULES
G.S. 113-182.	REGULATION OF FISHING AND FISHERIES
G.S. 113-182.1.	FISHERY MANAGEMENT PLANS
G.S. 113-221.1.	PROCLAMATIONS; EMERGENCY REVIEW
G.S. 113-292.	AUTHORITY OF THE WILDLIFE RESOURCES COMMISSION IN REGULATION OF INLAND FISHING AND THE INTRODUCTION OF EXOTIC SPECIES.
G.S. 143B-289.52.	MARINE FISHERIES COMMISSION—POWERS AND DUTIES

<u>*N.C. Marine Fisheries Commission Rules and N.C. Wildlife Resources Commission Rules* (15A NCAC)</u>

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

V. DISCUSSION

Results from the 2022 update to the A-R striped bass stock assessment indicate the stock continues to be overfished with overfishing occurring (Lee et. al 2022). The estimate of *F* in the terminal year of the assessment (2021) was 0.77, above the $F_{Threshold}$ of 0.20 and the F_{Target} of 0.14 (Table 1; Figure 1). The estimate of SSB was 35,553 lb, below the $SSB_{Threshold}$ of 275,286 lb (Table 1; Figure 2). Female SSB has declined steadily from a high of 762,977 lb in 2000 to a low of 35,566 lb in 2021. Results of the assessment also show a period of strong recruitment (the number of age-0 fish coming into the stock each year) from 1993 to 2000, then a period of much lower recruitment from 2002 to present (Figure 2). This lower recruitment has contributed to the decline in SSB since 2004. Average recruitment during 1993–2000 was 1,085,707 age-0 fish per year while average recruitment for 2001–2021 was 333,735 age-0 fish per year. Average recruitment during the last 10 years of the stock assessment update (2012–2021) was 214,728 age-0 fish per year.
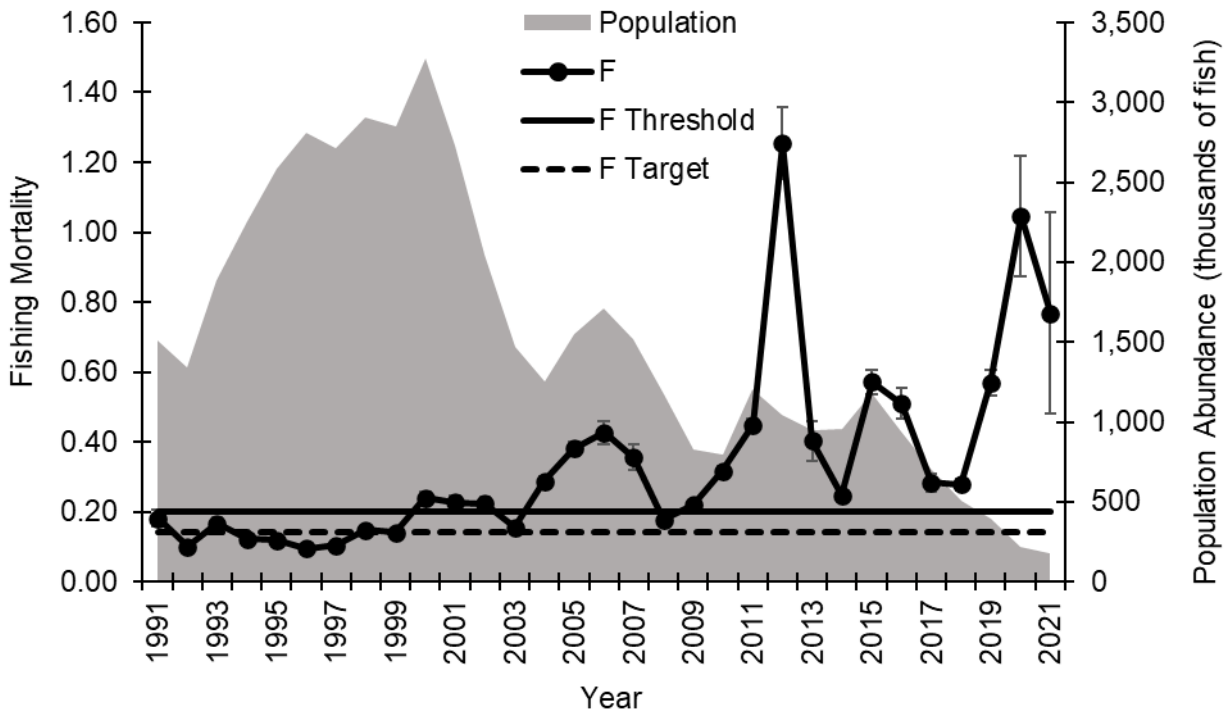
Figure 1. Estimates of fishing mortality (*F*) and total population abundance for the Albemarle Sound-Roanoke River striped bass stock, 1991–2021. Source: Lee et al. 2022
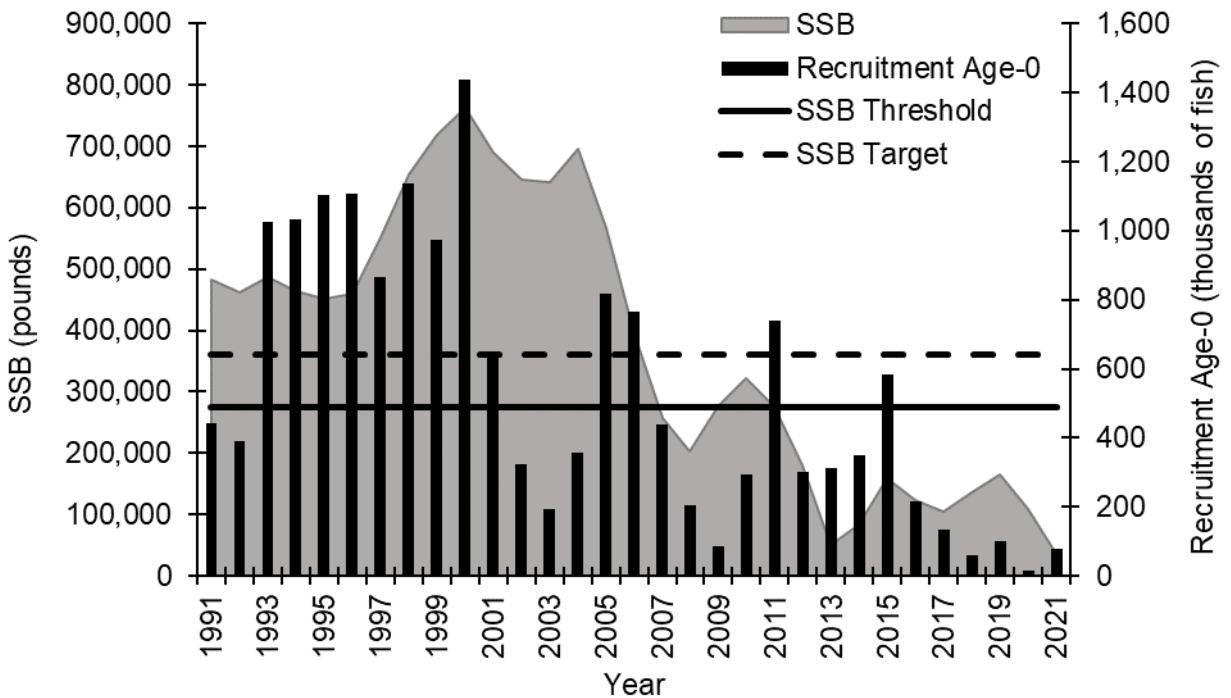
Figure 2. Estimates of spawning stock biomass (SSB) and recruitment of age-0 fish coming into the population each year for the Albemarle Sound-Roanoke River striped bass stock, 1991–2021. Source: Lee et al. 2022.

While fishing mortality is a primary contributing factor in both the decline in SSB and recruitment, environmental factors contribute to poor spawning success and can further exacerbate SSB decline. The environmental impact on spawning success is most evident when poor recruitment occurs during periods of high biomass. For example, appropriate river flow during the spawning period has long been recognized as an important factor in A-R striped bass spawning success (Hassler et. al 1981; Rulifson and Manooch 1990). Low to moderate flows (within a range of 6,000-8,000 cubic feet per second) have been identified as favorable for strong year-class production, while high flows (~12,000 cubic feet per second or greater) are unfavorable to the formation of strong year classes. It should be noted that while optimal flow increases the likelihood of a successful spawn, it does not always guarantee one will occur. The peer reviewers of the 2022 assessment update recognized poor recruitment with the stock cannot be fully explained by overfishing alone. They prioritized further exploration of environmental factors and their impact on spawning success. They noted potential factors limiting recruitment such as river flow, water quality, water temperatures and habitat conditions (Lee et. al 2022).

In addition to the quantitative stock assessment, similar negative trends in abundance are also evident in the available DMF and WRC juvenile and adult fishery-independent surveys used to monitor the A-R striped bass stock. Of particular concern is the trend in the juvenile abundance index (JAI) from the striped bass juvenile survey in the western Albemarle Sound. The survey measures the relative abundance of young-of-year (age-0) fish spawned each spring and is a good predictor of year class strength (Figure 3). The ASMFC Striped Bass Technical Committee has also established a spawning failure threshold (1.33 average fish per tow) for this survey. The JAI value has been below the spawning failure threshold for each year since 2018, and the 2017 value was only slightly above the threshold. The only other time the stock has experienced this many years of consecutive spawning failures was in the late 1970s through the 1980s when the stock was at very low levels of abundance and the abundance of older fish in the population was also at very low levels (Figure 3).
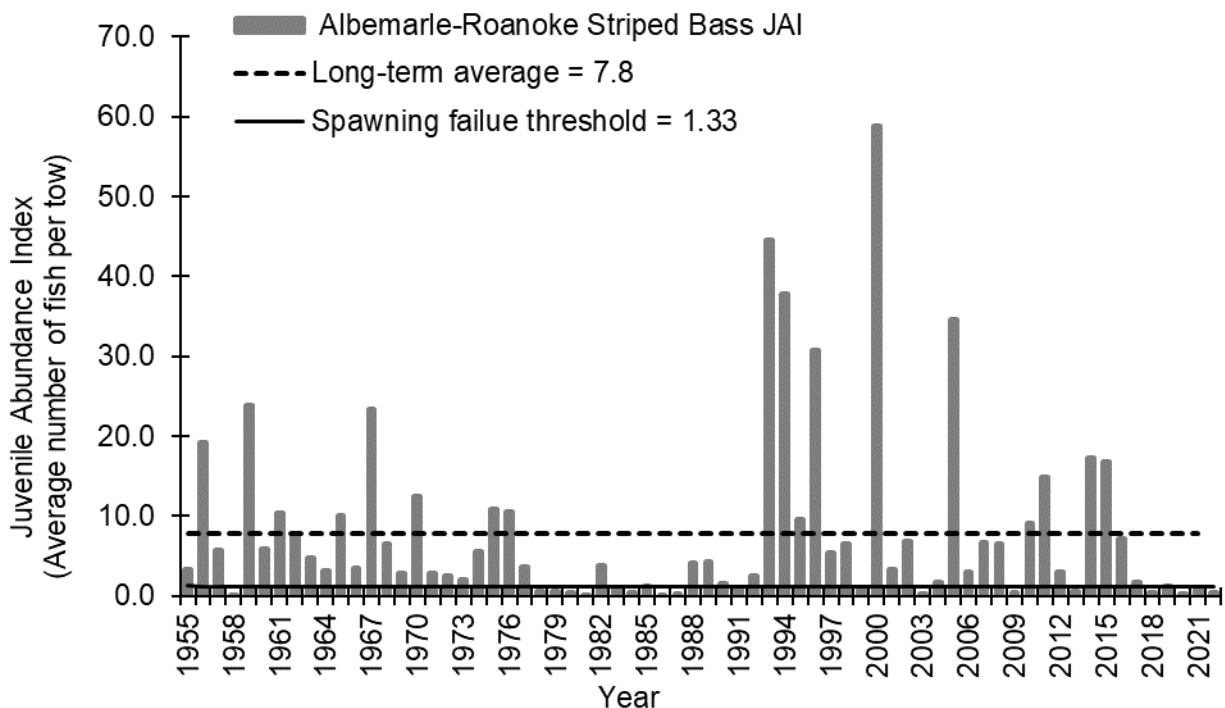
Figure 3. Juvenile abundance index (JAI) of Albemarle Sound-Roanoke River striped bass from the NCDMF juvenile trawl survey, western Albemarle Sound, NC, 1955–2022.

In addition to recruitment concerns, both DMF gill-net surveys (Figure 4) and the WRC electrofishing survey (Figure 5) show declining trends, especially in older fish. In recent years relative abundance in these surveys is similar or below levels observed when the stock was severely depressed in the early 1990s (Figures 4 and 5).
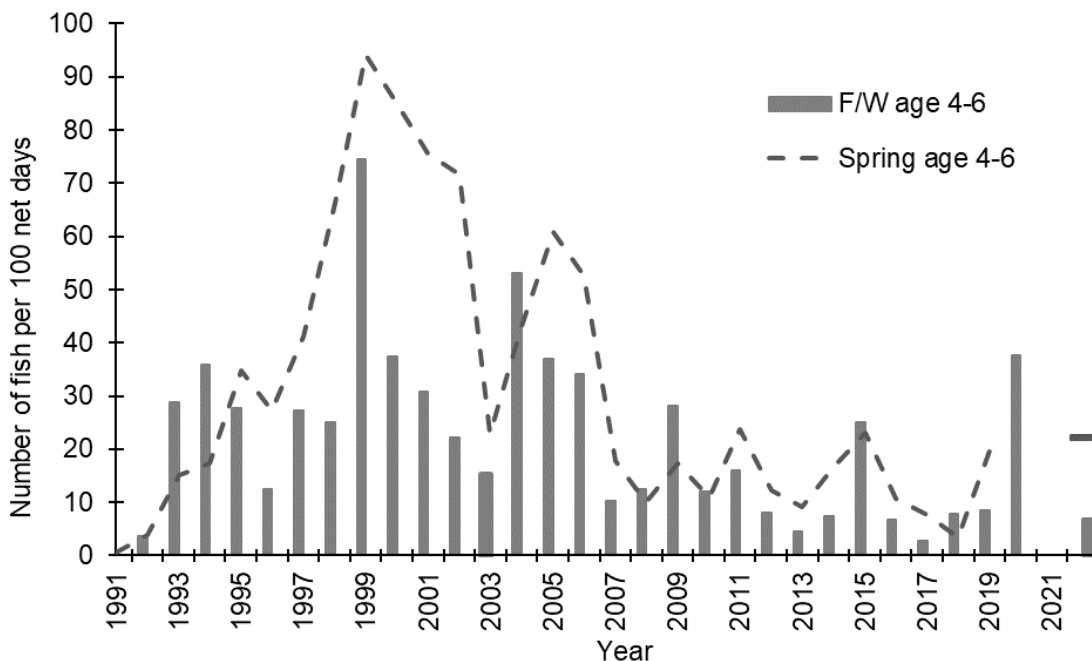
Figure 4. Relative abundance of age 4–6 Albemarle Sound-Roanoke River striped bass from the DMF fall/winter and spring independent gill net surveys, Albemarle Sound area, NC, 1991–2022.
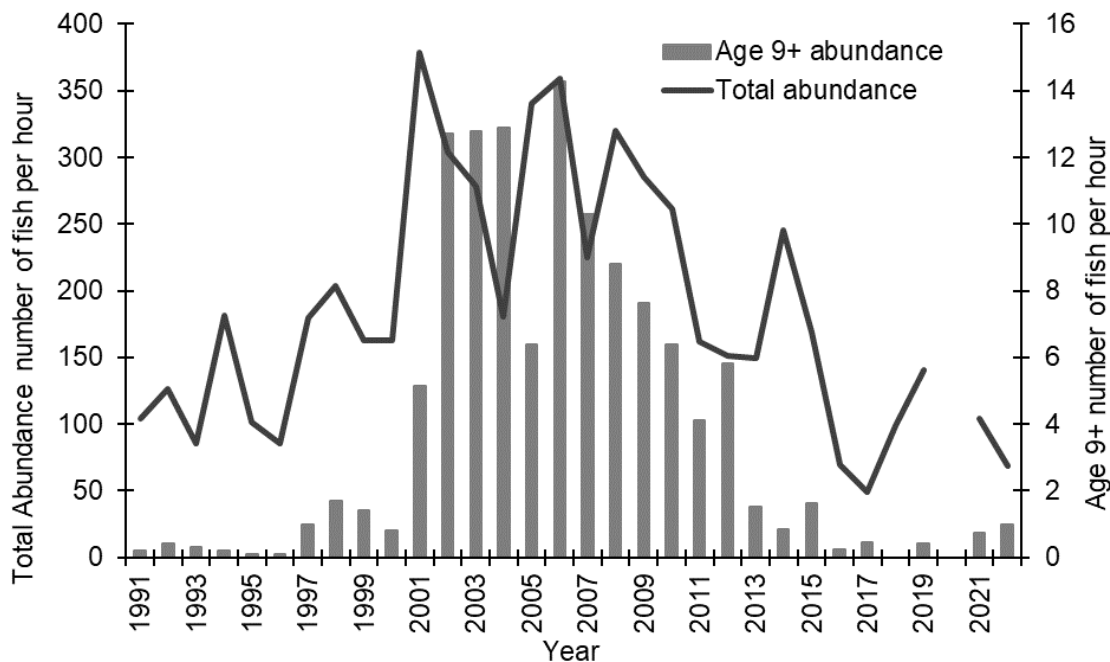
Figure 5. Total relative abundance and age 9+ relative abundance of Albemarle Sound-Roanoke River striped bass from the WRC spawning grounds electrofishing survey, Roanoke River near Weldon, NC, 1991–2022.

Declines in landings also support the precipitous decline in stock abundance and poor recruitment indicated by the assessment and fishery independent indices. Since the early 2000s, landings in both the recreational and commercial sectors have rarely achieved the available TAL, indicating a decline in availability of fish to the fishery. From 2004 through 2014 the TAL of 550,000 pounds was never caught. Total combined landings from both the ASMA and RRMA did not exceed 460,853 lb, averaging 235,278 lb per year with a low of 108,432 lb in 2013 (Figure 6). For the years 2005–2013, the commercial sector did not reach their TAL once. Even since the 2014 reduction in the TAL to 275,000 lb the commercial and recreational sectors in the ASMA did not reach the TAL during 2014–2017. Harvest in all sectors increased in 2017, with the commercial sector reaching the TAL in 2019 causing the DMF to close the fall commercial harvest season before Dec. 31 for the first time since 2010. This increase in harvest was likely due to the above-average year classes produced in 2014 and 2015 (Figure 6).
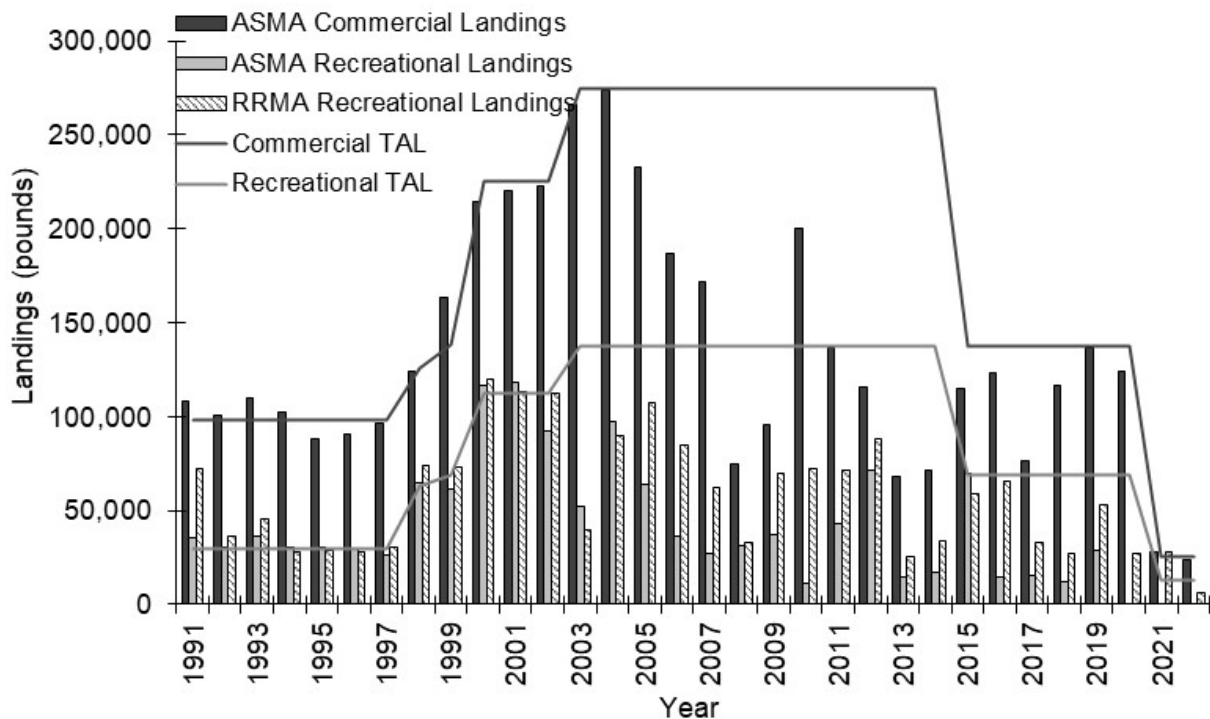
Figure 6. Striped bass landings from the Albemarle Sound Management Area commercial and recreational sectors and Roanoke River Management Area recreational sector and the total allowable landings, 1991–2022.

Reductions in the TAL to lower F to the F_{Target} reference point value

The 2022 update to the A-R striped bass benchmark stock assessment requires a 75% reduction in total removals relative to total removals in 2021 (the last year of data in the stock assessment update) to reduce F to the F_{Target}. After accounting for recreational and commercial dead discards (estimate was 9,833 pounds of dead discards for 2021) the new TAL is 8,349 pounds. The individual TAL for each sector is: ASMA commercial TAL = 4,175 pounds; ASMA recreational TAL = 2,089 pounds; RRMA recreational TAL = 2,089 pounds.

VI.   AMENDMENT 2 ADAPTIVE MANAGEMENT REVISION TO THE TOTAL ALLOWABLE LANDINGS

Amendment 2 to the North Carolina Estuarine Striped Bass FMP, in conjunction with the North Carolina FMP for Interjurisdictional Fisheries, sets the framework for management changes in

response to the current stock status (Figure 7). This document will be incorporated into Amendment 2 as the November 2023 Revision to the North Carolina Estuarine Striped Bass FMP.

A TAL of 8,349 pounds divided among three harvest sectors is too low to effectively manage and emphasizes the need to prioritize stock recovery over a very limited recreational fishery and commercial bycatch fishery. At such a low allowable TAL, either sector could harvest their entire TAL in one day. In addition, any harvest season for striped bass will result in additional dead discards from both the commercial and recreational sectors. With the stock abundance at the lowest level in the stock assessment time series, compounded by the recent consecutive years of recruitment failure, it is necessary to reduce fishing mortality on the stock to provide the greatest potential for stock recovery and allow as many females to return to the spawning grounds each year.

Therefore, effective January 1, 2024, a harvest moratorium is required until the population improves to a level capable of supporting sustainable harvest. This revision and all other management strategies contained in Amendment 2 will remain in effect until further changes are implemented through the adaptive management framework of the North Carolina Estuarine Striped Bass FMP Amendment 2 and its Revisions. Adaptive management in Amendment 2 provides the management framework and is illustrated below in Figure 7.

VII.   A-R STOCK EVALUATION AND STOCKING STRATEGY

The 2022 stock assessment update (data through 2021) satisfies the Adaptive Management strategy adopted through Amendment 2 that states "*stock assessments will be updated at least once between benchmarks*". All DMF and WRC juvenile and adult fishery-independent surveys used to monitor the A-R striped bass stock are updated annually through the Division of Marine Fisheries, Fishery Management Plan Review, and are available on the Division's website each August. These include the WRC's electrofishing spawning stock survey and the DMF's fall/winter overwintering gill net survey, spring spawning stock gill net survey, and the juvenile abundance survey. Through these surveys the relative abundance of year classes and the age and length structure of the stock will be evaluated annually to determine if improvements in the stock condition are occurring.

To address the concern with consecutive years of recruitment failure since 2017, stocking will be used to supplement natural production. The A-R striped bass broodstock progeny will be raised at hatcheries and stocked into the western Albemarle Sound nursery area during at least 2023–2025. Success of stocked fish will be evaluated using genetic markers unique to the broodstock of the stocked individuals. Annual determination for the number of fish stocked into which coastal system will occur though the North Carolina Interjurisdictional Fisheries Cooperative Work Plan. The annual work plan is a cooperative agreement between the U.S. Fish and Wildlife Service, Edenton National Fish Hatchery; the WRC, Inland Fisheries Division; and the North Carolina Department of Environmental Quality, DMF. The purpose of the annual work plan is to coordinate management of various anadromous fish species (including striped bass, American shad, and river herring) between the three agencies, including annual stocking of striped bass in coastal rivers. Results of the A-R stocking strategy will be evaluated annually. Genetic samples will be collected through at least 2030.

AMENDMENT 2: APPROVED NOVEMBER 2022

<u>Adaptive Management</u>

- Use peer reviewed stock assessments and updates to recalculate the BRPs and/or TAL. The current TAL of 51,216 lb remains in place until a new TAL is determined. Stock assessments will be updated at least once between benchmarks. Increases or decreases in the TAL will be implemented through Adaptive Management. <u>A harvest moratorium could be necessary if stock assessment results calculate a TAL that is too low to effectively manage, and/or the stock continues to experience spawning failures.</u>

- Use estimates of F from stock assessments to compare to the F BRP and if F exceeds the F_{Target} reduce the TAL to achieve the F_{Target} through Adaptive Management.

2022 Stock Assessment Results (data through terminal year 2021):

- F exceeding F_{Target}
- New TAL = 8,349 pounds
- 2022: another year of spawning failure (2018–2022)
- 2023: preliminary data indicate another year of spawning failure

2023 Revision to Amendment 2 to document adaptive management changes

- New TAL of 8,349 pounds is too low to effectively manage.
- Implement harvest moratorium due to low TAL, low SSB estimates, and six consecutive years of spawning failures.

Annual updates to all survey data through DMF Fishery Management Plan Review. Review trends in data and conduct stock assessment when necessary.

INTERJURISDICTIONAL FISHERIES COOPERATIVE WORK PLAN (USFWS, NCWRC, NCDMF)

- 2023–2025: Stock hatchery raised striped bass in western Albemarle Sound to bolster wild population
- 2023–2030: Use genetic markers to determine percent contribution of hatchery fish to wild population
- 2025: Evaluate; continue stocking if deemed necessary

Figure 7. Schematic of Adaptive Management framework under Amendment 2.

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Stock Assessment of the North Carolina Blue Crab (*Callinectes sapidus*), 1995–2022

Prepared by

North Carolina Division of Marine Fisheries

Blue Crab Plan Development Team

October 2023

NCDMF SAP-SAR-2023-01

This document may be cited as:

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.

This stock assessment represents an update of the benchmark stock assessment that was completed in 2018 and endorsed for management by an independent panel of experts. The update presented in this report represents the Blue Crab stock in North Carolina coastal fishing waters from 1995 to 2022. The stock assessment includes data from several fishery-independent surveys and commercial fishery monitoring programs. The sex-specific two-stage model was developed based on the catch-survey analysis designed for species lacking information on the age structure of the population. The model synthesized information from multiple sources, tracked population dynamics of male and female recruits and fully recruited animals, estimated critical demographic and fishery parameters such as natural and fishing mortality, and thus, provided a comprehensive assessment of blue crab stock status in North Carolina. The hierarchical Bayesian approach was used to estimate model parameters, which can incorporate uncertainty associated with the data and model assumptions.

The model estimated an overall declining trend in catch, relative abundance indices, population size of both male and female recruits and fully recruited crabs. The stock status of North Carolina blue crab in the current assessment update (2022) was determined based maximum sustainable yield (MSY). Based on results of this assessment, the North Carolina blue crab resource in 2022 is overfished with a probability of 100%, given the average spawner abundance in 2022 is estimated at 14.8 million crabs (below the threshold estimate of 120 million). Also, overfishing is occurring in 2022 with a probability of 100%, given the average fishing mortality in 2022 is estimated at 1.8 (above the fishing mortality threshold estimate of 0.61).

An external desk review was completed in December 2023 to review concerns with model specifications and results. The panel identified concerns with the strong residual patterns in the model fit to survey indices, especially Program 100, as well as with the extremely/unrealistically high estimated fishing mortality. Another concern was the classification of overfishing and overfished over the entire time series. The reviewers provided many recommendations to examine within the model for potential improvement that can only be accomplished through a benchmark stock assessment (Appendix A). Additionally, all available data, including fishery-independent indices and fishery performance, provide the same trend as the stock assessment model. Thus, we have confidence the stock continues to be overfished with overfishing occurring.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

1.1 The Resource

The blue crab, *Callinectes sapidus*, inhabits estuarine and nearshore coastal habitats throughout the western Atlantic and Caribbean from Maine to northern Argentina (Hay 1905; Williams 1984; Steele and Bert 1994; Guillory et al. 2001), as well as the Gulf of Mexico (Darden 2004; McMillen-Jackson et el. 1994). The blue crab is common to all North Carolina coastal waters, but the largest aggregations tend to live in the Albemarle and Pamlico sounds and the tributaries associated with these regions.

Blue crabs support commercial and recreational fisheries along the U.S. Atlantic and Gulf coasts. In North Carolina, the blue crab resource supports the state's most valuable commercial fishery. Blue crabs are also commonly harvested by recreational fishermen in North Carolina. The blue crab fisheries in the state of North Carolina are managed under the North Carolina Blue Crab Fishery Management Plan Amendment 3 (NCDMF 2020a) and the May 2020 Revision to Amendment 3 (NCDMF 2020b). The goal of Amendment 3 is to manage the blue crab fishery to achieve a self-sustaining population that provides sustainable harvest using science-based decision making. The harvest reductions needed to achieve sustainable harvest were based on the last benchmark stock assessment (NCDMF 2018). Amendment 3 also contained adaptive management requiring the stock assessment to be updated at least once between full reviews of the plan.

Details regarding the life history, habitat, fisheries, and fisheries management of North Carolina blue crab can be found in the last benchmark stock assessment (NCDMF 2018).

1.2 Previous Stock Assessment

The previous North Carolina Division of Marine Fisheries (NCDMF) stock assessment of the North Carolina blue crab stock was a benchmark stock assessment (i.e., peer-reviewed by an independent panel of experts) and was completed in 2018 (NCDMF 2018). The benchmark stock assessment was based on a sex-specific two-stage model. The model was applied to data collected from 1995 through 2016 and incorporated one fishing fleet and 16 indices representing multiple life stages from four fisheries-independent surveys.

The independent peer reviewers worked with the blue crab working group to develop a model that the peer review panel and the NCDMF endorsed for management use for at least the next five years and agreed the determination of stock status (overfished and overfishing) for the North Carolina blue crab stock in the terminal year (2016) concurred with professional opinion and observations.

The current stock assessment follows the methodology of the 2018 benchmark stock assessment. Any deviations from that methodology are noted in this report.

2 DATA

A complete description of the data sources that were used in the recent benchmark stock assessment and updated for use in this stock assessment can be found in the report for the benchmark stock assessment (NCDMF 2018). Estimates of input values were developed following the same methodology unless otherwise noted in this report.

The occurrence of COVID-19 caused disruptions in 2020 and 2021 to some of the fisheries-dependent monitoring and fisheries-independent survey programs. Any such disruptions are noted in the text below.

2.1 Fisheries-Dependent

2.1.1 Commercial Fishery Monitoring

2.1.1.1 Data Sources

No interruption to reporting of commercial landings occurred in 2020 or 2021. There were some interruptions to fisheries-dependent biological monitoring in early 2020. All NCDMF field operations were suspended in mid-March 2020 and did not resume until June 2020. Therefore, no biological data were collected from blue crabs landed at commercial fish houses during this time.

2.1.1.2 Development of Estimates

All trips landing hard blue crabs from 1994 to 2022 were subset from the trip ticket database.

2.1.1.3 Estimates of Commercial Fishery Statistics

Annual commercial landings of blue crabs are summarized by sex and stage in Table 2.1 and Figure 2.1. Total commercial landings have declined over the time series.

2.1.2 Recreational Fishery Monitoring

Recreational catch was not included in this assessment because the recreational catch of blue crab in North Carolina accounts for less than 0.4% of total (commercial plus recreational) blue crab removals in the state and no detailed information regarding recreational catch is currently available throughout the assessment time period.

2.2 Fisheries-Independent

2.2.1 Estuarine Trawl Survey (Program 120)

Due to suspension of NCDMF field operations from mid-March through May 2020, all Program 120 (P120) sampling occurred in June. Instead of sampling the 104 stations in May and June, the 104 stations were sampled prior to June 15 and again after June 15. Therefore, the number of samples collected in 2020 was not affected but the timing of sampling differs from historical sampling.

2.2.1.1 Development of Estimates

A generalized linear model (GLM) framework was used to model the relative abundance of female and male recruits captured in the P120 Survey. Details on the approach can be found in the benchmark stock assessment (NCDMF 2018).

2.2.1.2 Estimates of Estuarine Trawl Survey Statistics

Covariates available to the GLM for standardizing the female and male recruit indices included year, region, depth, bottom temperature, bottom salinity, bottom DO, sediment size, and bottom composition. Year, region, sediment size, and bottom composition were treated as categorical covariates in the models. The final, best-fitting model for female recruits in the P120 Survey was a negative binomial model and included year, region, depth, sediment size, and bottom composition as significant covariates (Table 2.2). The female recruit index developed from the P120 Survey shows a general decline over the time series (Figure 2.2). For the male recruits, the

best-fitting model was a negative binomial model and included year, region, depth, bottom salinity, bottom DO, sediment size, and bottom composition as significant covariates (Table 2.2). Like the female recruit index, the male recruit index derived from the P120 Survey exhibits a declining trend through the time series (Figure 2.2).

2.2.2 Juvenile Anadromous Trawl Survey (Program 100)

Because of the timing of sampling, there were no interruptions to Program 100 (P100) sampling in 2020 or 2021.

2.2.2.1 Development of Estimates

Four indices of relative abundance were developed using the P100 Survey data. Two indices were developed for the summer (July to August) component—fully recruited females and fully-recruited males. Indices of fully recruited females and males were also developed based on the fall (September to October) component. Attempts were made to standardize these indices using a GLM approach; however, none of the GLM models successfully converged. For this reason, nominal indices were computed for this survey.

2.2.2.2 Estimates of Juvenile Anadromous Trawl Survey Statistics

Indices for fully recruited females and fully recruited males occurring in the summer component of the P100 Survey were variable and without trend throughout the time series (Figure 2.3). For both indices, values tend to be lower overall prior to 2008 as compared to more recent years.

Indices developed for fully recruited females and fully recruited males from the fall component of the P100 survey were also variable without trend (Figure 2.4). Both fall indices show peaks in 2008.

2.2.3 Pamlico Sound Survey (Program 195)

Because of travel restrictions in 2020 related to COVID-19, sampling was limited to 28 stations sampled in June and 35 stations sampled in September. In June 2021, a total of 35 stations were sampled and in September 2021, a total of 32 stations were sampled (normal sample is 54 stations). Stations sampled were mostly limited to stations easily accessed during day trips in the rivers and on the western side of the sound.

2.2.3.1 Development of Estimates

The time series of data for this survey was limited to 1997 to 2022 because recording of surface and bottom dissolved oxygen did not start until 1997. The GLM approach was applied to Program 195 (P195) Survey data to develop indices for the June and September components of the survey. For both June and September, indices were developed for female recruits, female fully recruited, male recruits, and male fully recruited. An additional index of mature females was also developed from the September component of the survey.

2.2.3.2 Estimates of Pamlico Sound Survey Statistics

Covariates available from the P195 Survey included year, month, stratum, depth, bottom temperature, bottom salinity, and bottom dissolved oxygen. Month was added as a covariate to account for sampling extending beyond June or September due to mechanical issues or poor weather. See Table 2.2 for a summary of the covariates found to be significant in the GLMs used to develop each of the indices. Note that a GLM did not converge on the survey data representing female fully recruited blue crabs observed in September.

The June indices for female recruits (Figure 2.5 top), male recruits (Figure 2.5 bottom), and female fully recruited (Figure 2.6 top) are variable without trend. The index of male fully recruited occurring in June shows a general decline over the time series (Figure 2.6 bottom).

The September indices for female and male recruits and female fully recruited have been variable and declining over the available years (Figure 2.7–2.8).

The index of female spawners derived from the September component of the P195 Survey is highest in the earliest years and declines through the terminal year (Figure 2.9 top).

2.2.4 SEAMAP (Southeast Area Monitoring and Assessment Program) Trawl Survey

SEAMAP did not sample in 2020 and conducted limited sampling in 2021. In 2021, SEAMAP completed 38 summer stations and 74 fall stations. Because no sampling occurred in 2020 and limited sampling occurred in 2021, data from this survey in those years are not included.

2.2.4.1 Development of Estimates

An index of mature females was developed using the GLM approach based on data collected during the summer (mid-July to early August) using data only from stations located off the North Carolina coast.

2.2.4.2 Estimates of SEAMAP Trawl Survey Statistics

Available covariates for the GLM standardization included year, region, bottom temperature, and bottom salinity. Year and region were treated as categorical covariates in the models. The best-fitting model assumed a negative binomial distribution and included year, region, bottom temperature, and bottom salinity as significant covariates (Table 2.2). This index shows a peak in 1996, from which the index declines through 2016 (Figure 2.9 bottom). There is a small increase in relative abundance from 2016 to 2019, but the index in the final year (2022) is one of the lowest observed.

3 ASSESSMENT

3.1 Method

3.1.1 Scope

The unit stock is defined as all hard blue crabs occurring within North Carolina coastal fishing waters (Figure 3.1).

3.1.2 Description

This assessment is based on a sex-specific two-stage model that is adapted from catch-survey analysis (Collie and Sissenwine 1983). In this model, a sex-specific recruit fishery selectivity and a sex- and stage-specific natural mortality are assumed as free parameters to estimate based on the data. GLM-standardized abundance indices were used to remove influences of environmental factors on the annual trend (Maunder and Punt 2004), including spatial locations and geographic features such as sediment size and bottom habitat structure. Recruitment values were modeled as free parameters to estimate instead of assuming any spawner-recruitment relationship. Both process error and observation error were included to account for natural variation in the population that was in addition to the variation in response to harvesting. A Bayesian approach was applied to sufficiently incorporate data uncertainty and expert opinion in parameter estimation.

3.1.3 Dimensions

The assessment model was applied to data collected from within the range of the assumed biological stock unit (North Carolina coastal fishing waters).

The time period modeled was 1995 through 2022 using an annual time step based on the calendar year. The year 1995 was selected as the start year because that is the first year for which commercial fish house sampling data were available. The terminal year, 2022, was selected because it was the most recent year for which data were available at the start of the assessment update process.

3.1.4 Structure & Assumptions

In the two-stage model (also known as catch-survey analysis; Figure 3.2), the blue crab population consists of two stages, the recruits and the fully recruited crabs (Collie and Sissenwine 1983). The recruit stage contains blue crabs smaller than 127 mm CW, which is the legal harvestable size for male and immature female blue crabs in North Carolina, and the fully recruited stage includes blue crabs larger than or equal to 127 mm CW. In the model, all fully recruited blue crabs are subject to fishing mortality, and the recruits are subject to a partial fishing mortality because mature females at this stage are harvestable, and those male and immature female blue crabs at this stage may also be retained so long as they do not account for more than 10% of the catch. The population was modeled using an annual time step. All recruits become fully recruited at the beginning of the next year. The population dynamics of blue crab in the sex-specific two-stage model is described in terms of the number of male and female blue crabs at each stage over time (Miller et al. 2011):

Population size of recruits

$$R_y = \bar{R}\exp(\varepsilon_{R,y}),$$

$$R_{y,s} = R_y v_s,$$

Population size of fully recruited animals

$$N_{y+1,s} = \left(N_{y,s}\exp(-M_{N,s} - F_{N,y,s}) + R_{y,s}\exp(-M_{R,s} - F_{R,y,s})\right)\exp(\varepsilon_{N,y+1,s}),$$

Catch of recruits

$$C_{R,y,s} = \left(\frac{F_{R,y,s}}{F_{R,y,s} + M_{R,s}}\left(1 - \exp(-M_{R,s} - F_{R,y,s})\right)R_{y,s}\right)\exp(\varepsilon_{CR,y,s}),$$

Catch of fully recruited animals

$$C_{N,y,s} = \left(\frac{F_{N,y,s}}{F_{N,y,s} + M_{N,s}}\left(1 - \exp(-M_{N,s} - F_{N,y,s})\right)N_{y,s}\right)\exp(\varepsilon_{CN,y,s}),$$

Fishing mortality of recruits

$$F_{R,y,s} = F_y g_{R,s},$$

Fishing mortality of fully recruited animals

$$F_{N,y,s} = F_y g_{N,s},$$

Population size of female spawners

$$N_{sp,\,y} = N_{y,\,s=female} w_N + R_{y,\,s=female} w_R,$$

Abundance indices of female spawners

$$I_{sp,\,y,\,j} = \left(q_{sp,\,j} N_{sp,\,y}\right) \exp\left(\varepsilon_{sp,\,y,\,j}\right),$$

Abundance indices of recruits

$$I_{R,\,y,\,s,\,j} = \left(q_{R,\,s,\,j} R_{y,\,s}\right) \exp\left(\varepsilon_{IR,\,y,\,s,\,j}\right),$$

Abundance indices of fully recruited animals

$$I_{N,\,y,\,s,\,j} = \left(q_{N,\,s,\,j} N_{y,\,s}\right) \exp\left(\varepsilon_{IN,\,y,\,s,\,j}\right),$$

where R and N are the population size of recruits and fully recruited animals at the beginning of the year respectively, M and F are natural mortality and fishing mortality, v is the proportion of male or female recruits, C is catch in number, g is selectivity, w is proportion of mature female recruits or mature female fully recruited animals, I is fisheries-independent abundance index, q is the catchability; $\varepsilon_{N,\,y+1,\,s} \sim Normal\left(0,\,\sigma_N^2\right)$ and $\varepsilon_{R,\,y} \sim Normal\left(0,\,\sigma_R^2\right)$ are process errors, and

$$\varepsilon_{CN,\,y,\,s} \sim Normal\left(0,\,\sigma_{CN,\,s}^2\right), \qquad \varepsilon_{CR,\,y,\,s} \sim Normal\left(0,\,\sigma_{CR,\,s}^2\right), \qquad \varepsilon_{sp,\,y,\,j} \sim Normal\left(0,\,\sigma_{sp,\,j}^2\right),$$

$$\varepsilon_{IN,\,y,\,s,\,j} \sim Normal\left(0,\,\sigma_{IN,\,s,\,j}^2\right), \text{ and } \varepsilon_{IR,\,y,\,s,\,j} \sim Normal\left(0,\,\sigma_{IR,\,s,\,j}^2\right)$$ are observation errors, which follow a normal distribution with a mean of zero and a standard deviation of σ; the subscript y indexes the yth year, s represents either male or female, j indexes the jth fisheries-independent abundance index, R and N in subscripts denote the recruits and the fully recruited respectively, and sp in subscripts denotes spawner.

In the model, a 1:1 sex ratio and sex-specific natural mortalities ($M_{N,\,s}$ and $M_{R,\,s}$) were assumed. Natural mortality was assumed constant over time. The mature female proportion for female recruits (w_R) and female fully recruited animals (w_N) was set to be 0.044 and 0.9 (Eggleston et al. 2004). The selectivity for fully recruited animals ($g_{N,\,s}$) was set to be one (Rudershausen and Hightower 2016), and selectivity for recruits ($g_{R,\,s}$) was assumed sex-specific and free parameters to estimate in the model. The annual recruitment R_y was directly estimated to avoid assuming a fixed spawner-recruitment relationship because the spawner size can often only explain a small amount of the high variation in recruitment (Jiao et al. 2012). The annual recruitment R_y was assumed to follow a lognormal distribution that centers around an average of $\overline{R}$. In North Carolina, fall is the primary spawning season for blue crab, and most harvest occurs during May through October. Thus, in the model, indices sampled since September in the current year (i.e., the P100 fall and P195 September indices) were related to the abundance in the following year, except for the spawner indices (i.e., P195 spawner and SEAMAP spawner indices).

The model code was developed and run in R (version 4.3.1; R Core Team 2023).

3.1.5 Calibration

In this assessment, the Bayesian approach was applied to estimate parameters. The posterior distribution was obtained through the Metropolis-Hasting algorithm using Markov Chain Monte Carlo (MCMC) simulation (Hilborn et al. 1994; Hoff 2009). Three concurrent chains were run

with a total of 500,000 iterations for each chain. The first 470,000 iterations were discarded as burn-in and every 10th iteration from the remaining sample from each chain was used for analysis. The working group used JAGS (version 4.3.1) through implementation of the R package R2jags to run the Bayesian analysis (Su and Yajima 2021).

Noninformative priors were used, i.e., uniform priors, for initial population size ($N_{y=1995, s}$), average annual recruitment ($\bar{R}$), fishing mortality (F_y), recruits selectivity ($g_{R, s}$), catchability ($q_{sp, j}$, $q_{N, s, j}$ and $q_{R, s, j}$), and standard deviation (σ_N, σ_R, σ_{CN}, σ_{CR}, $\sigma_{sp, j}$, $\sigma_{IN, s, j}$, and $\sigma_{IR, s, j}$) of process and observation errors. The working group constructed a hierarchical prior for natural mortality parameters where $M_{N, s}$ and $M_{R, s}$ follow an unknown lognormal distribution centering around $\bar{M}$ that is further governed by a uniform distribution bounded by m_1 and m_2:

$$M_{N, s} \ or \ M_{R, s} = \bar{M} \exp(\varepsilon_M),$$

$$\bar{M} \sim Uniform(m_1, m_2),$$

where $\varepsilon_M \sim Normal(0, \sigma_M)$ is a random error.

Priors and parameters are listed in Tables 3.1 and 3.2.

3.1.6 Results

The model provided reasonable fits to the annual commercial landings, especially for the female and male fully recruited blue crabs (Figure 3.3). Fits to the female recruit commercial landings tended to be poor in the early part of the time series. The model fits to the fisheries-independent survey indices and associated residuals are shown in Figures 3.4–3.19. The survey indices were not fit as well as the commercial landings, but the predicted values captured the general observed trend. The model did show difficulty in predicting extreme peaks in abundance for all the survey indices (e.g., poor fit to 1996 and 1997 observations of female blue crab recruits observed in the September component of the Program 195 Survey, Figure 3.14). The survey indices derived from the Program 100 Survey were fit least well of the survey indices (Figures 3.6–3.9). For the Program 100 Survey indices, the observed values exhibit lower values in the early part of the time series (prior to 2008) and generally higher values in the later part of the series. While the model did capture the decline observed in the final few years, it did not predict the period of increased relative abundance prior to that and beginning in 2008.

Estimates of population size predicted by the stock assessment model are variable but declining over the modeled time series (Figure 3.20). Overall recruitment and female spawner abundance levels are highest in the earliest years of the time series and, while variable, trend downward through the terminal year (Figure 3.21). Estimates of fishing mortality are also higher in the early part of the time series and variable throughout the entire time period. Fishing mortality shows a small decline from 2021 to 2022 (Figure 3.21).

Estimates of natural mortality are higher for females than males (Figure 3.22). Natural mortality estimates for fully recruited females are associated with higher uncertainty than other stages.

3.2 Discussion of Results

Given results of this stock assessment update, much of the discussion detailed in the benchmark stock assessment report is applicable to this update (NCDMF 2018).

Estimates and trends of sex- and stage-specific abundance (Figure 3.23), total recruit abundance (Figure 3.24), female spawner abundance (Figure 3.25), and fishing mortality (Figure 3.26) are similar to those from the benchmark stock assessment (NCDMF 2018). Additionally, the natural mortality estimates for each sex and stage are similar to the estimates from the benchmark stock assessment (NCDMF 2018); however, estimated reference points for both female spawner abundance and fishing mortality (see next section) show a noticeable change. Note that the current assessment as well as the benchmark cover a relatively limited time period of declining recruitment and spawning abundance. This type of "one-way trip" is indicative of uninformative data and suggests that results should be interpreted with caution (Hilborn and Walters 1992).

4 STATUS DETERMINATION CRITERIA

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

The peer review panel for the 2018 benchmark stock assessment recommended the use of MSY-based reference points for the North Carolina blue crab stock (NCDMF 2018). These reference points include a fishing mortality threshold equal to the fishing mortality that maximizes the total yield (F_{MSY}) and a fishing mortality target equal to $0.75F_{MSY}$. The stock is considered to be experiencing overfishing if the average F in the terminal year (2022) is larger than F_{MSY}. Stock size reference points are defined in terms of female spawner abundance. The female spawner abundances at F_{MSY} (SP_{MSY}) and $0.75F_{MSY}$ ($0.75SP_{MSY}$) were set to the spawner abundance threshold and target, respectively. The population is determined to be overfished if the average female spawner abundance in the terminal year (2022) is less than SP_{MSY}.

The fishing mortality threshold, F_{MSY}, was estimated to be 0.61. The fishing mortality target, $0.75F_{MSY}$, was estimated to be 0.45. The stock assessment model estimated that fishing mortality in 2022 was 1.8, which is greater than the F threshold and indicates that the stock is currently experiencing overfishing (Figure 4.1). The probability that the stock is experiencing overfishing is 100%.

The stock assessment model estimated the female spawner abundance threshold, SP_{MSY}, to be 120 million crabs and the female spawner abundance target was estimated at 145 million crabs. The estimated female spawner abundance in 2022 was 14.8 million crabs, which is less than the threshold and so indicates the stock is currently overfished (Figure 4.1). The probability that the stock is overfished is 100%.

The estimated fishing mortality threshold (0.61) and target (0.45) are less than the threshold and target values estimated in the benchmark (benchmark F threshold = 1.5, benchmark F target = 1.2). The female spawner abundance threshold (120 million crabs) and target (145 million crabs) estimated in this update have higher values than those estimated in the benchmark (benchmark spawner abundance threshold = 64 million crabs, benchmark spawner abundance target = 73 million crabs). This is not unexpected since reference points are estimated from models based on data that change or are updated from one stock assessment to the next (Silvar-Viladomiu et al. 2021). The maximum sustainable yield (MSY)-based reference points used in this stock assessment assume equilibrium conditions; that is, the rate of removal is equal to the rate at which the population regenerates itself. Given that blue crabs have been harvested from North Carolina

waters for over a century (U.S. Fish Commission 1892), it is likely that we have a poor understanding of the optimal levels for spawner abundance and fishing mortality.

Preliminary projections of the stock suggest it is not possible to reach the estimated female spawner abundance target or threshold, even with no fishing mortality. A species' life history and fishing history impacts how the stock will respond to different management strategies and the stock's ability to sustain itself (Berger 2019). The results of the current stock assessment point to record low recruitment and spawner abundance in recent years. Unless there is a change in stock productivity, the stock may not be capable of reaching a sustainable state.

5 RESEARCH RECOMMENDATIONS

The research recommendations listed below were offered by the working group to improve future stock assessments of the blue crab stock in North Carolina. Those research recommendations denoted with an asterisk (*) were suggested (and ranked) by the external peer reviewers during the benchmark stock assessment (NCDMF 2018).

High

- Develop statewide fishery-independent survey(s) to monitor the abundance of all blue crab life stages

- Expand time and area coverage of existing fishery-independent surveys

- Better characterize the magnitude of recreational harvest *

- Develop better estimates of life-history parameters, especially growth and natural mortality *

- Explore alternative biological reference points *

Medium

- Identify key environmental factors that significantly impact North Carolina's blue crab stock and investigate assessment methods that can account for these environmental factors

- Implement monitoring of hazardous events (e.g., hurricane, extreme heat or cold weather) affecting blue crab population dynamics and harvest

- Explore alternative model types *

Low

- Investigate and support research on promising methods to age blue crabs

- Evaluate the genetic stock structure of blue crabs within North Carolina and the magnitude of mixing between populations

- Identify programs outside the NCDMF that collect data of potential use to the stock assessment of North Carolina's blue crabs

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7 TABLES

Table 2.1. Annual commercial landings of hard blue crabs (millions of crabs) in North Carolina by sex and stage, 1995–2022.

Year	Recruits		Fully Recruited	
	Males	**Females**	**Males**	**Females**
1995	11.72	5.998	58.22	57.90
1996	12.97	9.307	89.99	83.44
1997	11.15	11.18	65.97	74.83
1998	6.707	5.918	67.89	82.57
1999	5.346	23.17	57.43	85.27
2000	7.622	5.276	48.58	55.60
2001	3.786	4.983	35.35	42.02
2002	6.336	5.915	46.41	43.42
2003	3.361	8.036	57.74	51.44
2004	5.991	3.488	40.31	48.29
2005	4.614	6.129	31.66	30.90
2006	5.526	1.563	31.82	32.18
2007	2.537	1.222	32.26	22.46
2008	2.824	1.491	40.89	42.69
2009	1.631	0.5519	40.29	33.08
2010	4.150	0.8040	48.92	32.33
2011	3.715	1.306	42.40	34.79
2012	3.791	0.9756	36.72	30.22
2013	1.331	1.045	31.67	24.61
2014	1.939	0.6878	43.00	22.79
2015	3.196	0.4255	49.80	31.37
2016	2.453	0.7274	36.16	30.16
2017	1.912	0.8314	28.48	20.21
2018	1.645	0.3380	28.73	15.45
2019	2.438	1.187	27.85	34.93
2020	2.597	1.209	20.68	15.29
2021	1.555	0.4295	21.98	13.87
2022	1.190	0.1452	14.15	9.625

Table 2.2. Summary of available covariates considered in the standardization of fisheries-independent indices. Covariates formatted in bold were found to be significant in the GLM process.

Survey	Sex	Stage	Covariates
P120	female	recruits	**year**, **region**, **depth**, btemp, bsal, bdo, **sedsize**, **btmcomp**
P120	male	recruits	**year**, **region**, **depth**, btemp, **bsal**, **bdo**, **sedsize**, **btmcomp**
P100 summer	female	fully recruited	*n/a* (nominal index)
P100 summer	male	fully recruited	*n/a* (nominal index)
P100 fall	female	fully recruited	*n/a* (nominal index)
P100 fall	male	fully recruited	*n/a* (nominal index)
P195 June	female	recruits	**year**, **stratum**, **depth**, btemp, **bsal**, **bdo**
P195 June	male	recruits	**year**, **stratum**, **depth**, **btemp**, **bsal**, **bdo**
P195 June	female	fully recruited	**year**, **stratum**, **depth**, btemp, bsal, **bdo**
P195 June	male	fully recruited	**year**, **stratum**, depth, btemp, **bsal**, bdo
P195 September	female	recruits	**year**, month, **stratum**, depth, **btemp**, **bsal**, **bdo**
P195 September	male	recruits	**year**, **month**, **stratum**, depth, **btemp**, **bsal**, **bdo**
P195 September	female	fully recruited	*n/a* (nominal index)
P195 September	male	fully recruited	**year**, **month**, **stratum**, depth, **btemp**, **bsal**, bdo
P195 September	female	mature	**year**, month, **stratum**, **depth**, **btemp**, **bsal**, bdo
SEAMAP summer	female	mature	**year**, **region**, **btemp**, **bsal**

Table 3.1. Parameters and priors. U denotes uniform distribution.

	Parameter	Value	Reference
Input Parameters	Sex ratio	1:1	
	Selectivity for fully recruited	$g_{N,s} = 1$	Rudershausen and Hightower 2016
	Proportion of mature females	$w_N = 0.9$; $w_R = 0.044$	Eggleston et al. 2004
	Natural mortality (Model 3)	$M = 0.55$	Eggleston et al. 2004
Priors	Initial population size (10^6)	$N_{y=1995, s=male} \sim U(58, 5800)$ $N_{y=1995, s=female} \sim U(58, 5800)$	Derived from catch data in initial year (1995)
	Average recruitment (10^6)	$\bar{R} \sim U(10, 1000)$	Derived from catch data
	Initial recruitment (10^6; Model 4)	$R_{y=1995} \sim U(10, 1000)$	
	Natural mortality (yr^{-1})	$\bar{M} \sim U(0.5, 2)$	Murphy et al. 2007; Miller et al. 2011
	Fishing mortality (yr^{-1})	$F_y \sim U(0.001, 3)$	Eggleston et al. 2004
	Selectivity for recruits	$g_{R,s} \sim U(0, 0.6)$	Rudershausen and Hightower 2016
	Ricker productivity parameter (# offspring per spawner; Model 4)	$\alpha \sim U(1, 15)$	Eggleston et al. 2004; VanderKooy 2013
	Ricker density-dependence parameter (Model 4)	$\beta = 0.005$	Eggleston et al. 2004; VanderKooy 2013
	Standard deviation of process errors	$\sigma_N, \sigma_R \sim U(0.001, 10)$	
	Standard deviation of observation errors	$\sigma_{CN,s}, \sigma_{CR,s} \sim U(0.001, 10)$ $\sigma_{sp,j}, \sigma_{IN,s,j}, \sigma_{IR,s,j} \sim U(0.001, 10)$	
	Standard deviation of natural mortality error	$\sigma_{MM}, \sigma_M \sim U(0.001, 1)$	

Table 3.2. Priors for catchability (q; 10^{-6}). U denotes uniform distribution. Derived from catch and abundance index data by assuming catch is the lower bound for population size and 100 x catch is the upper bound. Set 0.0001 as lower bound and maximum index / minimum catch as upper bound.

Abundance Index	Prior
P120 male recruits	U(0.0001, 34)
P195 male recruits June	U(0.0001, 222)
P195 male recruits September	U(0.0001, 16)
P120 female recruits	U(0.0001, 297)
P195 female recruits June	U(0.0001, 1551)
P195 female recruits September	U(0.0001, 99)
P100 male fully recruited summer	U(0.0001, 0.4)
P100 male fully recruited fall	U(0.0001, 1)
P195 male fully recruited June	U(0.0001, 5)
P195 male fully recruited September	U(0.0001, 1)
P100 female fully recruited summer	U(0.0001, 0.3)
P100 female fully recruited fall	U(0.0001, 1)
P195 female fully recruited June	U(0.0001, 5)
P195 female fully recruited September	U(0.0001, 2)
P195 spawner	U(0.0001, 2)
SEAMAP spawner	U(0.0001, 6)
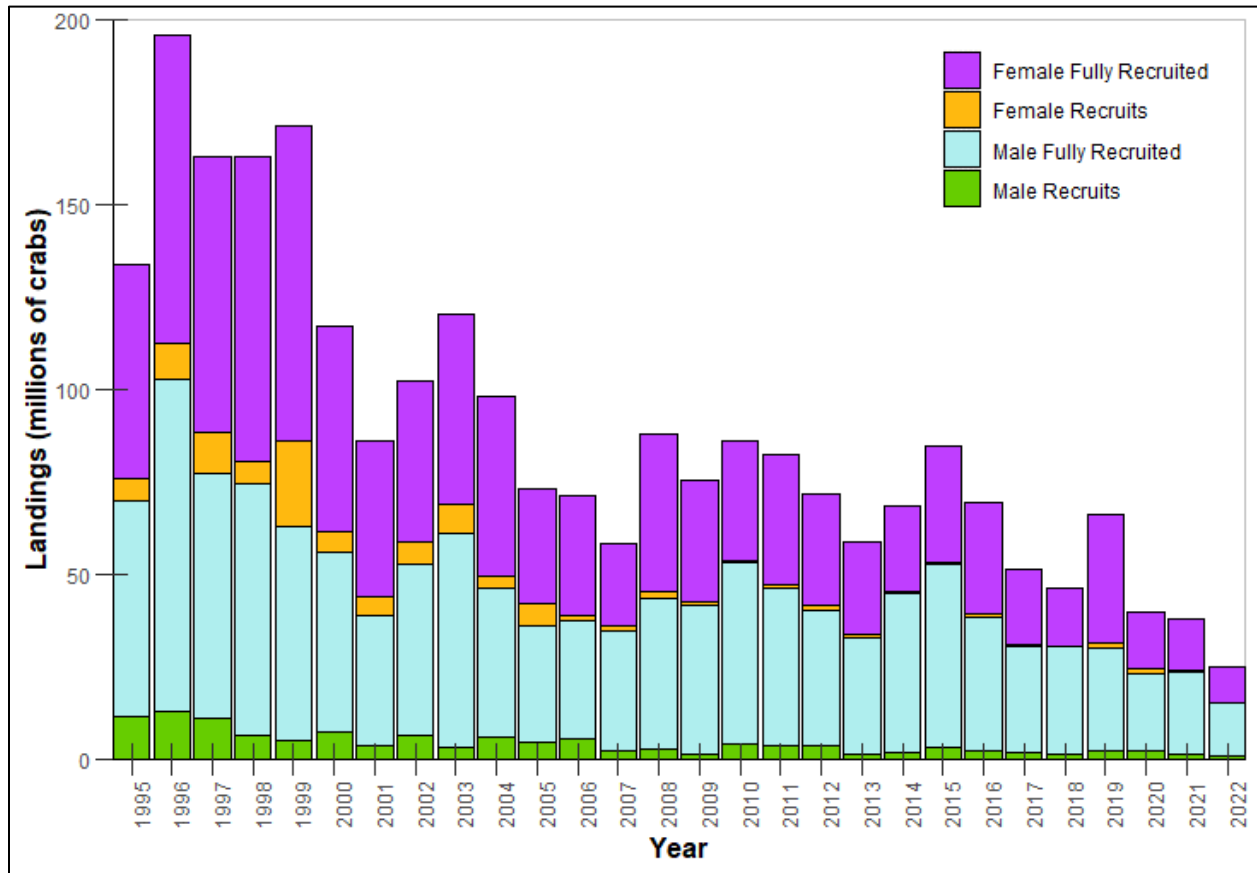
Figure 2.1. Annual commercial landings of hard blue crabs in North Carolina by sex and stage, 1995–2022.
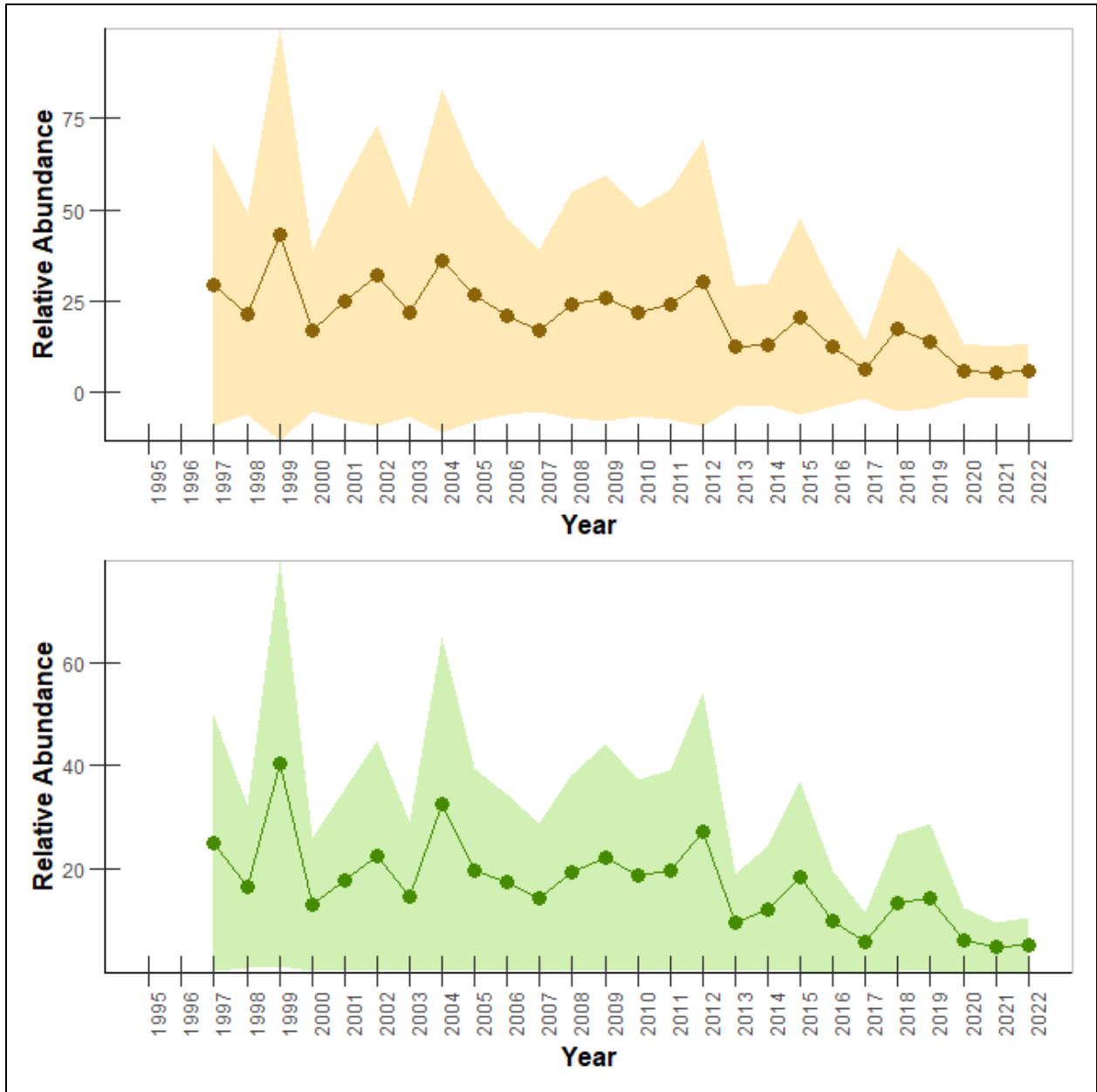
Figure 2.2. GLM-standardized indices of relative abundance for female (top) and male (bottom) blue crab recruits observed in the Program 120 Survey, 1997–2022.
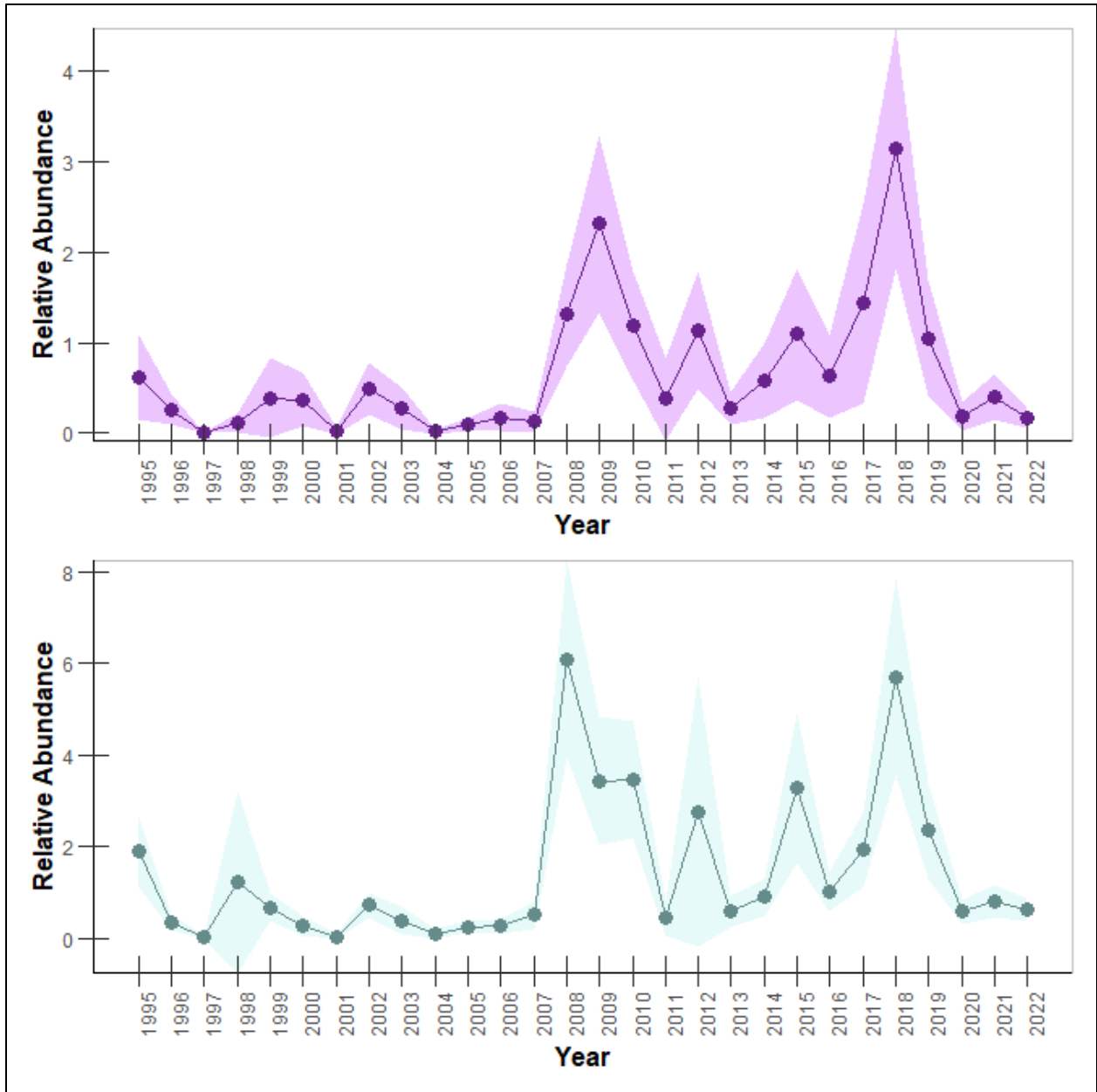
Figure 2.3. Nominal indices of relative abundance for female (top) and male (bottom) fully recruited blue crabs observed in the summer component of the Program 100 Survey, 1995–2022.
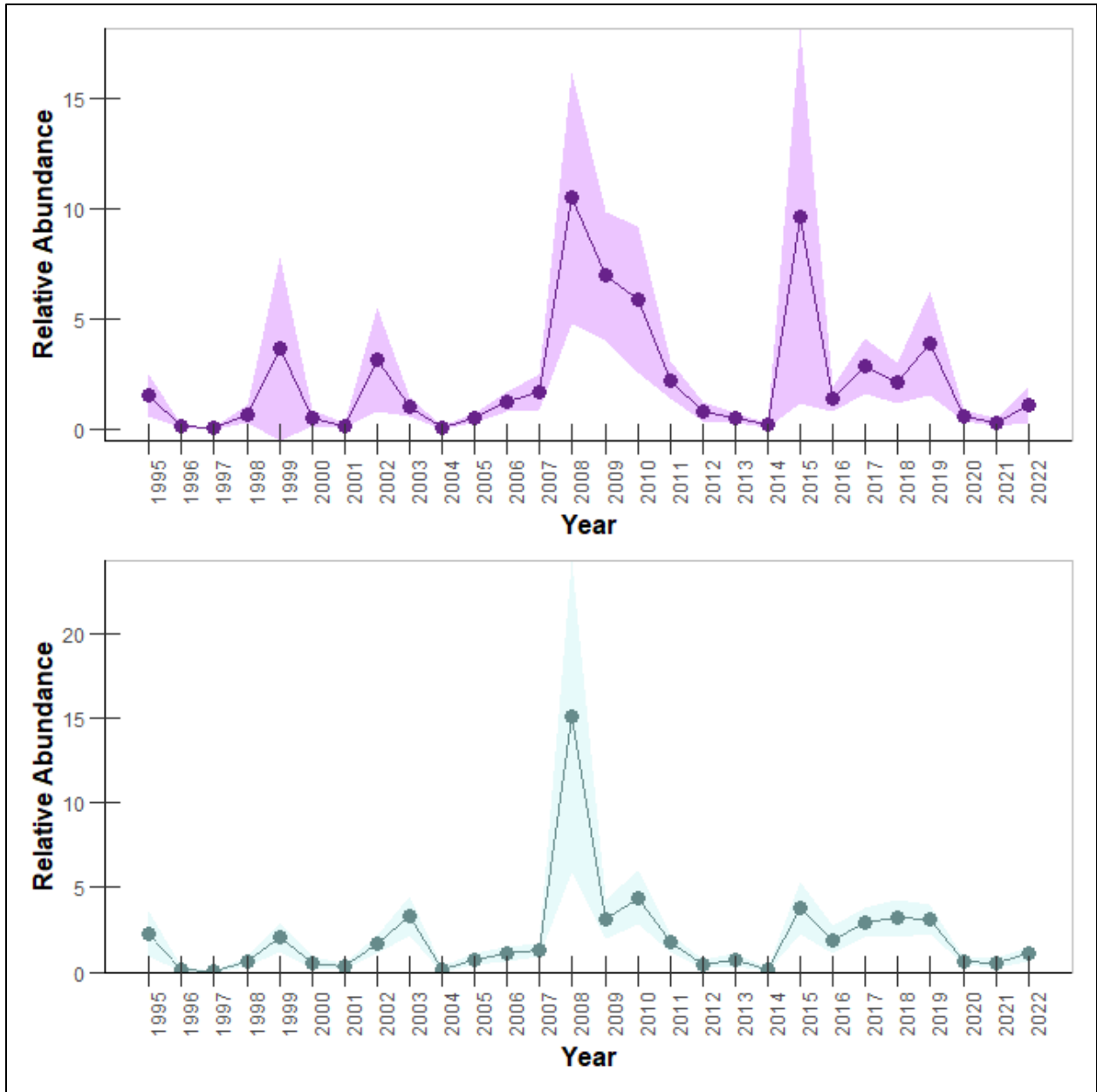
Figure 2.4. Nominal indices of relative abundance for female (top) and male (bottom) fully recruited blue crabs observed in the fall component of the Program 100 Survey, 1995–2022.
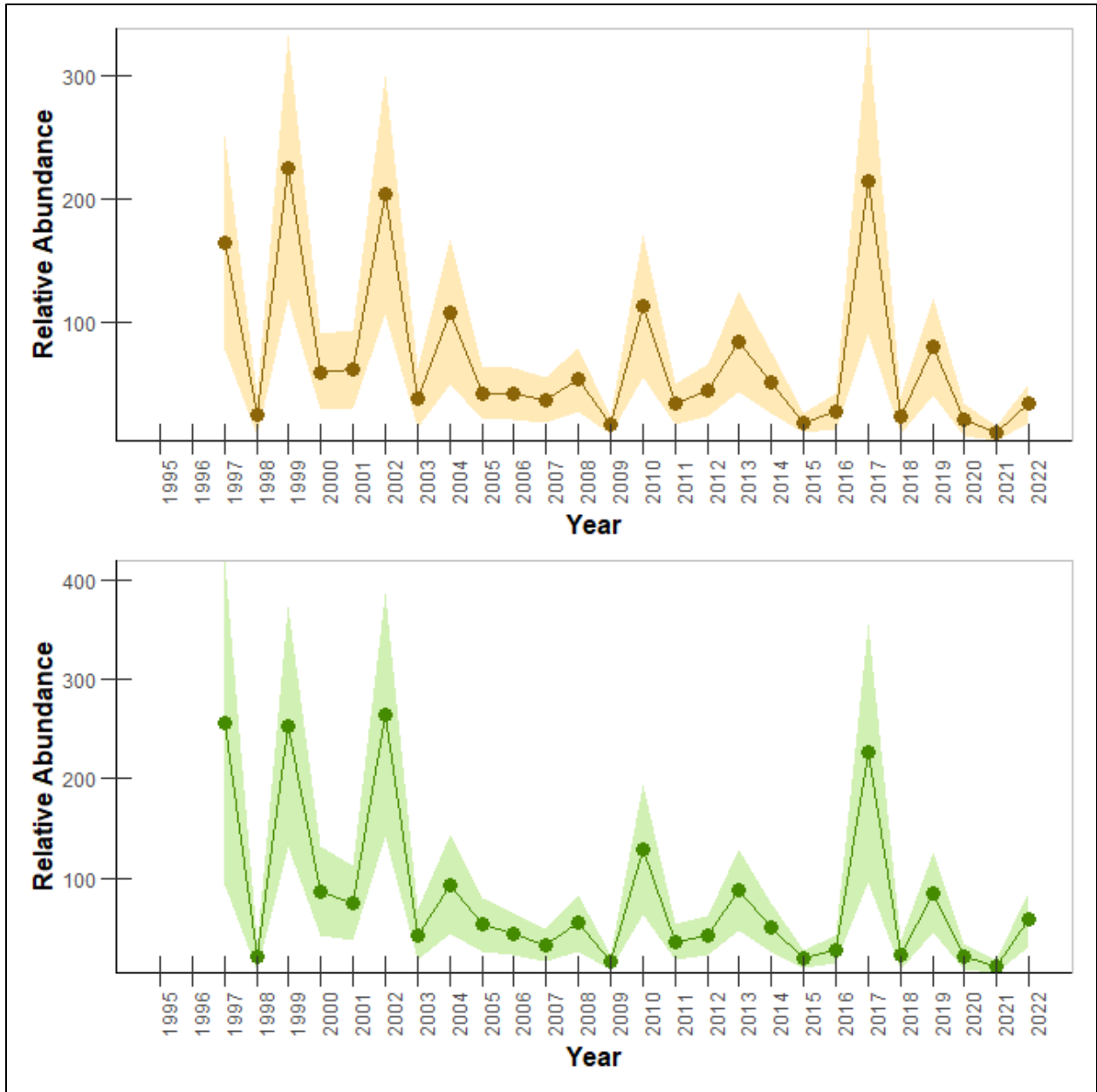
Figure 2.5. GLM-standardized indices of relative abundance for female (top) and male (bottom) blue crab recruits observed in the June component of the Program 195 Survey, 1997–2022.
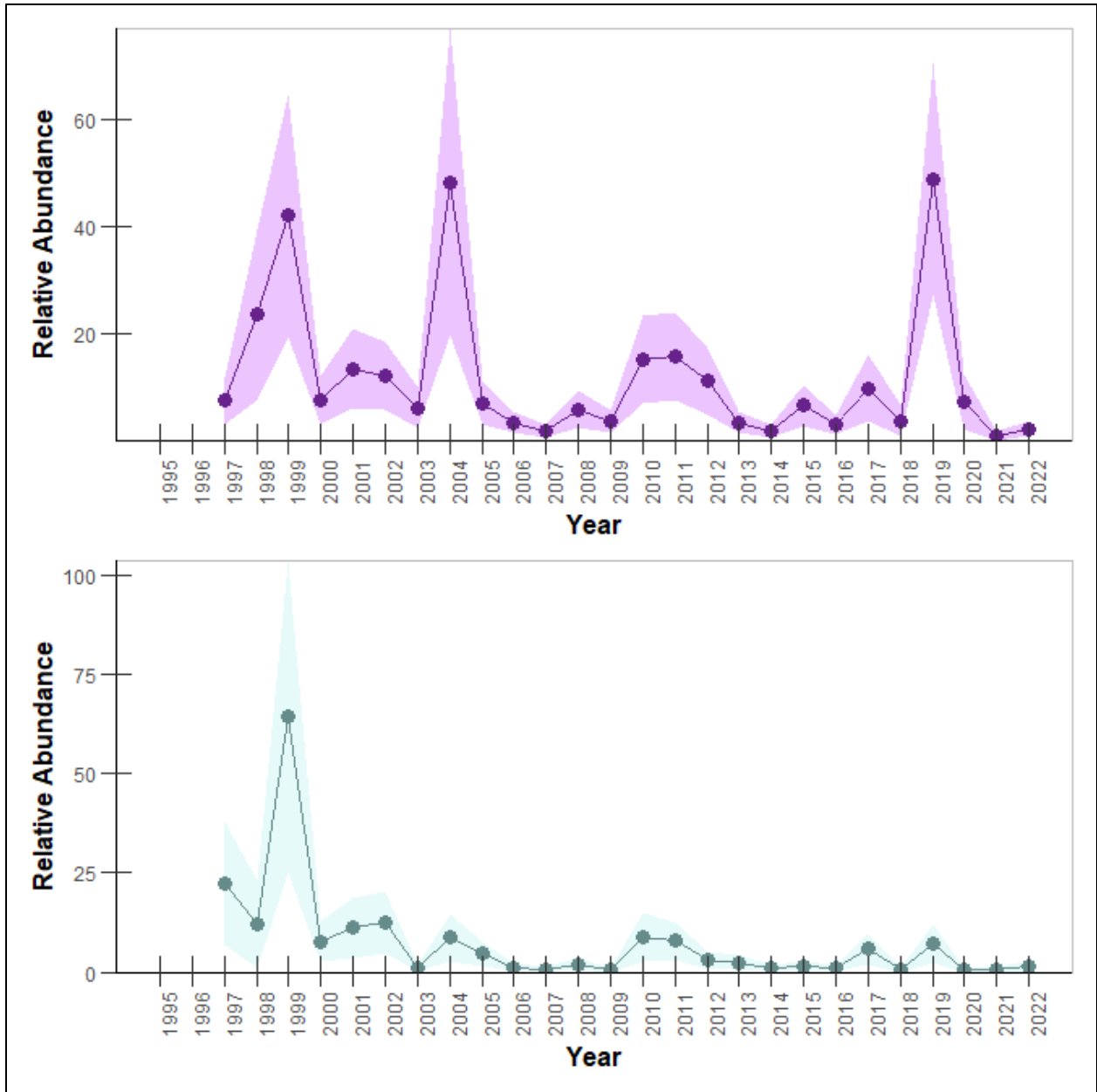
Figure 2.6. GLM-standardized indices of relative abundance for female (top) and male (bottom) fully recruited blue crabs observed in the June component of the Program 195 Survey, 1997–2022.
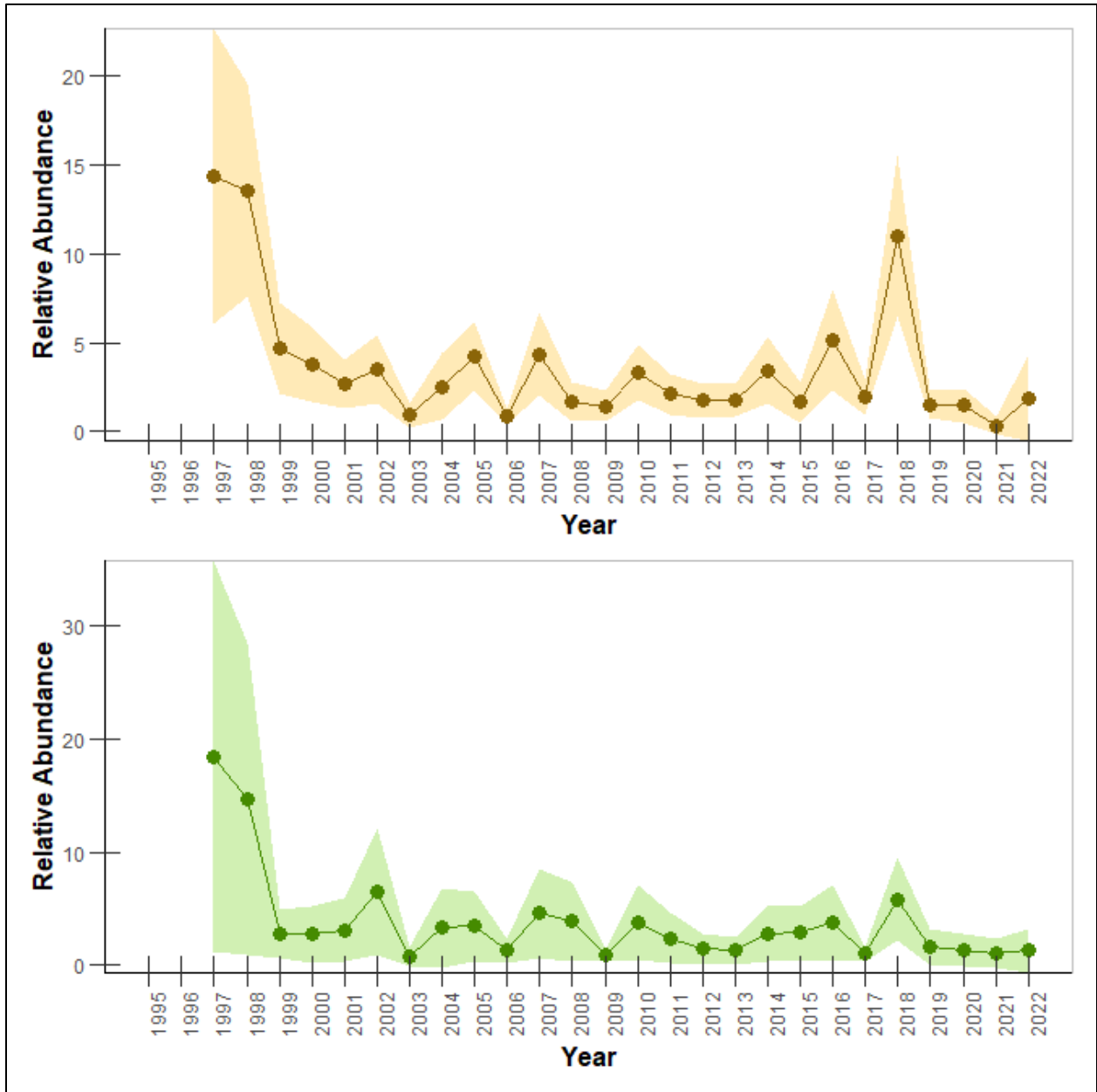
Figure 2.7. GLM-standardized indices of relative abundance for female (top) and male (bottom) blue crab recruits observed in the September component of the Program 195 Survey, 1997–2022.
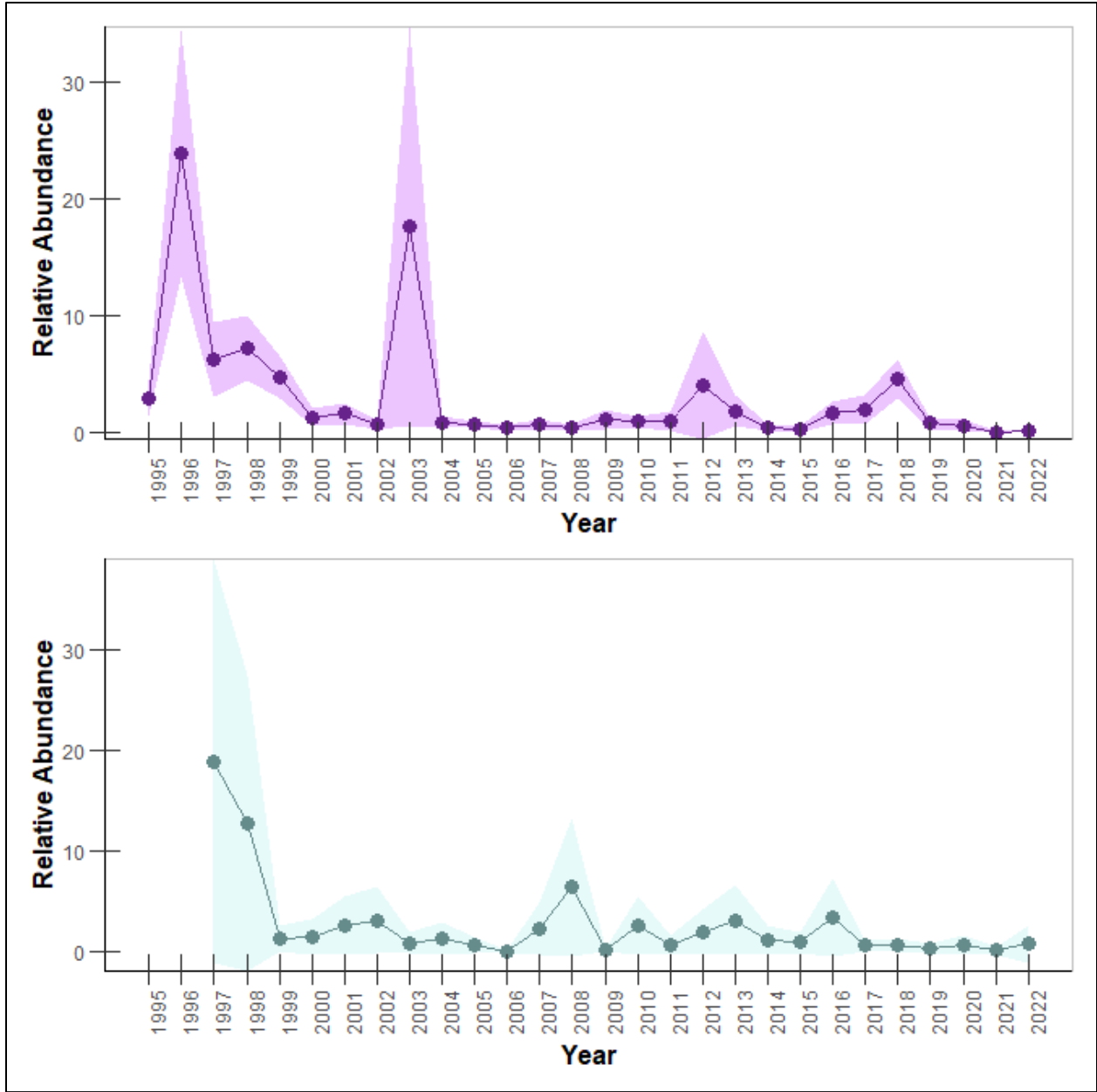
Figure 2.8. Nominal index for female fully recruited blue crabs (top) and GLM-standardized index for male fully recruited blue crabs (bottom) observed in the September component of the Program 195 Survey, 1995–2022.
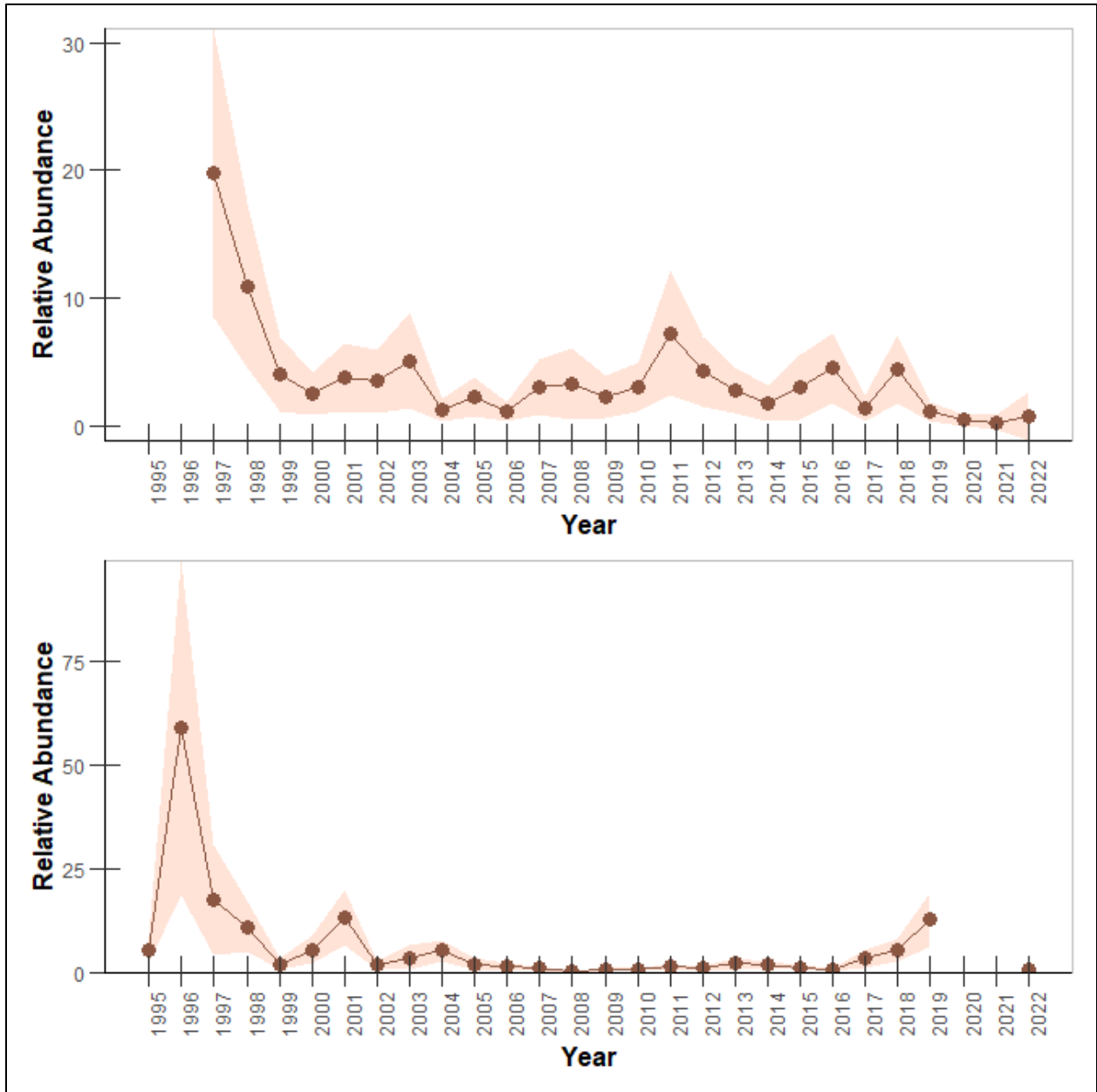
Figure 2.9. GLM-standardized indices of relative abundance for mature female blue crabs observed in the September component of the Program 195 Survey (top) and the summer component of the SEAMAP Survey (bottom), 1995–2022.
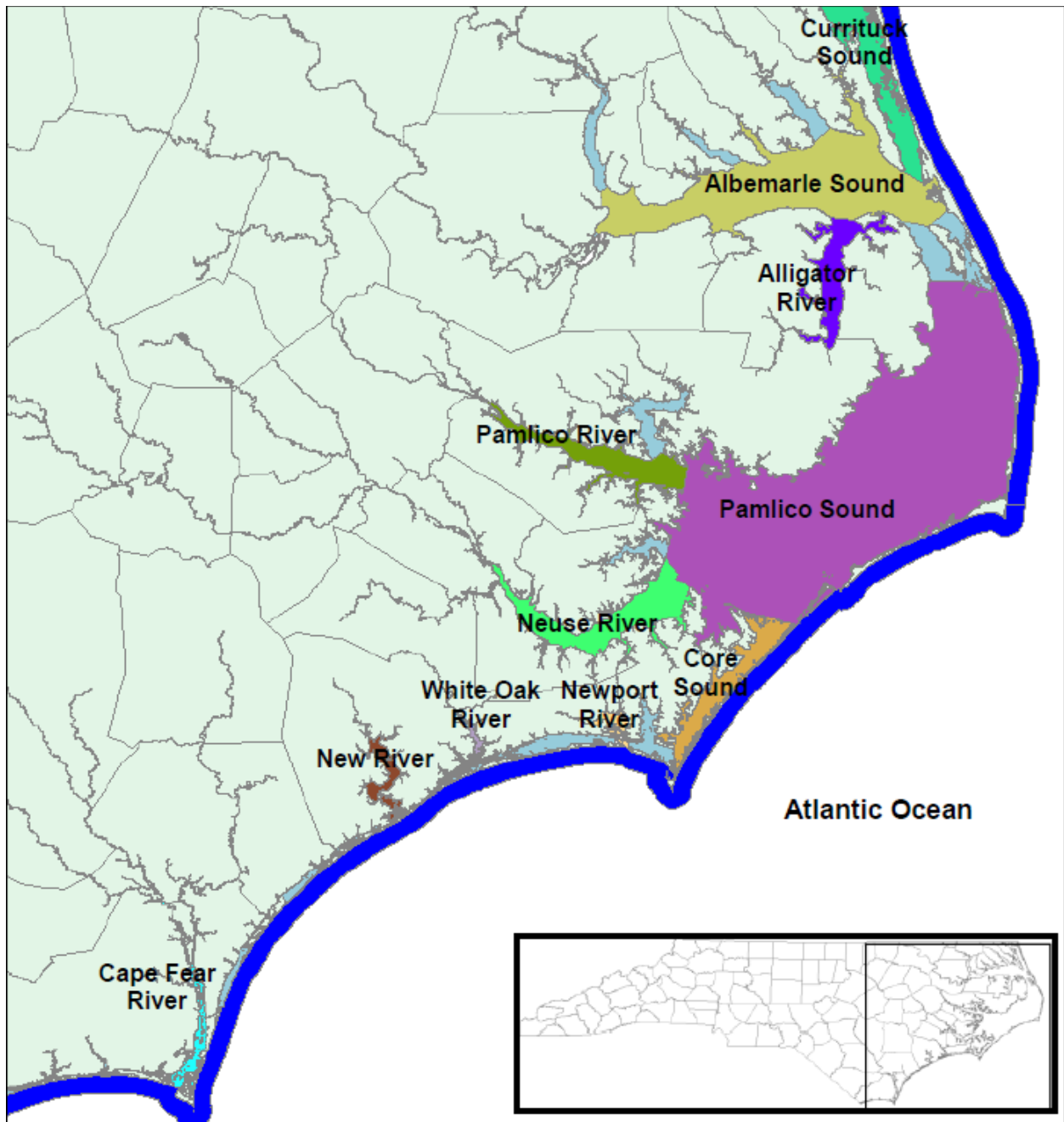
Figure 3.1. Major water bodies within and around North Carolina. The darker blue area represents the range of the state's coastal fishing waters, which extend to three miles offshore.

Fit fully recruited catch data ⇕

Fit recruits catch data ⇕

$$C_{N,y,s} = \left(\frac{F_{N,y,s}}{F_{N,y,s} + M_{N,s}} \left(1 - \exp\left(-M_{N,s} - F_{N,y,s}\right)\right) N_{y,s} \right) \exp\left(\varepsilon_{CN,y,s}\right)$$

$$C_{R,y,s} = \left(\frac{F_{R,y,s}}{F_{R,y,s} + M_{R,s}} \left(1 - \exp\left(-M_{R,s} - F_{R,y,s}\right)\right) R_{y,s} \right) \exp\left(\varepsilon_{CR,y,s}\right)$$

Fully recruited   Recruits

$$N_{y+1,s} = \left(N_{y,s} \exp\left(-M_{N,s} - F_{N,y,s}\right) + R_{y,s} \exp\left(-M_{R,s} - F_{R,y,s}\right) \right) \exp\left(\varepsilon_{N,y+1,s}\right)$$

$$N_{sp,y} = N_{y,s=female} w_N + R_{y,s=female} w_R$$

$$R_y = \bar{R} \exp\left(\varepsilon_{R,y}\right)$$
$$R_{y,s} = R_y v_s$$

$$I_{N,y,s,j} = \left(q_{N,s,j} N_{y,s} \right) \exp\left(\varepsilon_{IN,y,s,j}\right)$$

$$I_{R,y,s,j} = \left(q_{R,s,j} R_{y,s} \right) \exp\left(\varepsilon_{IR,y,s,j}\right)$$

⇕   ⇕

Fit fully recruited   Fit spawner
abundance index   abundance index

⇕
Fit recruits abundance index

Figure 3.2. Schematic diagram of the two-stage model for the North Carolina blue crab stock assessment. Refer to text for symbol explanation.
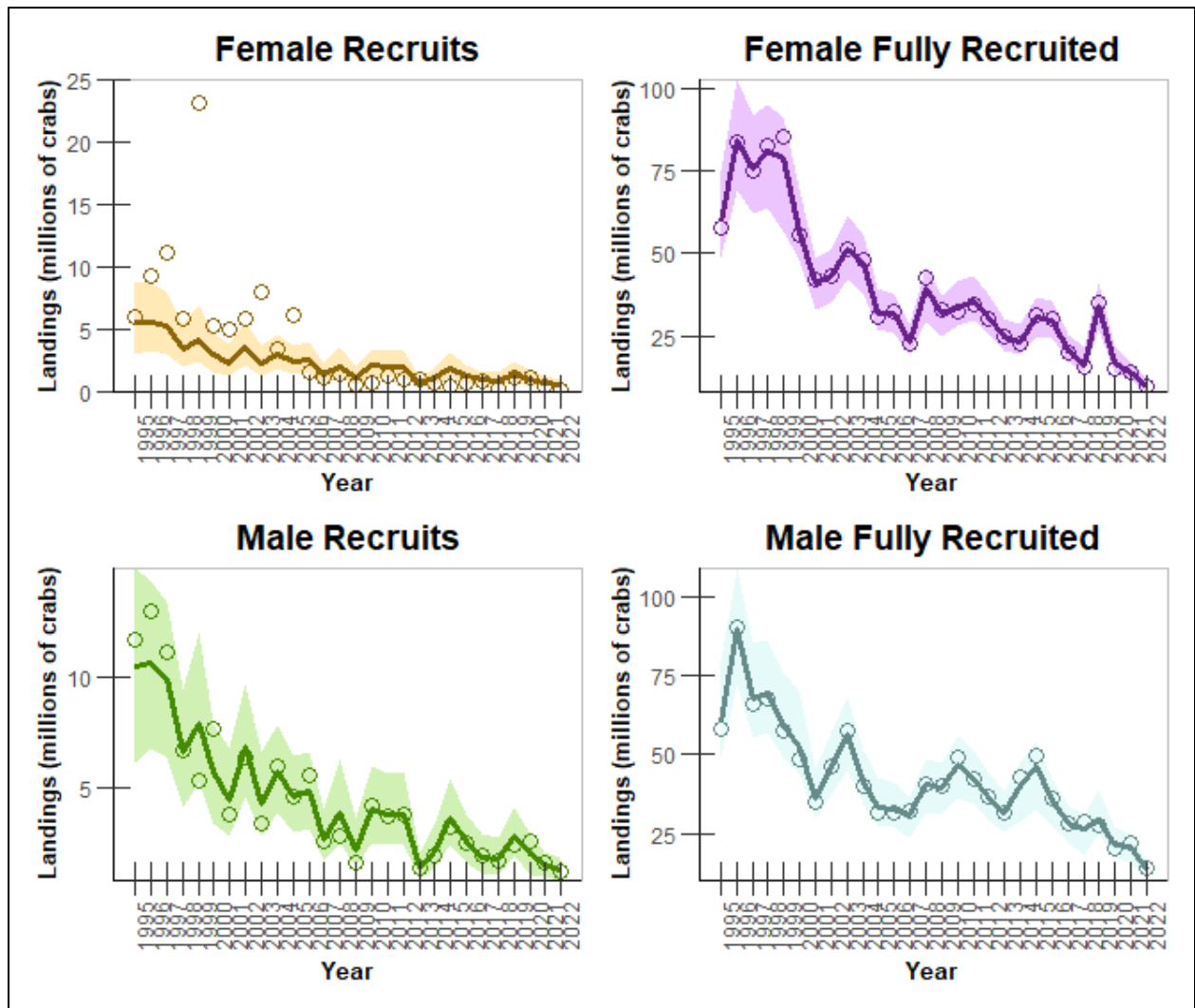
Figure 3.3. Observed (open circles) and predicted (solid lines) commercial landings of hard blue crabs by sex and stage, 1995–2022. Lines represent posterior mean and shaded area represents 95% credible interval.
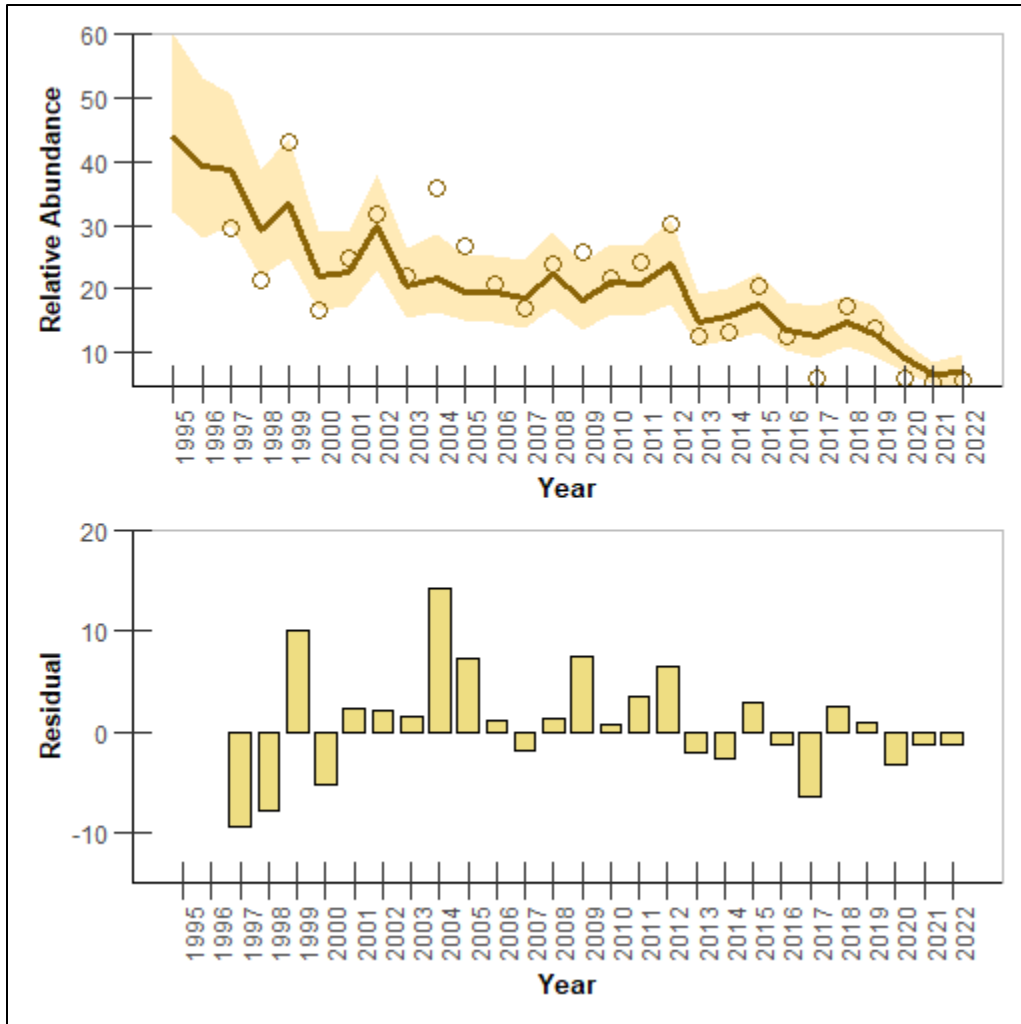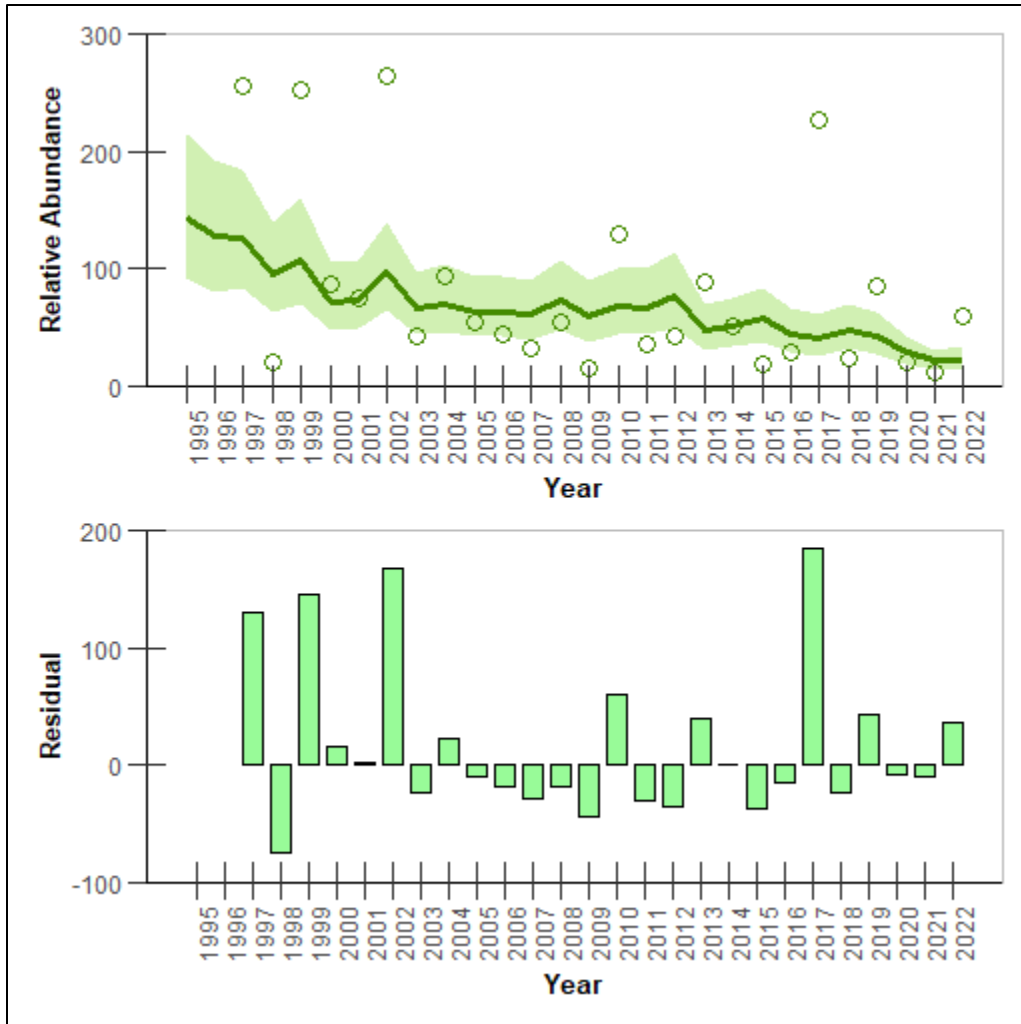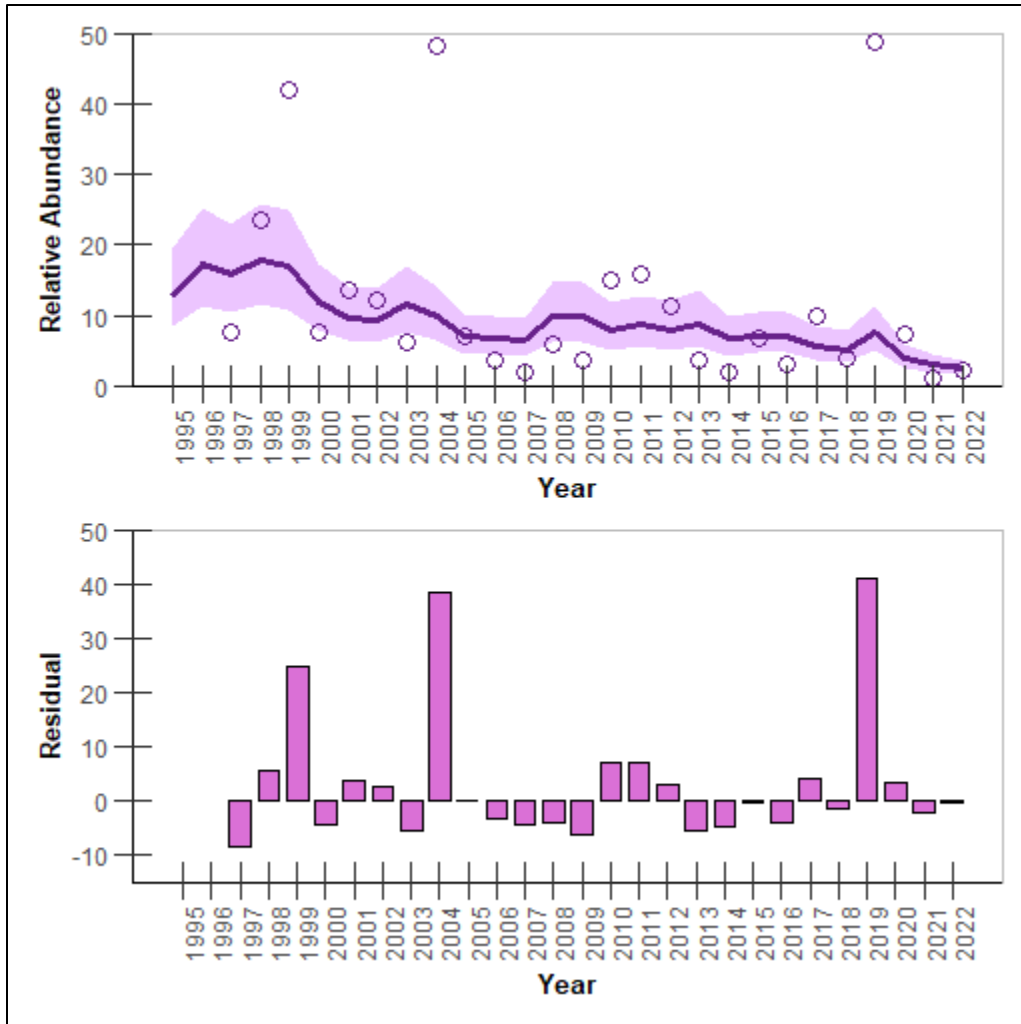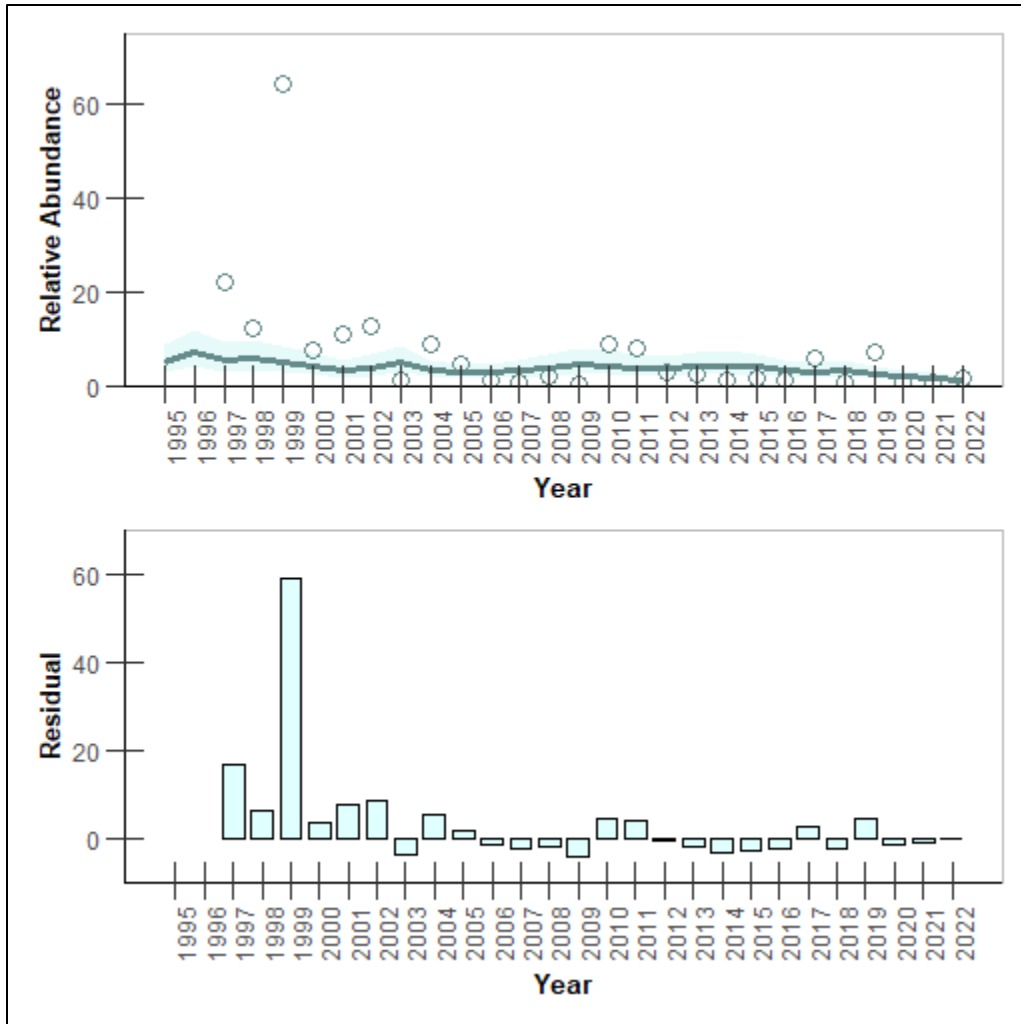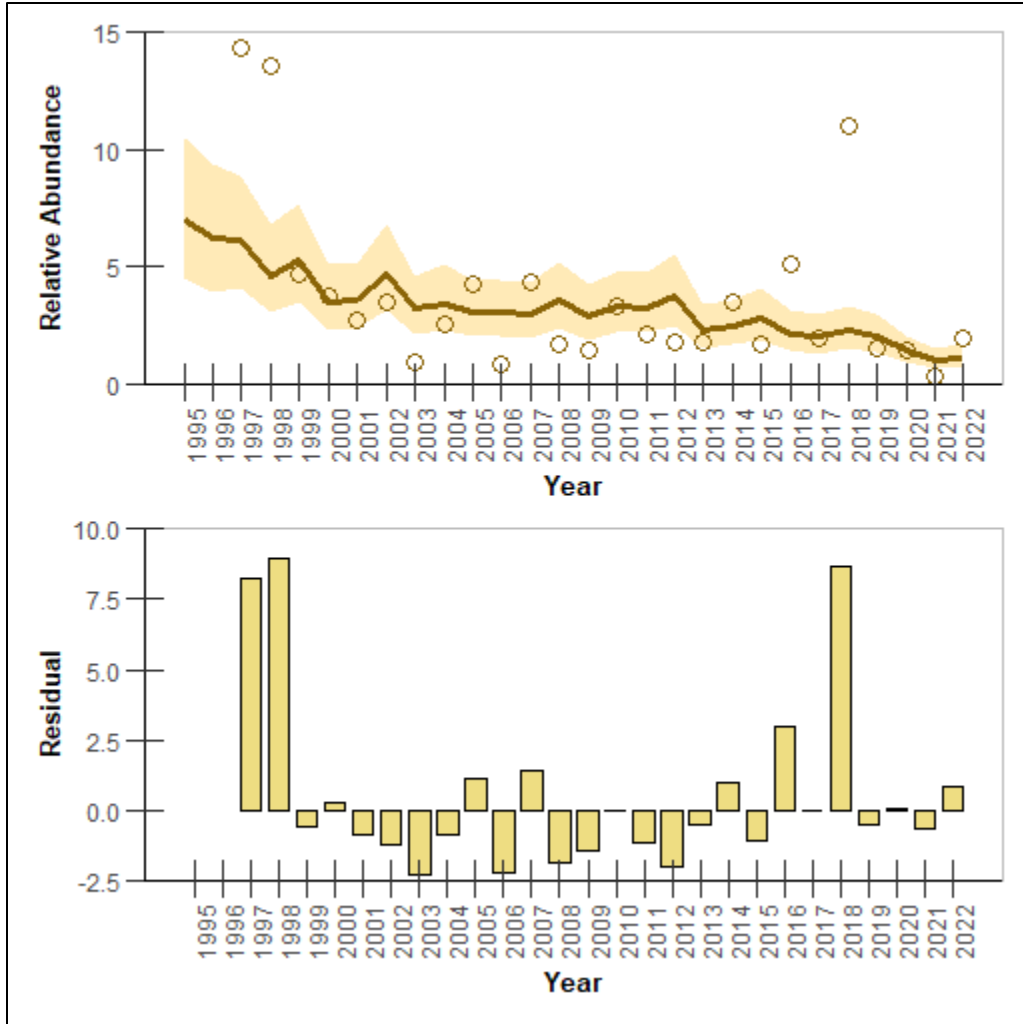
Figure 3.4. Observed (open circles) and predicted (solid line) relative abundance of female blue crab recruits observed in the Program 120 Survey (top) and associated residuals (bottom), 1997–2022.
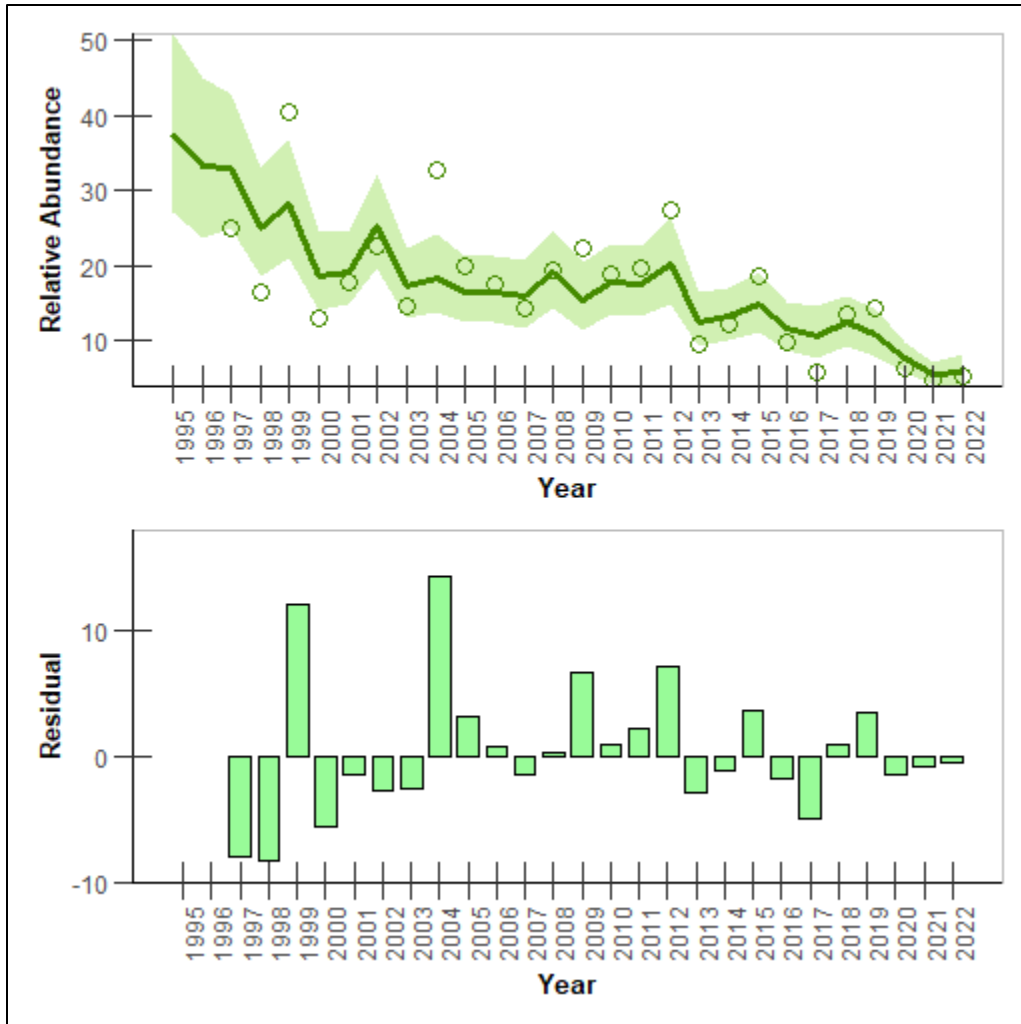
Figure 3.5. Observed (open circles) and predicted (solid line) relative abundance of male blue crab recruits observed in the Program 120 Survey (top) and associated residuals (bottom), 1997–2022.
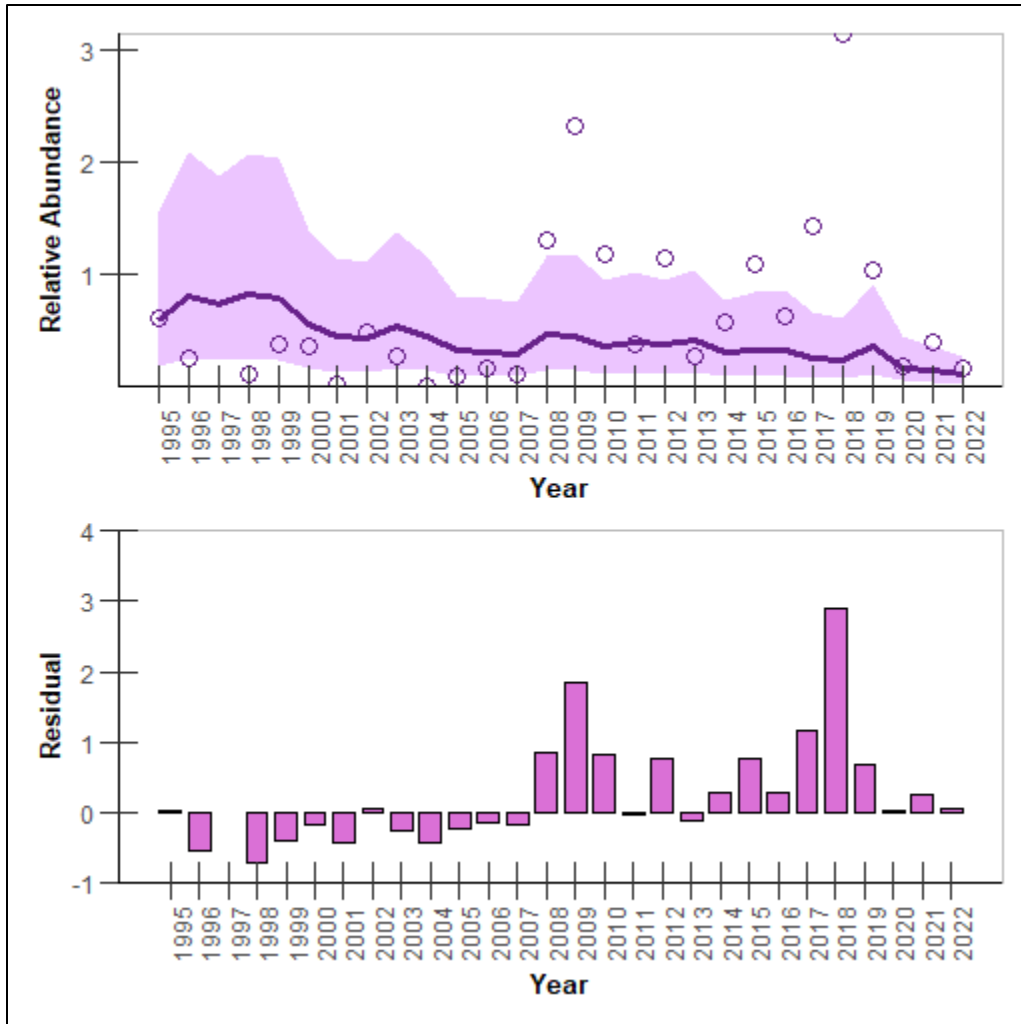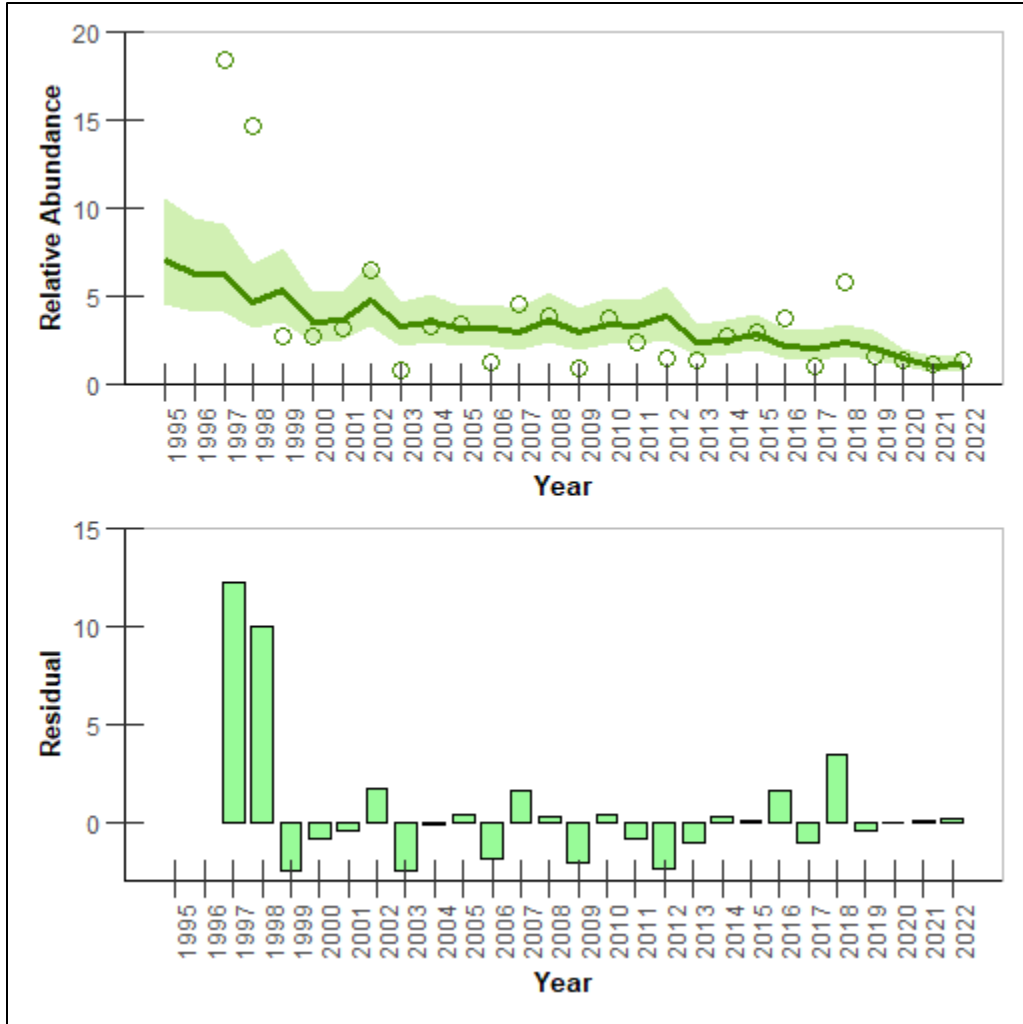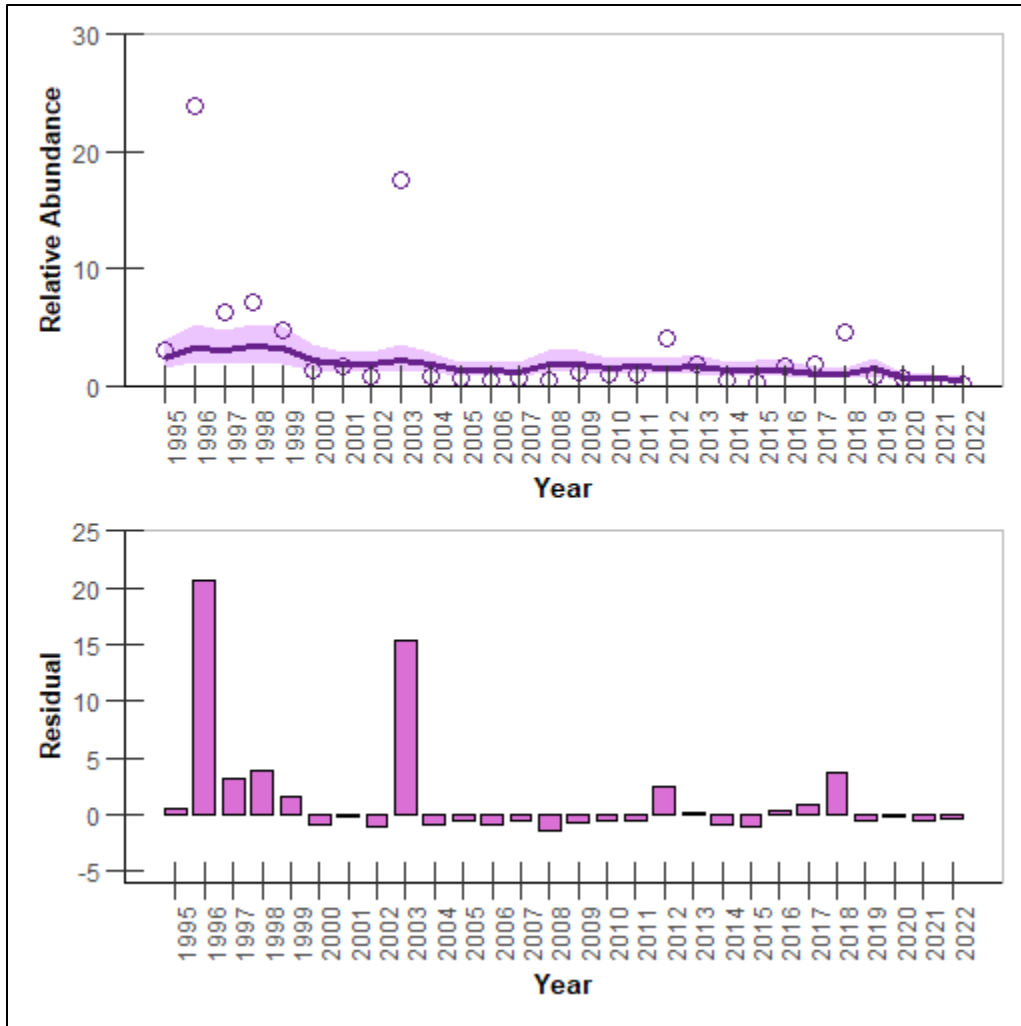
Figure 3.6. Observed (open circles) and predicted (solid line) relative abundance of female fully recruited blue crabs observed in the summer component of the Program 100 Survey (top) and associated residuals (bottom), 1995–2022.
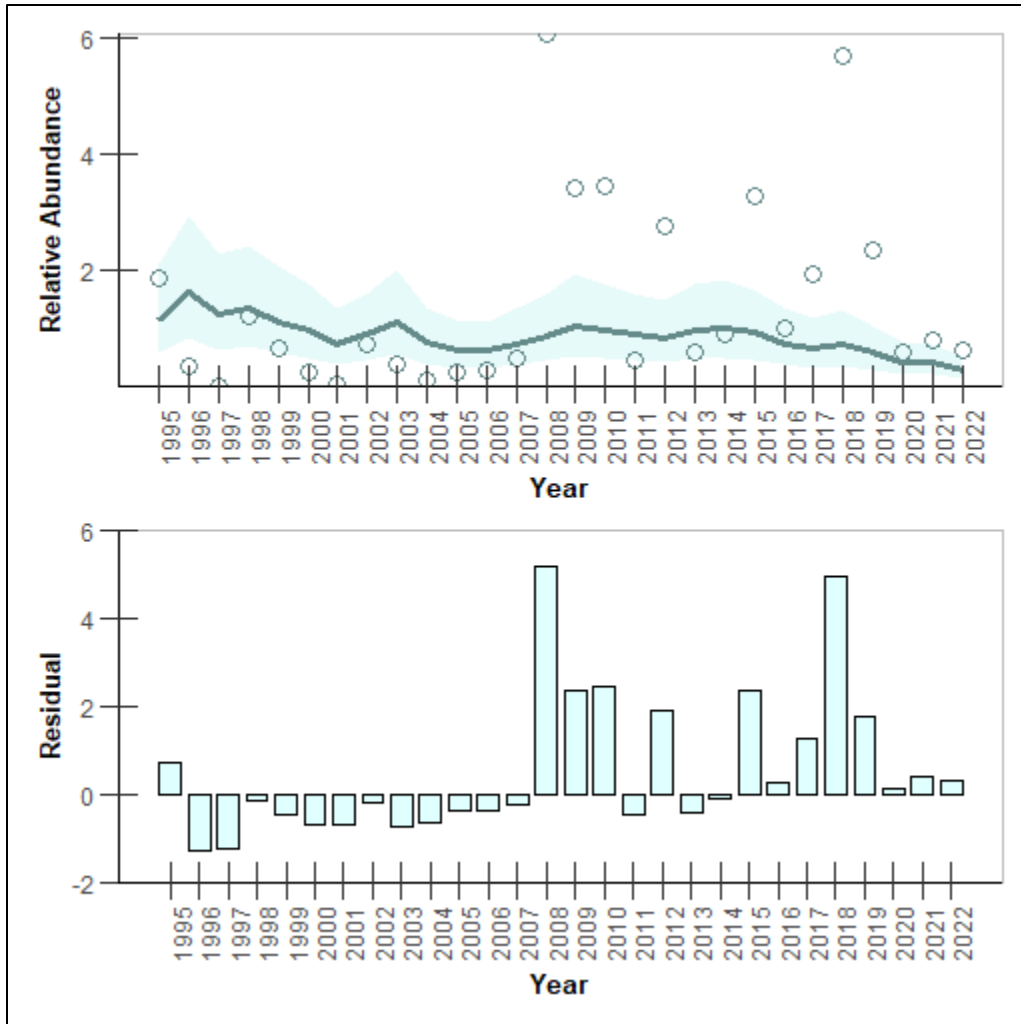
Figure 3.7. Observed (open circles) and predicted (solid line) relative abundance of male fully recruited blue crabs observed in the summer component of the Program 100 Survey (top) and associated residuals (bottom), 1995–2022.
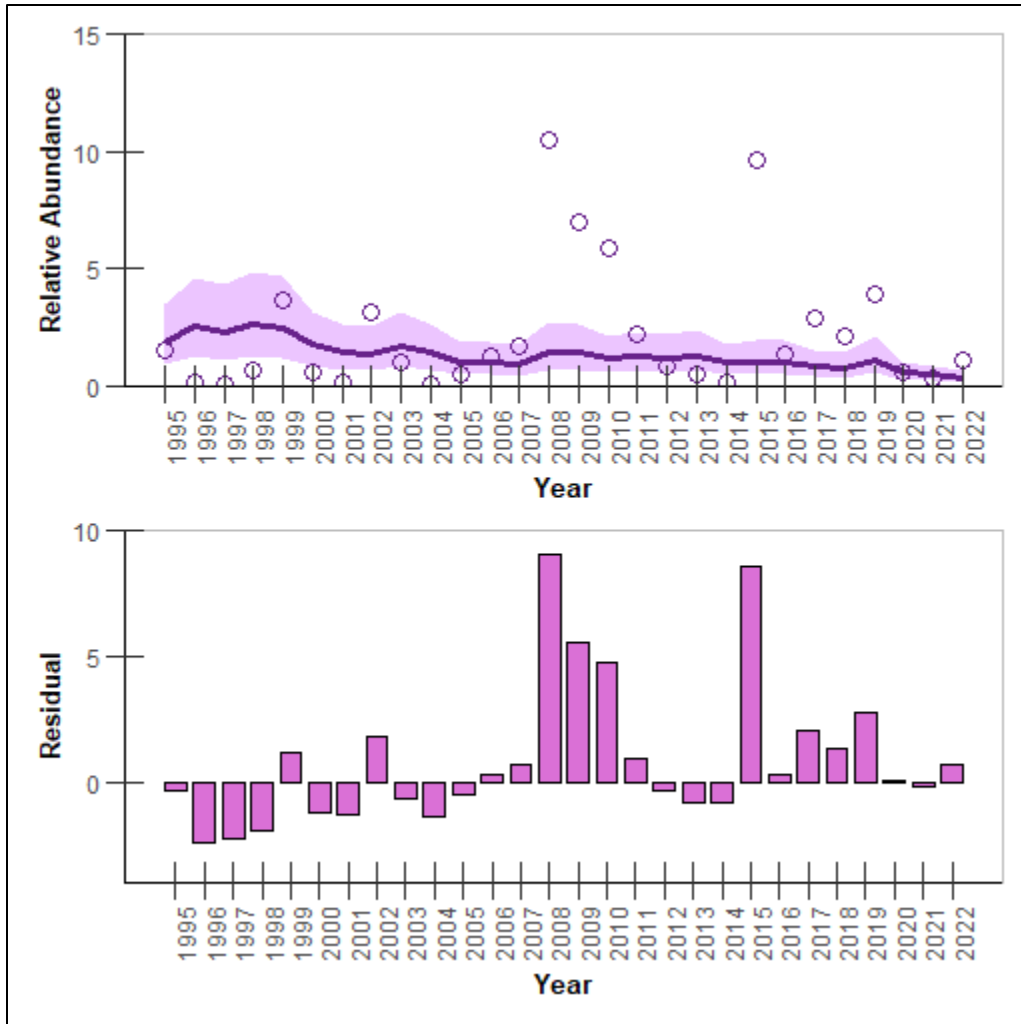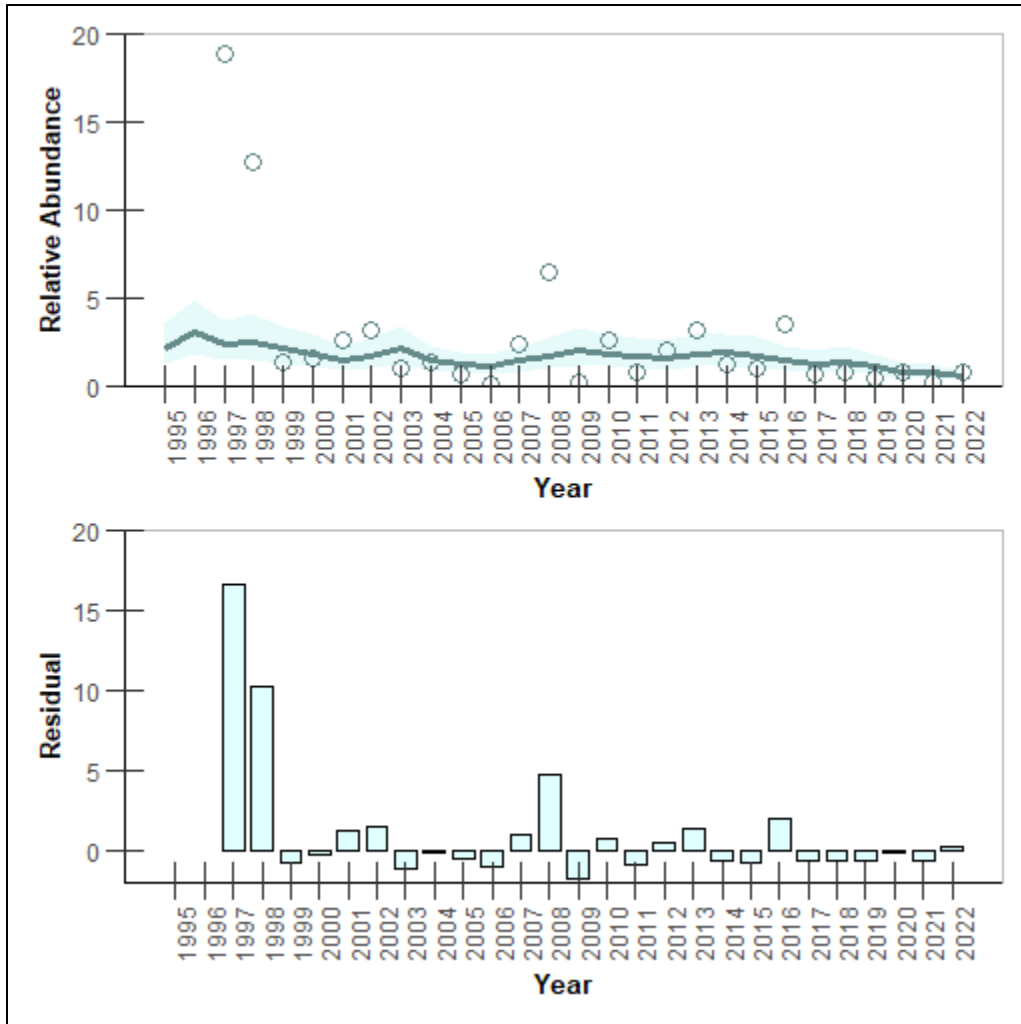
Figure 3.8. Observed (open circles) and predicted (solid line) relative abundance of female fully recruited blue crabs observed in the fall component of the Program 100 Survey (top) and associated residuals (bottom), 1995–2022.
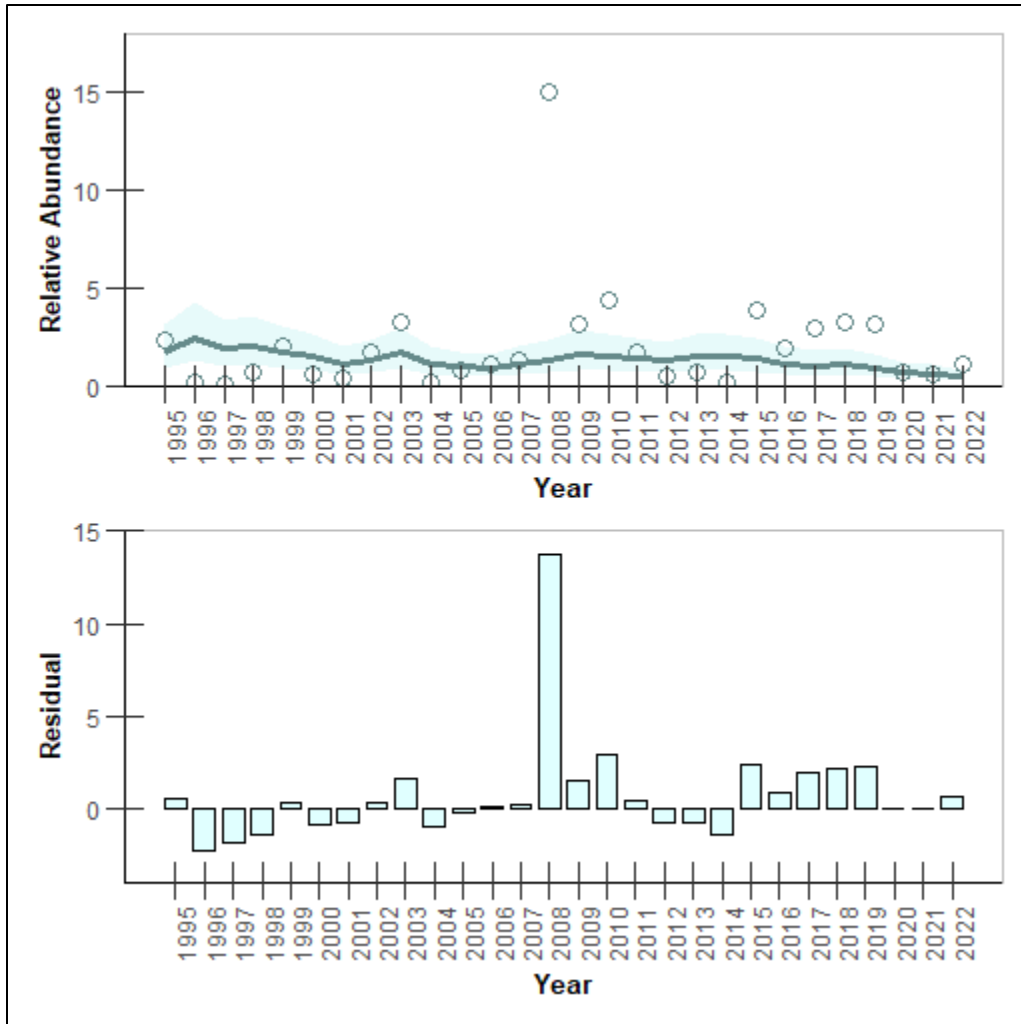
Figure 3.9. Observed (open circles) and predicted (solid line) relative abundance of male fully recruited blue crabs observed in the fall component of the Program 100 Survey (top) and associated residuals (bottom), 1995–2022.
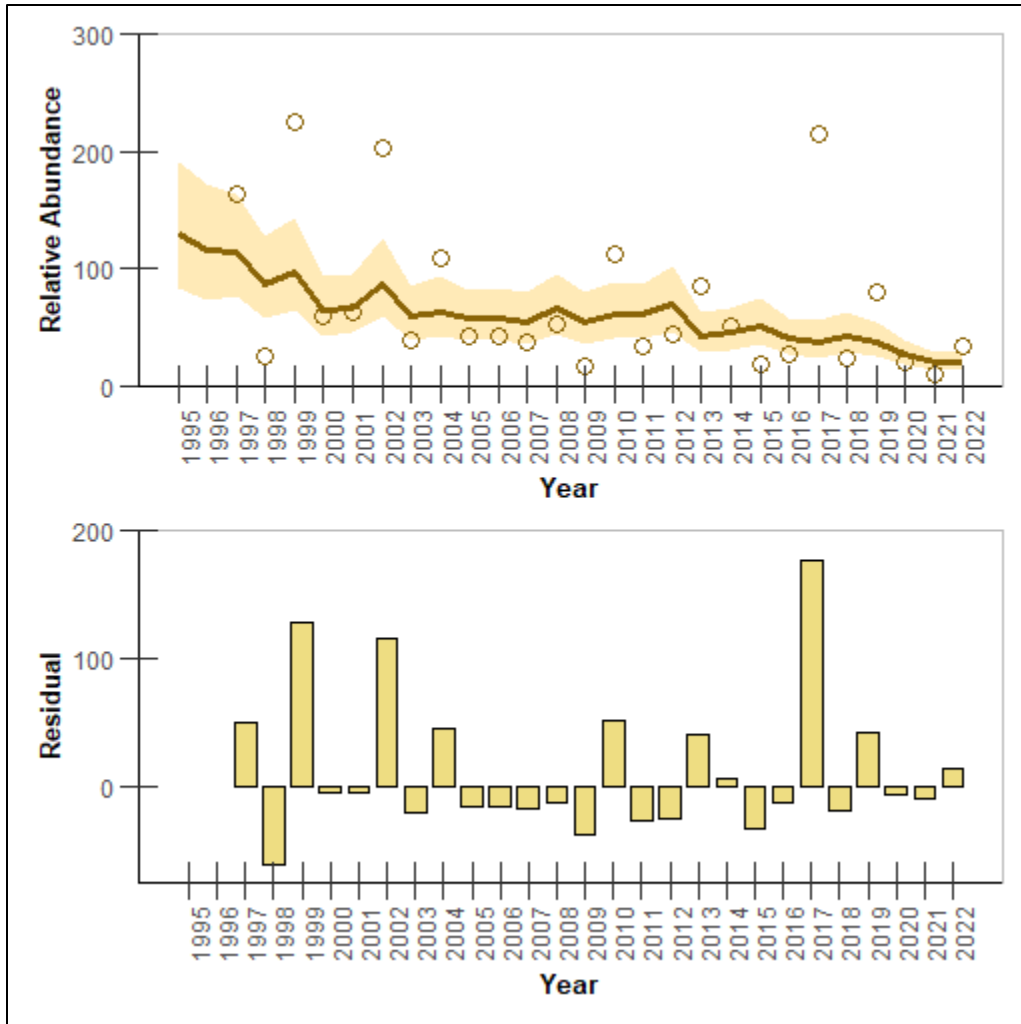
Figure 3.10. Observed (open circles) and predicted (solid line) relative abundance of female blue crab recruits observed in the June component of the Program 195 Survey (top) and associated residuals (bottom), 1997–2022.
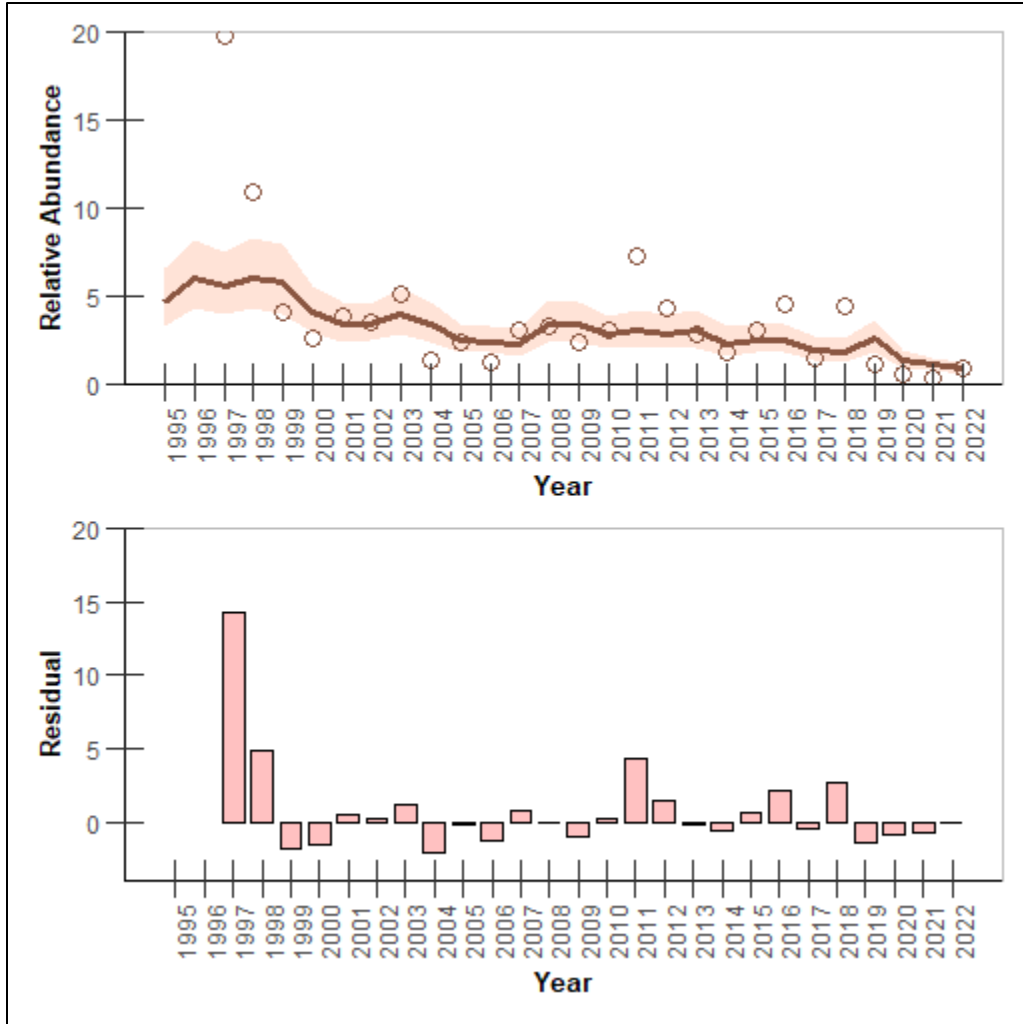
Figure 3.11. Observed (open circles) and predicted (solid line) relative abundance of male blue crab recruits observed in the June component of the Program 195 Survey (top) and associated residuals (bottom), 1997–2022.

Figure 3.12. Observed (open circles) and predicted (solid line) relative abundance of female fully recruited blue crabs observed in the June component of the Program 195 Survey (top) and associated residuals (bottom), 1997–2022.
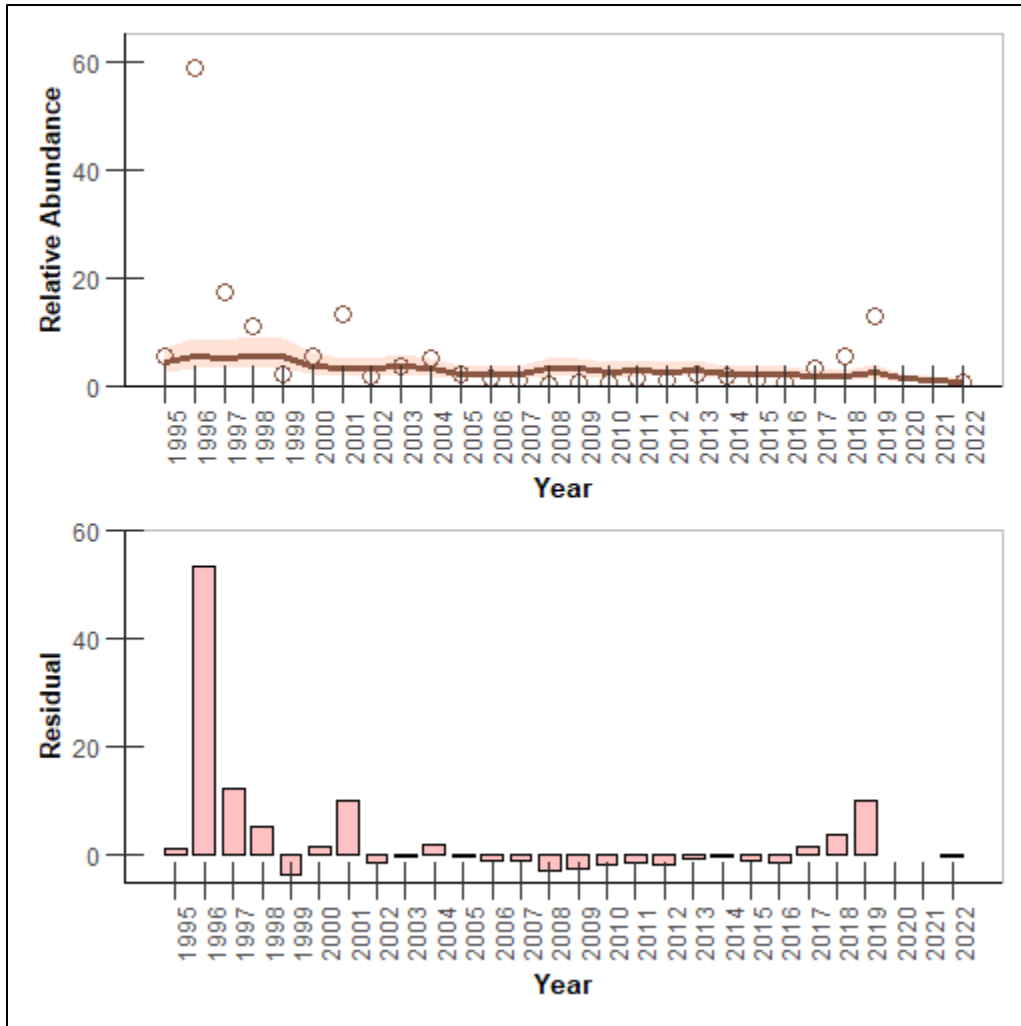
Figure 3.13. Observed (open circles) and predicted (solid line) relative abundance of male fully recruited blue crabs observed in the June component of the Program 195 Survey (top) and associated residuals (bottom), 1997–2022.

Figure 3.14. Observed (open circles) and predicted (solid line) relative abundance of female blue crab recruits observed in the September component of the Program 195 Survey (top) and associated residuals (bottom), 1997–2022.

Figure 3.15. Observed (open circles) and predicted (solid line) relative abundance of male blue crab recruits observed in the September component of the Program 195 Survey (top) and associated residuals (bottom), 1997–2022.

Figure 3.16. Observed (open circles) and predicted (solid line) relative abundance of female fully recruited blue crabs observed in the September component of the Program 195 Survey (top) and associated residuals (bottom), 1995–2022.

Figure 3.17. Observed (open circles) and predicted (solid line) relative abundance of male fully recruited blue crabs observed in the September component of the Program 195 Survey (top) and associated residuals (bottom), 1997–2022.

Figure 3.18. Observed (open circles) and predicted (solid line) relative abundance of mature female blue crabs observed in the September component of the Program 195 Survey (top) and associated residuals (bottom), 1997–2022.

Figure 3.19. Observed (open circles) and predicted (solid line) relative abundance of mature female blue crabs observed in the summer component of the SEAMAP Survey (top) and associated residuals (bottom), 1995–2022.
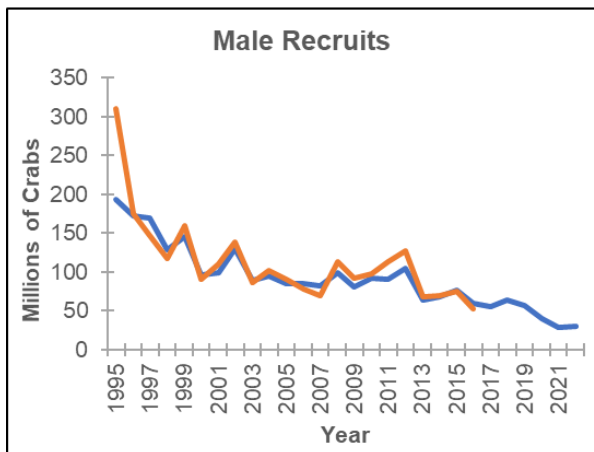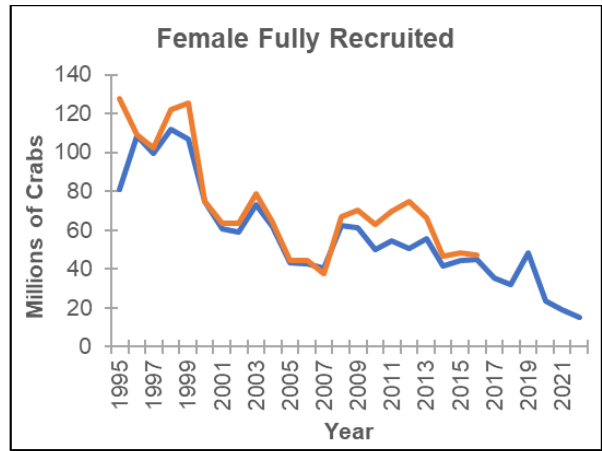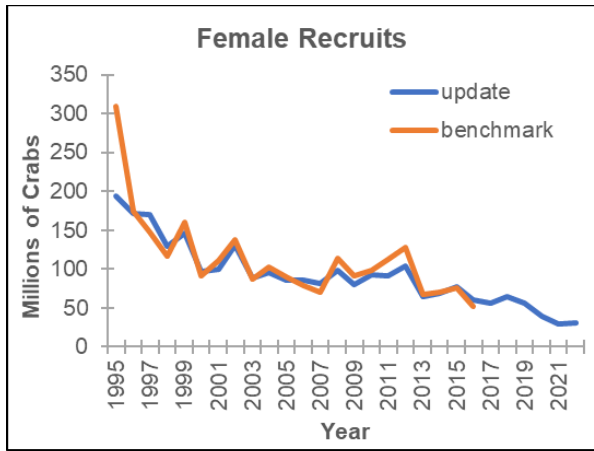
Figure 3.20. Population size of hard blue crabs in North Carolina by sex and stage, 1995–2022.
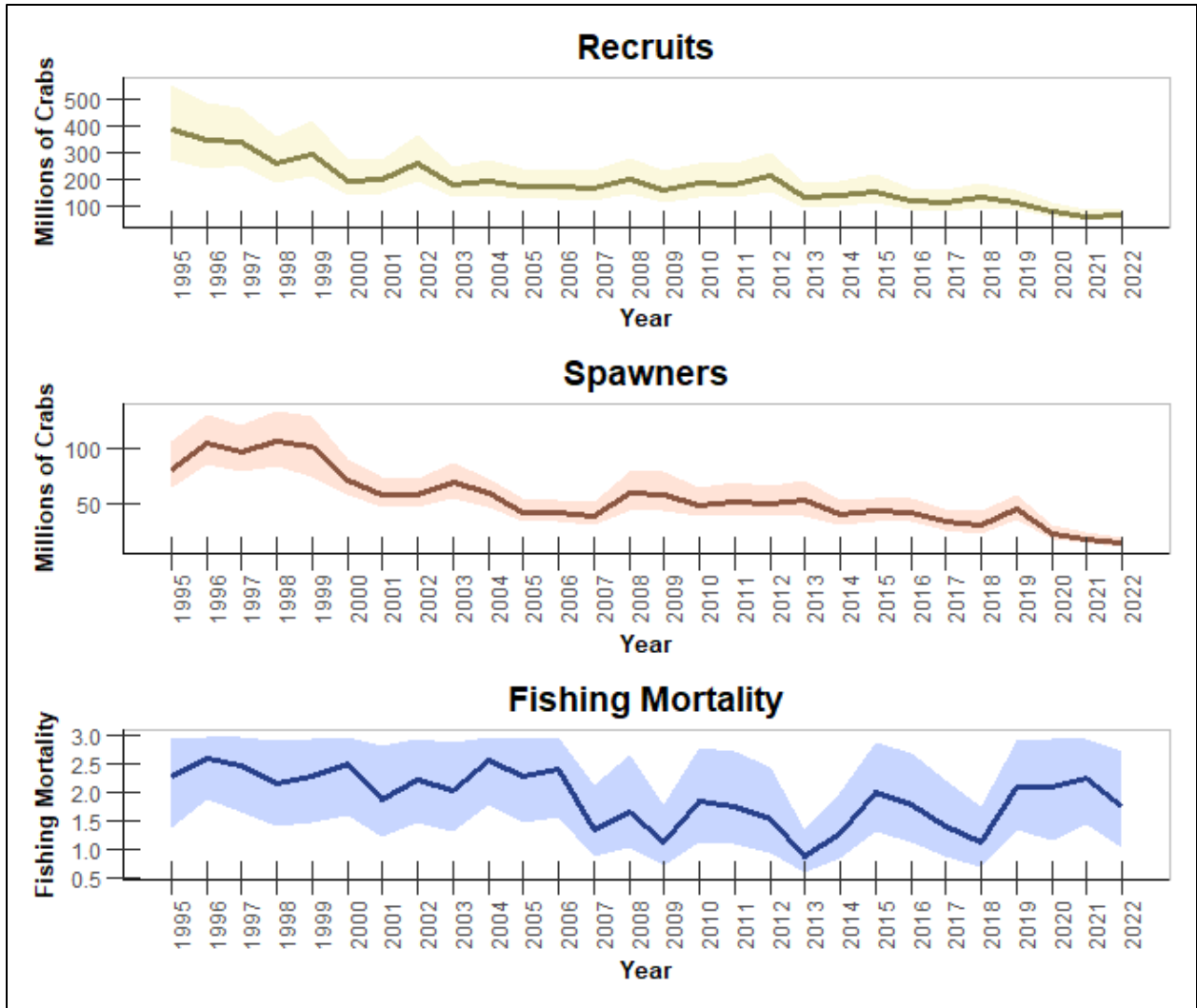
Figure 3.21. Annual estimates of recruits (top), spawners (middle), and fishing mortality (bottom) for hard blue crabs in North Carolina, 1995–2022.
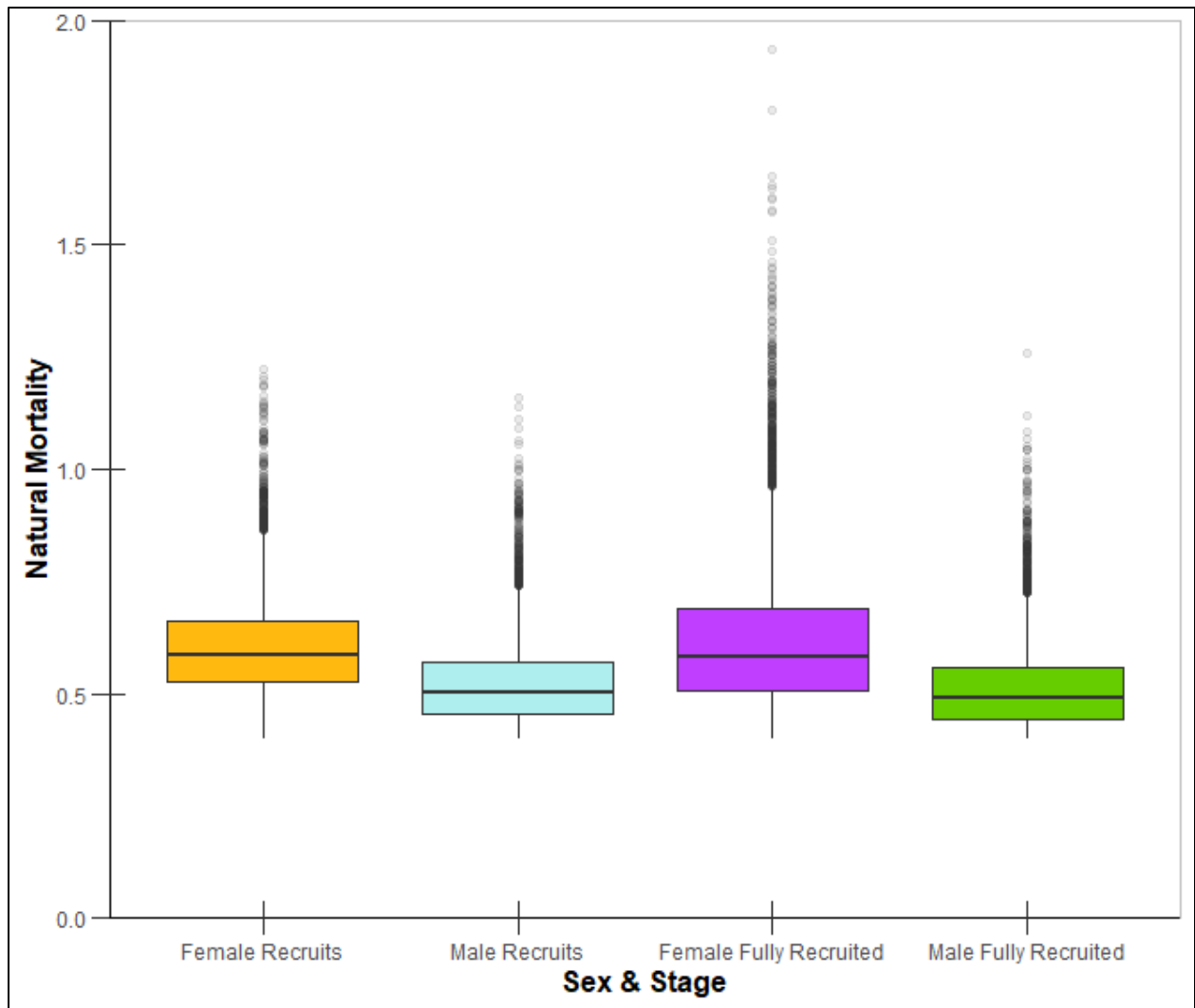
Figure 3.22. Box plots summarizing stock assessment model estimates of natural mortality for hard blue crabs in North Carolina.
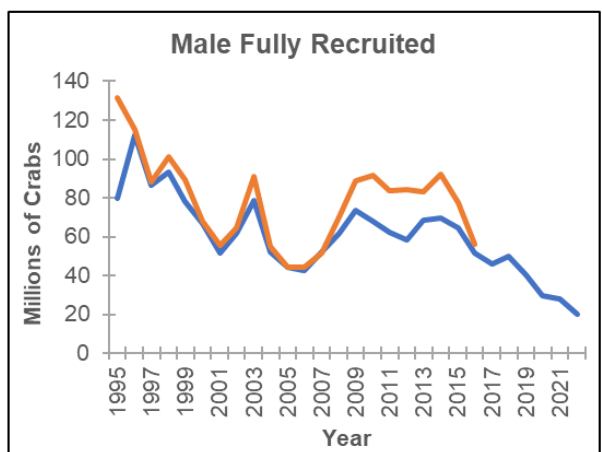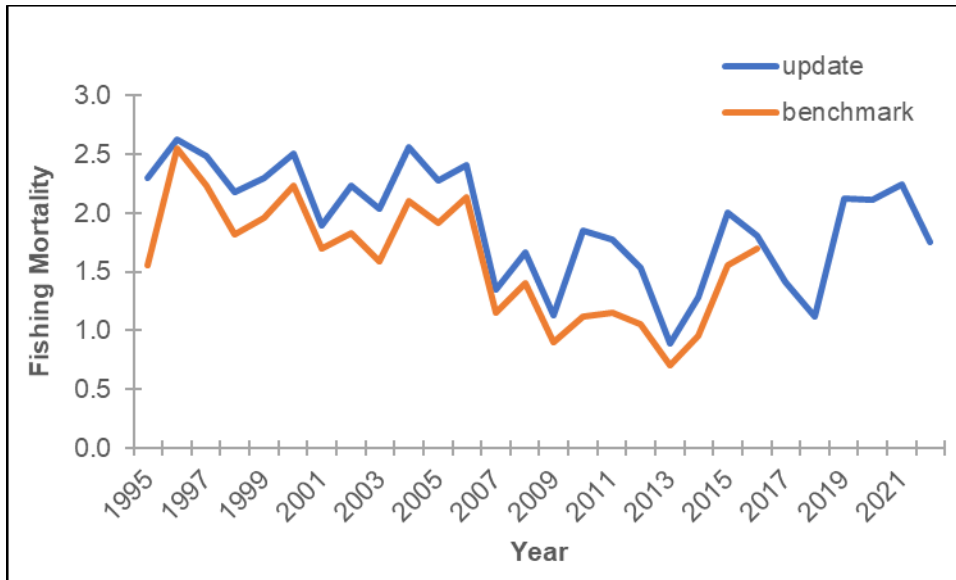
Figure 3.23. Comparison of sex- and stage-specific population size between the current assessment update and the previous benchmark stock assessment.
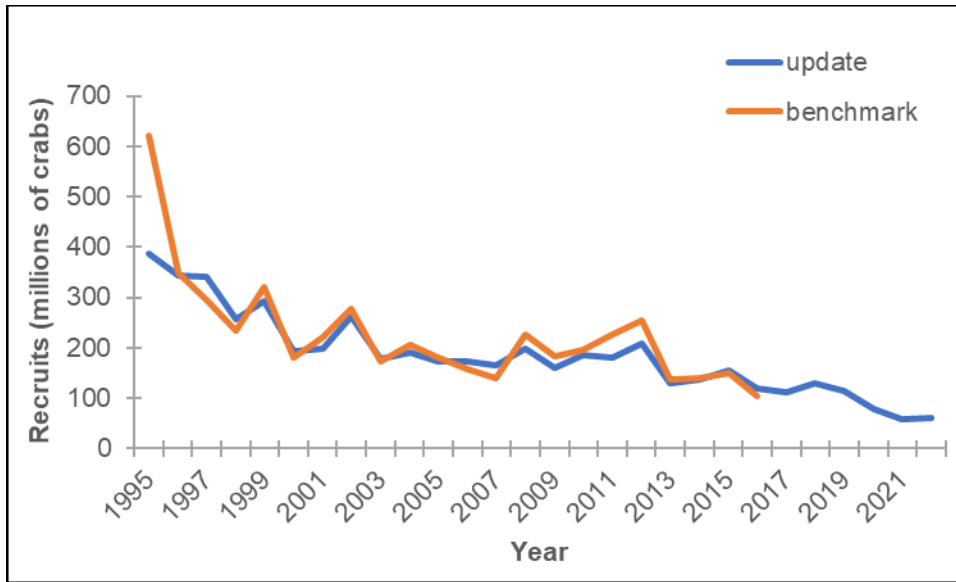
Figure 3.24. Comparison of estimates of total recruitment between the current assessment update and the previous benchmark stock assessment.
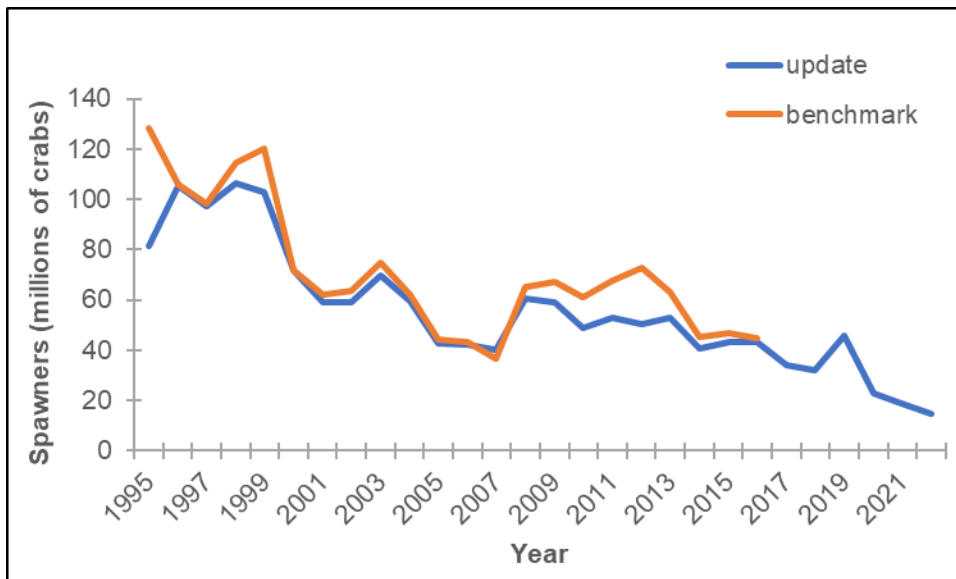
Figure 3.25. Comparison of estimates of female spawner abundance between the current assessment update and the previous benchmark stock assessment.

Figure 3.26. Comparison of estimates of fishing mortality between the current assessment update and the previous benchmark stock assessment.
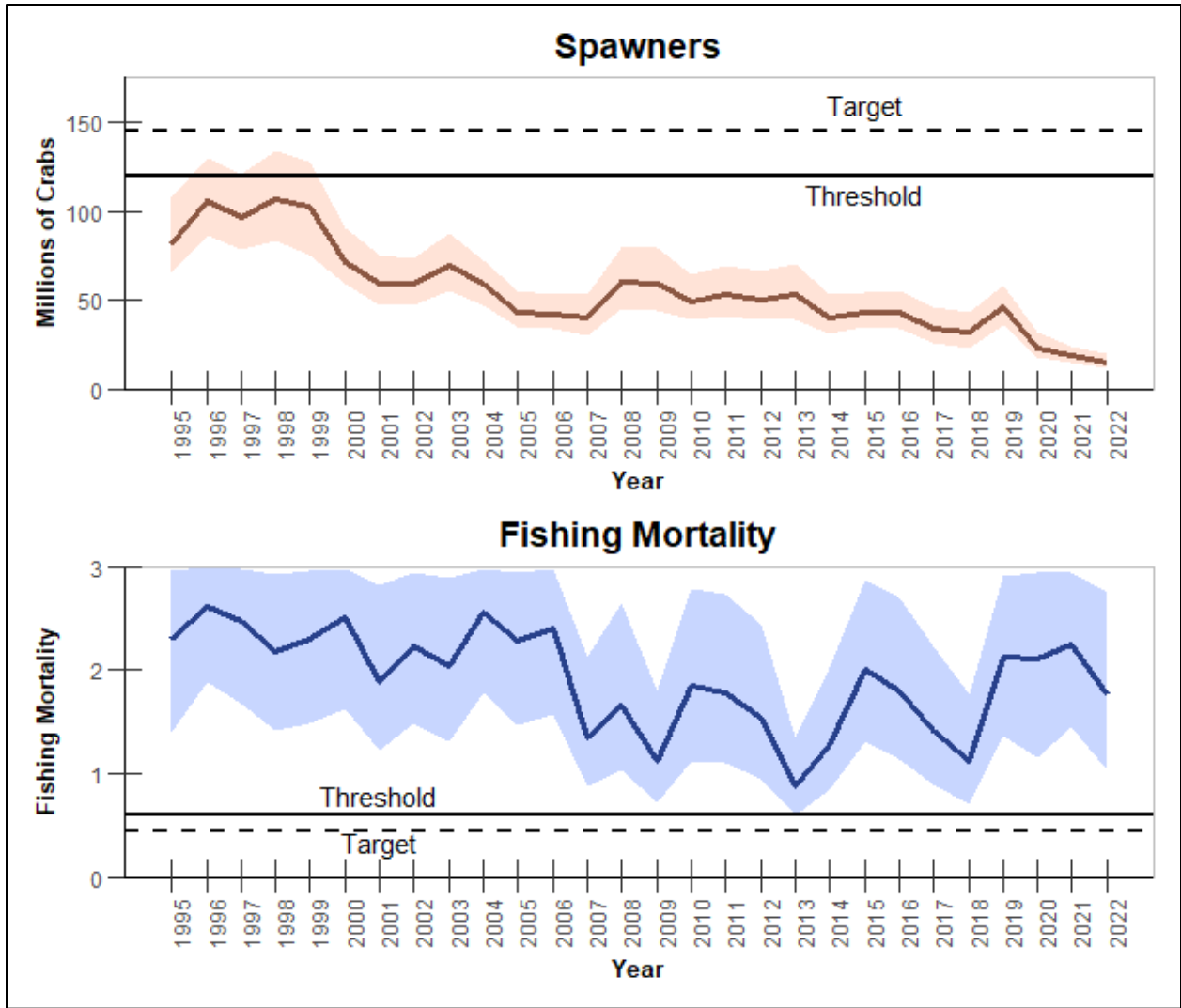
Figure 4.1. Annual estimates of spawner abundance (top) and fishing mortality (bottom) relative to associated reference points for hard blue crabs in North Carolina.

Review Report
for the
2023 Update Stock Assessment
of
Blue Crab in the North Carolina

Dr. Jie Cao, Assistant Professor

Center for Marine Sciences and Technology (CMAST), North Carolina State University

Dr. Yan Li, Lead Analyst for 2018 Stock Assessment

Current Institution: Duke Cancer Institute Biostatistics Shared Resource, Duke University

January 3, 2024

A desk review of the update stock assessment of North Carolina blue crab (*Callinectes sapidus*) was conducted in November-December 2023. The reviewers evaluated the data sources, the model configuration, and model diagnostics. The reviewers also compared the results of this update assessment with those from the 2018 benchmark assessment. The reviewers appreciate all the hard work by the Assessment Team (AT) and are impressed with the quantity and quality of research and analysis conducted by the AT. The reviewers also thank Steve Poland, the Chief of Fisheries Management for providing an assessment report and additional support throughout the review.

Based on the information provided in the assessment report the reviewers believe the AT did an excellent job of summarizing and analyzing a large number of complex data sets that went into the assessment model. However, the reviewers feel the current model results are concerning due to (1) the strong residual pattens in the model fit to survey indices, especially Program 100 indices, (2) the extremely high estimates of fishing mortality over the entire assessment period, and (3) the constantly overfishing/overfished stock status over the entire assessment period. The following report provides detailed comments and recommendations from the reviewers:

1. Strong residual patterns were shown in the model fits to Program 100 indices (i.e., female fully recruit summer index, male fully recruit summer index, female fully recruit fall index, and male fully recruit fall index). Almost all residuals are negative before 2008 and positive afterwards (Figs. 3.6 and 3.7). Also, the model does not fit the high and variable indices after 2007/2008. This indicates potential model misspecifications. These strong residual patterns and lack of fit would undermine the validity and credibility of the overall results and conclusions, and thus, the reviewers strongly recommend resolving this issue before basing any management decisions on this update assessment. The reviewers recommend the following:
   a. Investigate the Program 100, especially any changes before and after 2008 in fisheries management, environmental conditions or fishing behaviors
   b. Consider time-block catchability when fitting these indices, with one catchability before and one after 2008
   c. Reviewers did not find the CVs used for these indices (therefore, not sure about how they were weighted in the model fitting process). Suggest investigating the uncertainty associate with each index and weight them accordingly.
   d. Run a sensitivity analysis with Program 100 indices removed
   e. There are multiple surveys included in the assessment. Given the nature of these surveys (e.g., spatial coverages, survey timing), they may measure different portions of the blue crab population. The reviewers understand that catch rates were standardized using GLM for each index. However, the potential issue of sampling representativeness may remain. Therefore, the reviewers strongly recommend

future studies should explore combining all the survey and develop an integrated single index which may be more representative of the population.

2. The estimated fishing mortality is extremely/unrealistically high (Fig. 4.1). The estimated fishing mortality of the early time period was above 2, which suggests that about 90% of the population was removed by the fishery. The estimated natural mortality had an upper bound as twice as the one in the 2018 benchmark assessment (Fig. 3.32). The reviewers recommend the following:
   a. Compared to the 2018 benchmark assessment, the estimated initial population size was low (Figs. 3.23-3.25). Setting a reasonable prior for the initial population is critical to regulate the overall scale of the estimation of parameters including fishing mortality.

3. The stock status of overfishing and overfished over the entire assessment period seems uncommon and concerning (Fig. 4.1). Addressing the above issues may potentially help resolve this issue.

4. The reviewers finally recommend investigating an integrated seasonal size-structured assessment model, which is often used for crustacean, in future. Such a model can potentially better describe the life history of blue crab and account for seasonality.

DECISION DOCUMENT

Blue Crab Fishery Management Plan

Amendment 3 Adaptive Management

This document was developed to help the MFC track previous activity and prepare for upcoming actions for Blue Crab FMP Amendment 3 Adaptive Management.

May 2024

Background

The original North Carolina Blue Crab Fishery Management Plan (FMP) was adopted in December 1998, Amendment 1 was adopted in December 2004, and Amendment 2 was adopted in November 2013. The adaptive management strategy adopted in Amendment 2 relied on annual updates to the Traffic Light Assessment (TLA) to provide information on relative condition of the stock. Based on results of the TLA update that included data through 2015, management action was required by the North Carolina Marine Fisheries Commission (MFC). To improve the condition of the blue crab stock, the MFC adopted management measures documented in the May 2016 Revision to Amendment 2.

Comprehensive review of the Blue Crab FMP was originally scheduled to begin in July 2018, but at its August 2016 business meeting, the MFC voted to immediately begin formal review to assess the status of the blue crab stock and identify more comprehensive management strategies. Consequently, development of Amendment 3 began in August 2016.

Amendment 3 Background

As part of Amendment 3 to the North Carolina Blue Crab FMP, a benchmark stock assessment was undertaken using data from 1995-2016. Based on assessment results, the N.C. blue crab stock was classified as overfished in 2016. The probability the stock was overfished was 98% with the average spawner abundance in 2016 estimated at 50 million crabs (below the threshold estimate of 64 million crabs). Overfishing was also occurring in 2016 with a 52% probability. The average fishing mortality in 2016 was estimated at 1.48 (above the fishing mortality threshold of 1.46).

The North Carolina Fishery Reform Act requires the State to implement management that ends overfishing within two years and achieves sustainable harvest within 10 years of the adoption of the plan. To meet the legal requirement, the division determined reductions in commercial harvest were necessary. A harvest reduction of 0.4% (in numbers of crabs) was projected to end overfishing and a harvest reduction of 2.2% was projected to achieve sustainable harvest and rebuild the blue crab spawning stock within 10 years with a 50% probability of success (Table 1).

Table 1. Catch reduction projections for varying levels of fishing mortality (F), based on 2016 data from the stock assessment, and the probability of achieving sustainable harvest within the 10-year rebuilding period defined in statute. The bolded row indicates the minimum requirement defined in statute.

F (yr-1)	Catch Reduction (%)	Probability of achieving sustainable harvest within 10 years (%)	Comments
1.48	0.0	31	2016 average F from stock assessment
1.46	0.4	45	Catch reduction to meet F threshold and end overfishing
1.40	1.7	46	Catch reduction to meet spawner abundance threshold and end overfished status
1.38	**2.2**	**50**	**Catch reduction to meet minimum statutory requirement for achieving sustainable harvest**
1.30	3.8	67	
1.22	5.9	90	Catch reduction to meet F target
1.10	9.3	96	
1.00	12.3	100	
0.90	15.7	100	
0.80	19.8	100	Catch reduction to meet spawner abundance target
0.70	24.3	100	

The MFC adopted Amendment 3 to the Blue Crab FMP in February 2020 to rebuild the blue crab stock. The management changes adopted in Amendment 3 were:

- Season closures (pot closure periods):
  - **January 1-31** north of the Highway 58 bridge
  - **March 1-15** south of the Highway 58 bridge
  - Possession of blue crabs is prohibited during the season closure period.
- A 5-inch minimum size limit for mature female crabs statewide.
- Remove all cull ring exempted areas.
- New crab spawning sanctuaries were established in Beaufort, Bogue, Bear, Browns, New River, Topsail, Rich, Mason, Masonboro, Carolina Beach, Cape Fear River, Shallotte, Lockwoods Folly, and Tubbs inlets with a **March 1-October 31** closure.
- Crab trawls prohibited in areas where shrimp trawls were already prohibited in the Pamlico, Pungo, and Neuse rivers.
- Crab bycatch allowance in oyster dredges reduced to 10% of the total weight of the combined oyster and crab catch or 100 pounds, whichever is less.
- Criteria were approved for designating Diamondback Terrapin Management Areas where use of approved terrapin excluders will be required.
- The adaptive management framework was revised (more details about this are below).

The adopted management strategy was estimated to provide a 2.4% harvest reduction with a 50% probability of achieving sustainable harvest. Amendment 3 management strategies have been fully in place since January 2021. Amendment 3 also maintained all measures implemented with the May 2016 Revision to the Blue Crab FMP. A summary of all management measures in place through Amendment 3 can be found in the annual FMP Update or in the Amendment 3 flyer.

Amendment 3 Adaptive Management

1. Update the stock assessment at least once in between full reviews of the FMP, timing at the discretion of the division.
    a. If the stock is overfished and/or overfishing is occurring or it is not projected to meet the sustainability requirements, then management measures shall be adjusted using the director's proclamation authority.
    b. If the stock is not overfished and overfishing is not occurring, then management measures may be relaxed provided it will not jeopardize the sustainability of the blue crab stock.
2. Any quantifiable management measure, including those not explored in this paper, with the ability to achieve sustainable harvest (as defined in the stock assessment), either on its own or in combination, may be considered .
3. Use of the director's proclamation authority for adaptive management is contingent on:
    a. Consultation with the Northern, Southern, and Shellfish/Crustacean advisory committees.
    b. Approval by the Marine Fisheries Commission.

Upon evaluation by the division, if a management measure adopted to achieve sustainable harvest (either through Amendment 3 or a subsequent Revision) is not working as intended, then it may be revisited and either: 1) revised or 2) removed and replaced as needed provided it conforms to steps 2 and 3 above.

Post Amendment 3 Stock Assessment Update

Following full implementation of Amendment 3 management measures in 2021, division monitoring programs continued to observe historically low commercial landings, coupled with continued low abundance of all blue crab life stages (e.g., male and female juveniles, male and female adults, mature females). In response to stock concerns expressed by commercial crabbers and continued poor trends in abundance since adoption of Amendment 3, the division began updating the stock assessment with data through 2022, adding six years of data to the benchmark assessment. As an assessment update, there were no changes to model parameters and a peer review was not conducted, as the model configuration of the prior peer reviewed model was maintained. Results of the model update indicate the magnitude and trends for estimated recruitment, female spawner abundance, and fishing mortality were similar to the prior benchmark assessment (Figure 1), however, the Maximum Sustainable Yield (MSY) based reference points used to determine stock status for both female spawner abundance and fishing mortality both drastically changed with the updated time series (Figure 2 and Figure3). Due to the magnitude of the change in reference points, the division requested an external review of the updated stock assessment.
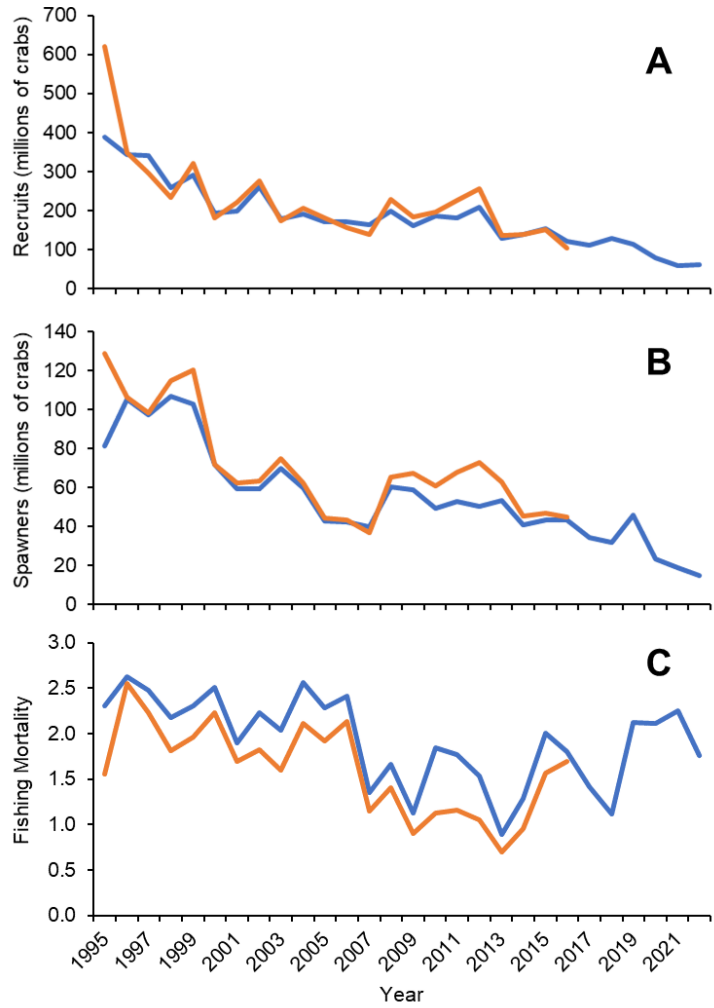
Figure 1. Comparison of estimates of (A) total recruitment, (B) female spawner abundance, and (C) fishing mortality between the 2023 stock assessment update (blue line) and the 2018 benchmark stock assessment (orange line).
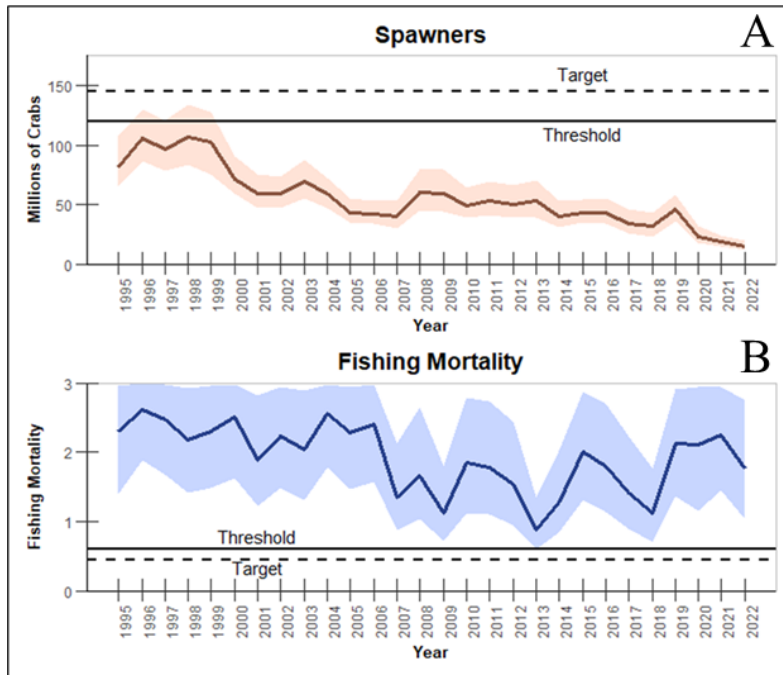
Figure 2. Annual estimates of (A) mature female spawner abundance and (B) fishing mortality relative to associated reference points for hard blue crabs in North Carolina from the 2023 stock assessment update.
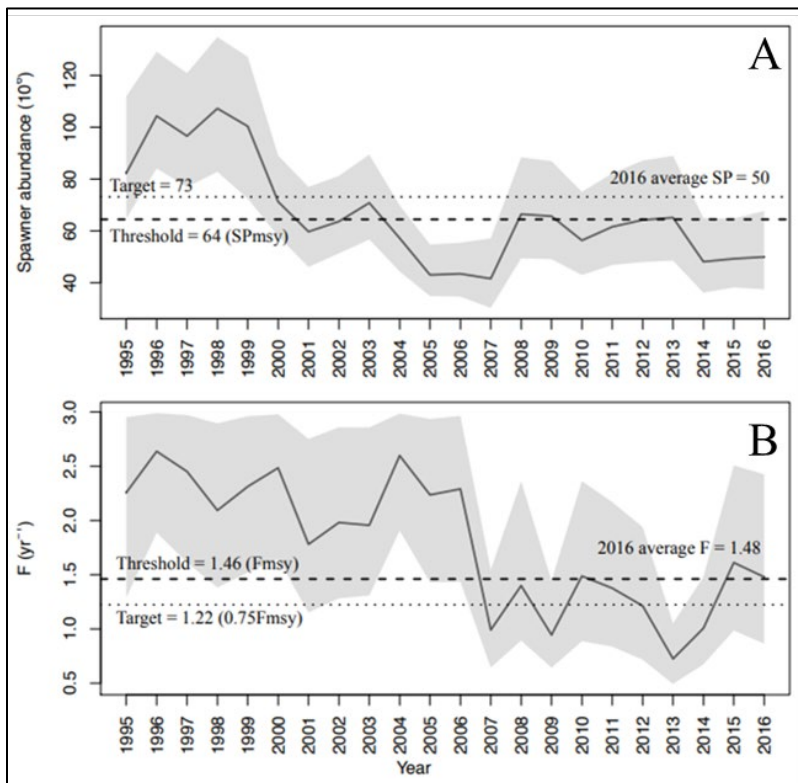

Figure 3. Annual estimates of (A) mature female spawner abundance and (B) fishing mortality relative to associated reference points for hard blue crabs in North Carolina from the 2018 benchmark stock assessment.

This external review was completed in late December 2023. The reviewers identified concerns with model specifications and results and strongly recommended resolving these issues before basing any management decisions solely on the assessment update. However, the suggestions provided by reviewers can only be incorporated with a new benchmark stock assessment. Given concerns with the assessment update identified by the division and external peer reviewers, **the division does not recommend using results of the 2023 stock assessment update to inform harvest reductions**.

Regardless of the availability of management advice from an updated stock assessment, stock concerns raised by commercial crabbers and trends in available data clearly show Amendment 3 management measures have not worked to reverse declining population trends as intended. Amendment 3 adopted management measures were only projected to result in a 2.4% harvest reduction with a 50% probability of achieving sustainable harvest, the minimum required by statute.

In addition, declines in the North Carolina blue crab stock are not unique, as blue crab stocks in other Atlantic coast states have shown similar declines. In January 2023 the South Carolina Department of Natural Resources released a status report for the South Carolina blue crab fishery. The report concluded the South Carolina blue crab stock has been in decline for nearly two decades and provided recommendations to prevent overharvesting, gradually reduce fishing pressure, prevent overexploitation, and strengthen enforcement capabilities. Concerns for the Chesapeake Bay blue crab stock have also persisted. While the Chesapeake Bay blue crab stock is not depleted and overfishing is not occurring, juvenile abundance remains low. Precautionary management, focusing on protecting mature females and juveniles, has been recommended for the Chesapeake Bay stock and a benchmark stock assessment has been started to better understand the population.

Adaptive Management

All available information suggests the blue crab stock has continued to decline since adoption of Amendment 3 management measures in February 2020. The Amendment 3 adaptive management framework will be used to immediately address the overall declining trends in the blue crab stock. This action is appropriate given the Amendment 3 adaptive management framework states: "*upon evaluation by the division, if a management measure adopted to achieve sustainable harvest is not working as intended, then it may be revisited and either 1) revised or 2) removed and replaced as needed…*".

Because the 2023 stock assessment update cannot be used to inform harvest reduction decisions, the division will develop management recommendations based on results of the 2018 stock assessment. Using 2018 assessment results provides some guidance on what harvest reductions should be in lieu of a current stock assessment. Essentially, the division will develop recommendations that would have resulted in higher harvest reductions with a greater probability of achieving sustainable harvest based on 2018 assessment results and apply them to the current fishery (see Table 1 for harvest reductions and probability of achieving sustainable harvest).

The Amendment 3 adaptive management framework allows any quantifiable management measure, including those not discussed in Amendment 3, that has the ability to achieve sustainable harvest either on its own or in combination to be considered. Prior to implementation, the division will consult with the Northern, Southern, and Shellfish/Crustacean advisory committees and management recommendations will be brought to the MFC for approval.

Amendment 3 Adaptive Management Timeline (gray indicates a step is complete)

May 2024	Division presents results of stock assessment update and adaptive management plan to MFC
May 2024 – August 2024	Division drafts management options
August 2024	Division updates the MFC on progress
September – October 2024	Division consults with Northern, Southern, and Shellfish/Crustacean advisory committees
November 2024	Division provides MFC with management recommendations and MFC votes on final approval
January 2025	New blue crab management measures implemented via proclamation

Key Takeaways

- Amendment 3 management strategies have been fully in place since January 2021.
- The Blue Crab Stock Assessment Update was completed in 2023, but given the concerns expressed by the external peer reviewers, the Division does not recommend using the results of that update to inform harvest reductions.
- All available information suggests that the blue crab stock has continued to decline since the adoption of Amendment 3 management measures by the Commission in February 2020.
- The Amendment 3 adaptive management framework will be used to address the overall declining trends in the blue crab stock.
- The division will develop management recommendations that would have resulted in higher harvest reductions with a greater probability of achieving sustainable harvest based on 2018 assessment results and apply them to the current fishery.
- The Amendment 3 adaptive management framework allows any quantifiable management measure, including those not discussed in Amendment 3, that has the ability to achieve sustainable harvest either on its own, or in combination, to be considered.
- Prior to the implementation of any management, the Division will consult with the Northern, Southern, and Shellfish/Crustacean advisory committees, and management recommendations will be brought to the MFC for approval.