

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 and overfishing is 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 spawning stock biomass (SSB) over the last several decades. Model results also indicate consistent overestimation of biomass and the highest 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, the terminal year of the assessment, F was 0.42, greater than the $F_{25\%}$ threshold, indicating overfishing is occurring (Base Plan 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 (Base Plan 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 recruitment. The 2022 stock assessment indicates recruitment has not only declined but has been below average since 2009 (Figure 1). Stock projections based on the stock assessment indicate a conservative, 21.3-35.4% reduction in total 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. A 21.3-35.4% reduction in total removals is projected to, at a minimum, rebuild SSB to the threshold even if low recruitment continues (Figures 2-3). Assuming average recruitment, a 21.3% reduction in total removals rebuilds SSB to the target in eight years with a 78% probability of success and a 35.4% reduction in total removals rebuilds SSB to the threshold in four years with a 100% probability of success (Table 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 fishing mortality (F) to the F threshold and a 33% reduction reaches the F target.

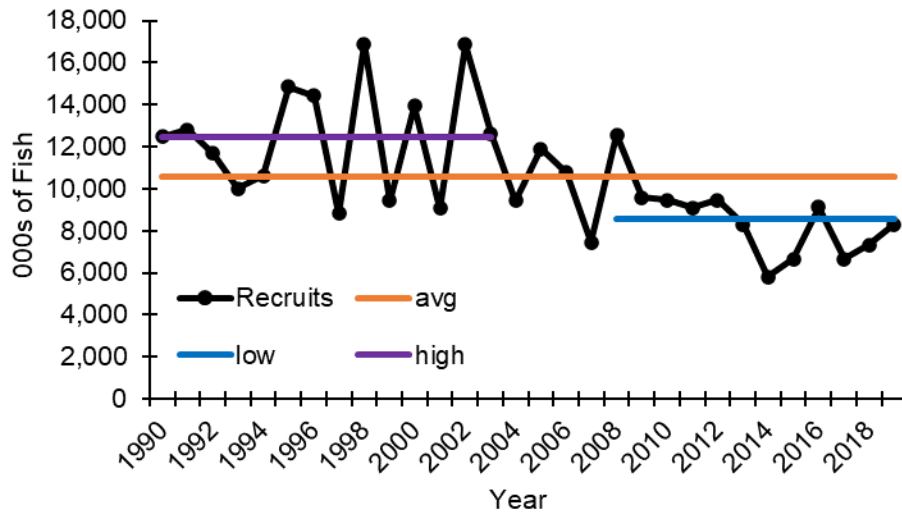


Figure 1. Estimates of striped mullet recruitment from the 2022 striped mullet stock assessment (NCDMF 2022). Average recruitment is the average number of recruits from 1990 to 2019, high recruitment is the average number of recruits from 1990 to 2003, and low recruitment is the average number of recruits from 2008 to 2019.

Table 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 total removals assuming low and average recruitment. Removals assumed are in comparison to removals in 2019. Both reduction scenarios end overfishing.

Reduction	Recruitment Assumption	n Years from 2024		Removals Assumed (lb)
		Reach Target	Reach Threshold	
21.3%	Low	Never (0%)	7 (68%)	1,072,538
	Average	8 (78%)	2 (100%)	
35.4%	Low	Never (0%)	3 (99%)	880,418
	Average	4 (100%)	2 (100%)	

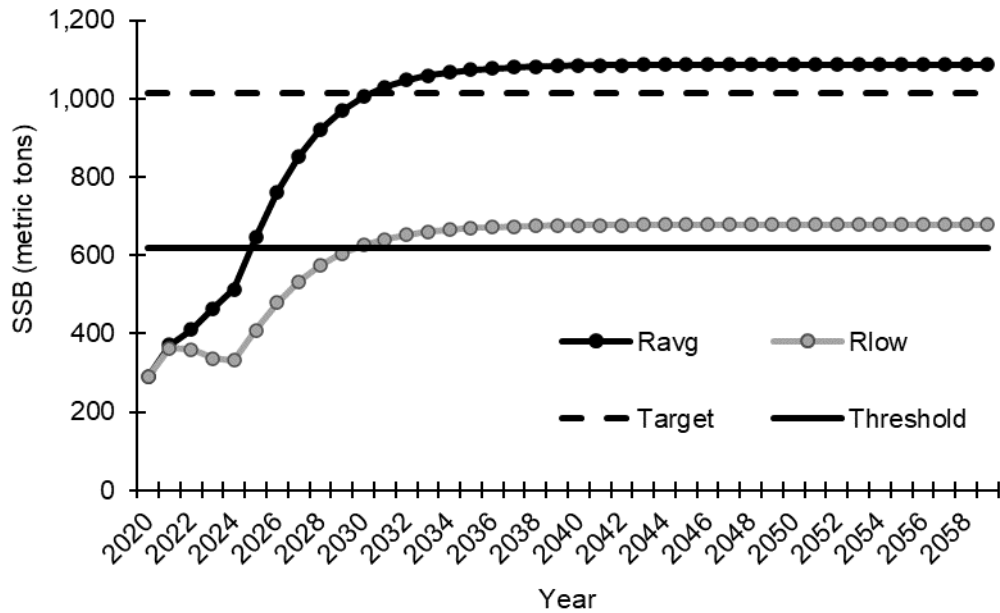


Figure 2. Projected striped mullet spawning stock biomass at various recruitment levels (average and low) compared to the SSB_{Target} (dashed line) and $SSB_{Threshold}$ (solid line) assuming a 21.3% reduction in total removals.

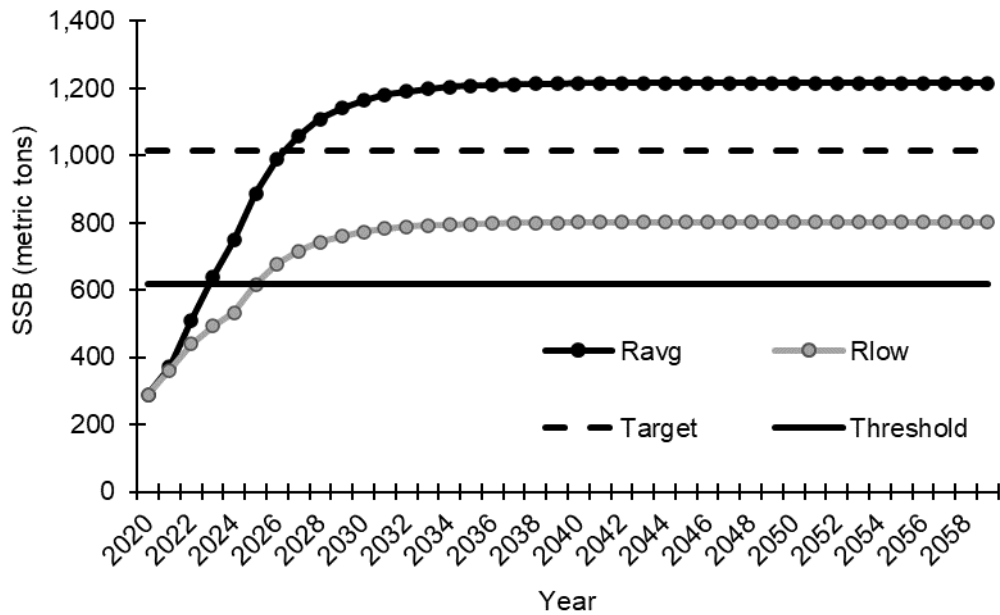


Figure 3. Projected striped mullet spawning stock biomass at various recruitment levels (average and low) compared to the SSB_{Target} (dashed line) and $SSB_{Threshold}$ (solid line) assuming a 35.4% reduction in total removals.

Several management tools are available to achieve sustainable harvest in the striped mullet fishery. This discussion includes specific management measures that are both quantifiable and

projected to meet the required harvest reduction for striped mullet needed to meet 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 intended 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 primarily focuses on reductions in the commercial fishery where most striped mullet harvest occurs. Because recreational harvest estimates are highly uncertain, harvest reductions from any specific management measure cannot be calculated. In 2019, recreational striped mullet harvest accounted for around 1.7% of total harvest and has accounted for around 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 harvest reductions cannot be quantified for the recreational sector due to data limitations, overall reduction calculations are based solely on striped mullet landings from the commercial fishery (Table 2). All management options are presented as percentage reductions to the 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. Harvest reduction, and commercial only harvest reduction necessary to end overfishing and rebuild the stock. Target landings are 2019 commercial landings reduced by the given percentage.

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 success of any management measure in meeting sustainability objectives is dependent on compliance and enforcement. Implementing management in the striped mullet fishery represents a significant change to a fishery that has operated for decades without any direct harvest limits. Communication and outreach regarding new management measures will be essential to promoting compliance.

Size Limits

Throughout this section, unless otherwise stated, all lengths will be 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 history inform managers of 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 at 100% maturity 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.

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 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 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 the demand for roe increases (Tables 4-5; Figure 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 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

¹Figure may be overestimated because average was obtained from only two samples, 491 and 495 mm FL.

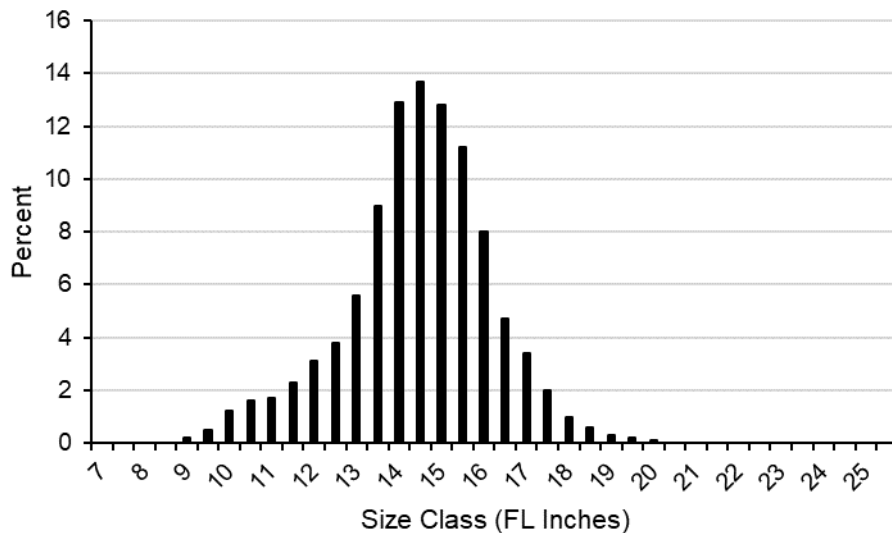


Figure 4. Length-frequency of striped mullet harvested in North Carolina commercial fisheries based on commercial fish house sampling, 2017-2021.

On its own, implementation of a minimum size limit 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 ever migrating offshore to spawn meaning, if a minimum size limit 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 6), but would be unlikely to reduce overall harvest because harvest would likely be delayed until those fish reach harvestable size preventing overall reductions. In addition, minimum size limits would likely increase discards if gear modifications and changes in fishery behavior do not occur.

Implementing a maximum size limit or seasonal maximum size limit, like what is done in Texas, may 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 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 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.

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.

Any change to 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 (Small Mesh Gill Net Characterization in the North Carolina Striped Mullet Fishery), the primary method for harvesting striped mullet is runaround gill nets with a modal mesh size of 3.75 inches stretched mesh (ISM; Appendix 1, Table 3), but mesh sizes ranging from less than 3.0 ISM up to 4.5 ISM are also 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 (Appendix 1, Figure 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.

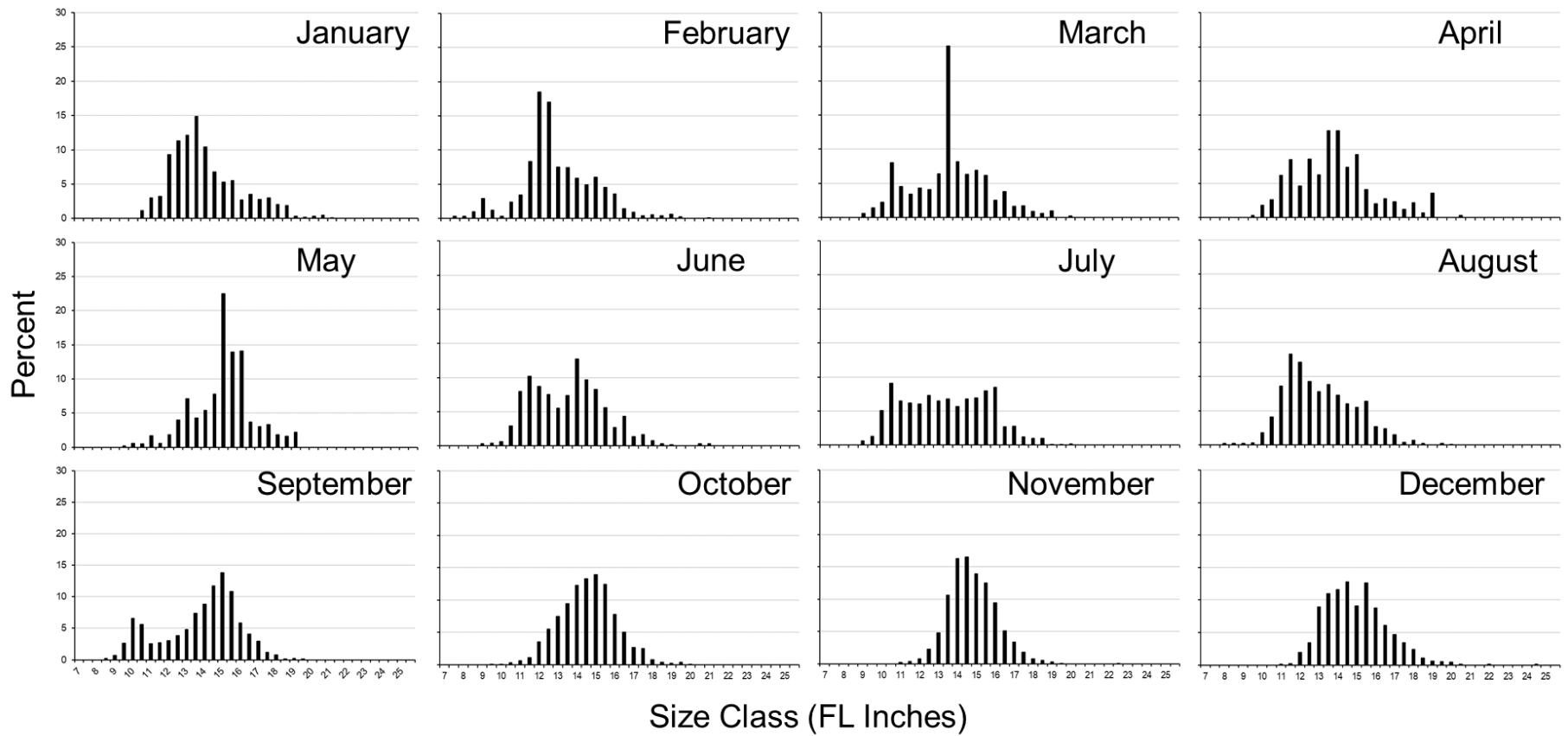


Figure 5. Length-frequency (inches) of striped mullet harvested in North Carolina commercial fisheries by month based on commercial fish house sampling, 2017-2021.

Table 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 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

Table 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

Size Limit Options with associated positives (+) and negatives (-)

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

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

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

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

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 North Carolina Marine Fisheries Commission (NCMFC) 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. 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 1 and 2 (Table 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.

Table 7. End of year season closure options that reduce harvest to end overfishing and recover the stock. Option 3 ends overfishing but does not recover the stock and cannot be considered for adoption in Amendment 2.

Option	Season Closure	Reduction	End Overfishing?	Recover Stock?
1*	October 29 - December 31	33.7	Yes, Target	Yes, See Table 1
2	November 7 - December 31	22.1	Yes, Below Target	Yes, See Table 1

*Adding an additional closure day exceeds a 35.4% reduction

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 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 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			
4	Oct. 28-Dec. 31	Oct. 30-Dec.31	35.6	Yes, Target	Yes, See Table 1
5	Nov. 7-Dec. 31	Nov. 10-Dec. 31	21.7	Yes, Below Target	Yes, See Table 1

Options 4 and 5 (Table 8), which meet the reduction level needed to end overfishing and recover the stock, would 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. These season closure options assume an equal reduction between the two regions. However, additional options could be developed 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 Small Mesh Gill Net Characterization in the North Carolina Striped Mullet Fishery for additional information). However, most of these landings occur in January and February which are not being considered for striped mullet season closures. Because there is not a 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.

Season Closure Options with associated positives (+) and negatives (-)

Status Quo – Manage fishery with other measures

- + Prevents extended 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

Statewide Season Closure – Option 1 and 2 (Table 7)

- + 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

Regional, North/South, Season Closure – Option 4 and 5 (Table 8)

- + 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 or prevent excessive harvest during the open season. Many options, like trip limits, would need to be implemented in conjunction with small mesh gill net restrictions. See Appendix 1 Small Mesh Gill Net Characterization in the North Carolina Striped Mullet Fishery 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 trip limit or seasonal trip limit to striped mullet commercial catches could be used to reduce harvest, or 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 9 and 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 Small Mesh Gill Net Characterization in the North Carolina Striped Mullet Fishery) In high volume fisheries, 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, trip limits could be used to limit landings by discouraging participants from targeting large numbers of fish. Reduced trip limits could be applied early in the season when the fishery lands less and larger trip limits could be applied during the peak season to allow for the typical volume of landings. Restrictive trip limits may cause increased discards if participant behavior does not change, and trips continue to target the highest number of mullet possible. It is also possible implementation of trip limits, particularly early season trip limits, may just delay harvest and necessary harvest reductions may not be realized. For this reason, combining trips limits with other management measures may be beneficial for reducing total harvest.

Any trip limit option would need to be implemented in tandem with yardage limits on runaround gill nets. Appendix 1 (Small Mesh Gill Net Characterization in the North Carolina Striped Mullet Fishery) provides a review of gear characteristics in the small mesh gill net fishery. To effectively constrain landings, and prevent excessive discards, trip limit options should be implemented with restrictions limiting runaround gill nets to 300-500 yards.

Table 9. Percentage of commercial trips landing striped mullet by landings bin, 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 10. Percent harvest reduction from 2019 commercial landings based on various 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

Trip limits and associated positives (+) and negatives (-)

- + 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 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 12). Typically, the lowest landings occur on Saturday and Sunday.

Striped mullet are most available to the fishery during the fall when they migrate to the ocean to spawn. Conventional thinking suggests striped mullet begin their migration and 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. For example, prohibiting fishing for striped mullet on Saturday and Sunday would have reduced landings by 25.7% compared to 2019 landings (Table 11). This percentage reduction is relatively consistent for the

period 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. But 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. In addition, weekend closures may also reduce user group conflict and preferentially benefit full-time fishery participants.

Table 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 12. Percent of commercial landings by month and day of week, 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

Day of week closures and associated positives (+) and negatives (-)

Status Quo – Manage fishery with other measures

- + 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. This allows multiple management objectives to be met in addition to sustainability objectives. 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 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 high or average 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 trip limits may be suitable to reduce harvest while allowing traditional fisheries and uses to continue. 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. As an example, implementing a December closure, a year-round weekend closure (Saturday-Sunday), and a 1,000 lb. trip limit from January-September would result in a 31% reduction (Table 13). In this example there would be minimal discarding of fish from the trip limit early in the season and it would allow 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.

Table 13. Management measure combinations to end overfishing and achieve sustainable harvest, compared to 2019 commercial landings. Number in parentheses indicates the percent contribution of each measure to the total reduction.

Season Closure	Trip Limit (lb.)	Day of Week Closure	% Reduction
Nov 8-Dec 31	2,000	.	26.2
Nov 8-Dec 31	1,750	.	27.7
Nov 8-Dec 31	1,500	.	29.4
Nov 8-Dec 31	1,250	.	31.9
Nov 8-Dec 31	.	Sat	31.4
Nov 10-Dec 31	1,500	.	26.4
Nov 10-Dec 31	1,250	.	29.0
Nov 10-Dec 31	2,000	Sun	32.2
Nov 10-Dec 31	1,750	Sun	33.5
Nov 12-Dec 31	1,500	.	22.1
Nov 12-Dec 31	1,250	.	24.9
Nov 15-Dec 31	1,500	Sun	27.9
Nov 15-Dec 31	2,000	Sat	26.2
Nov 15-Dec 31	.	Sat-Sun	31.5
.	1,750	Sat-Sun	32.4
Dec 1-Dec 31	Jan-Sep 1,000	Sat-Sun	31.6
.	Jan-Sep, Dec 500 (0.10); Oct-Nov 2,000	Sat-Sun	38.4
.	.	Jan-Sep, Dec Sat-Sun; Oct-Nov Sat-Mon	33.9
.	.	Jan-Sep, Dec Sat-Sun; Oct-Nov Fri-Mon	41.0
Nov 15-Dec 31	.	Jan-Sep, Dec Sat-Sun; Oct-Nov Fri-Mon	45.6
Dec 1-Dec 31	.	Jan-Sep Sat-Sun; Oct-Nov Fri-Mon	43.5
Nov 15-Dec 31	.	Jan-Sep, Dec Sat-Sun; Oct-Nov Sat-Mon	39.1
Dec 1-Dec 31	.	Jan-Sep, Sat-Sun; Oct-Nov Sat-Mon	36.9

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 that 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 2017-2021, the season would close between November 6 (21.3% reduction) - October 23 (35.4% 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 1994-2021, 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 14. 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 15), or use allocations from 2019 which is the year reductions are calculated from (Table 16).

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, accounting for stop net landings separately would be necessary. 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.

Table 14. 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 15. 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 16. 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

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 constrain harvest would likely still be necessary to either extend the fishing season or ensure the 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 (Small Mesh Gill Net Characterization in the North Carolina Striped Mullet Fishery) 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.*), and spot (*Leiostomus xanthurus*) would likely be impacted.

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 high or average recruitment occurs the 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 even when it is no longer necessary.

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, less resource intensive or less restrictive measures.

Seasonal Catch Limit Options with associated positives (+) and negatives (-)

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

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

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

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 and 2021, the stop net fishery was open from October 15 through December 31 (Proclamations M-17-2020 and M-21-2021). Due to the schooling nature of striped mullet, the beach seine fishery is a high-volume fishery with thousands of pounds landed during a single trip.

From 2017-2021 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 few trips occurring in October and December, but minimal landings occurred 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 the 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 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 (Table 17). However, given the limited extent and seasonality of the fishery some restrictions may disproportionately impact the stop net fishery. In addition, strict 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 quota, as is done with spotted seatrout. Because there is minimal participation and effort, and daily reporting of spotted seatrout landings is already required, daily reporting of striped mullet landings could be accomplished.

Table 17. 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

Stop net fishery management options and associated positives (+) and negatives (-)

Status Quo – Manage fishery with same measures applied to the rest of the fishery

- + Prevents confusion
- + Minimizes user group conflict
- Some measures may completely eliminate stop net fishery
- May not meet sustainability objectives
- Could increase discards

Stop Net Specific Quota

- + 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

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 1997-2001, 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 areas closures (Figure 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.

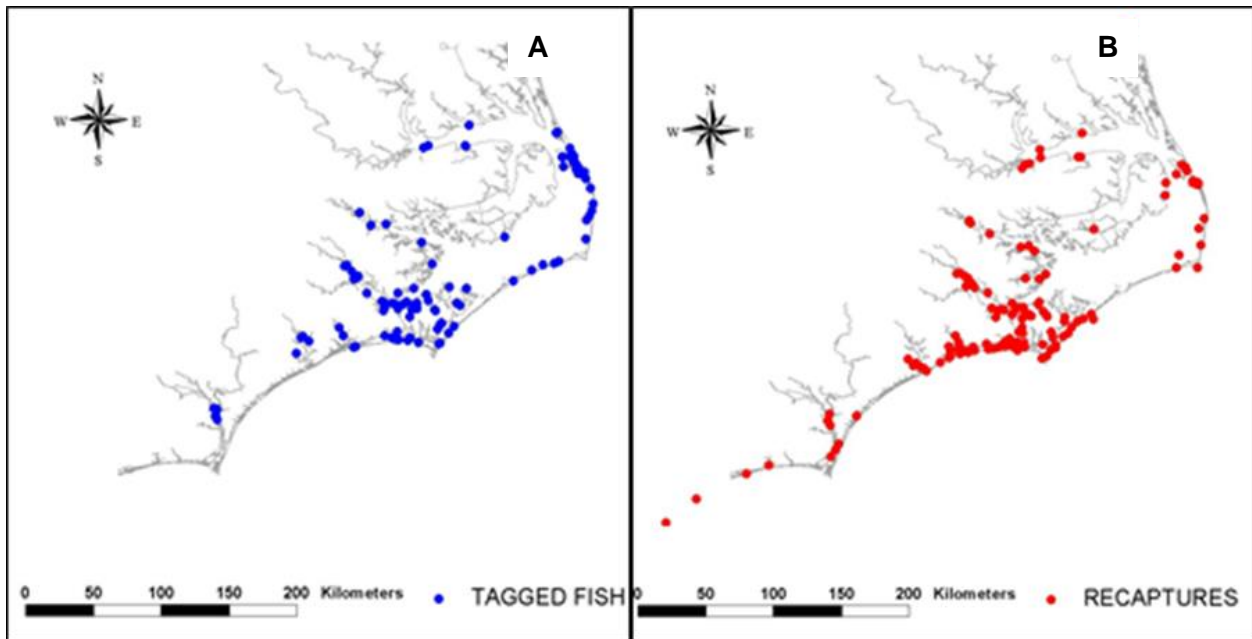


Figure 6. Tagging location of recaptured striped mullet (A) and recapture location for all striped mullet tag returns (B). A single dot may indicate multiple fish. From Wong (2001).

One recent example of an area closure impacting the striped mullet fishery is the prohibition of all gill nets above the ferry lines in the Pamlico and Neuse rivers (Proclamation [M-6-2019](#); Figure 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 had 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 saxatilis*) 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. 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, to make their spawning run, striped mullet cross the ferry line when moving down river becoming susceptible to the fishery.

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 objectives.

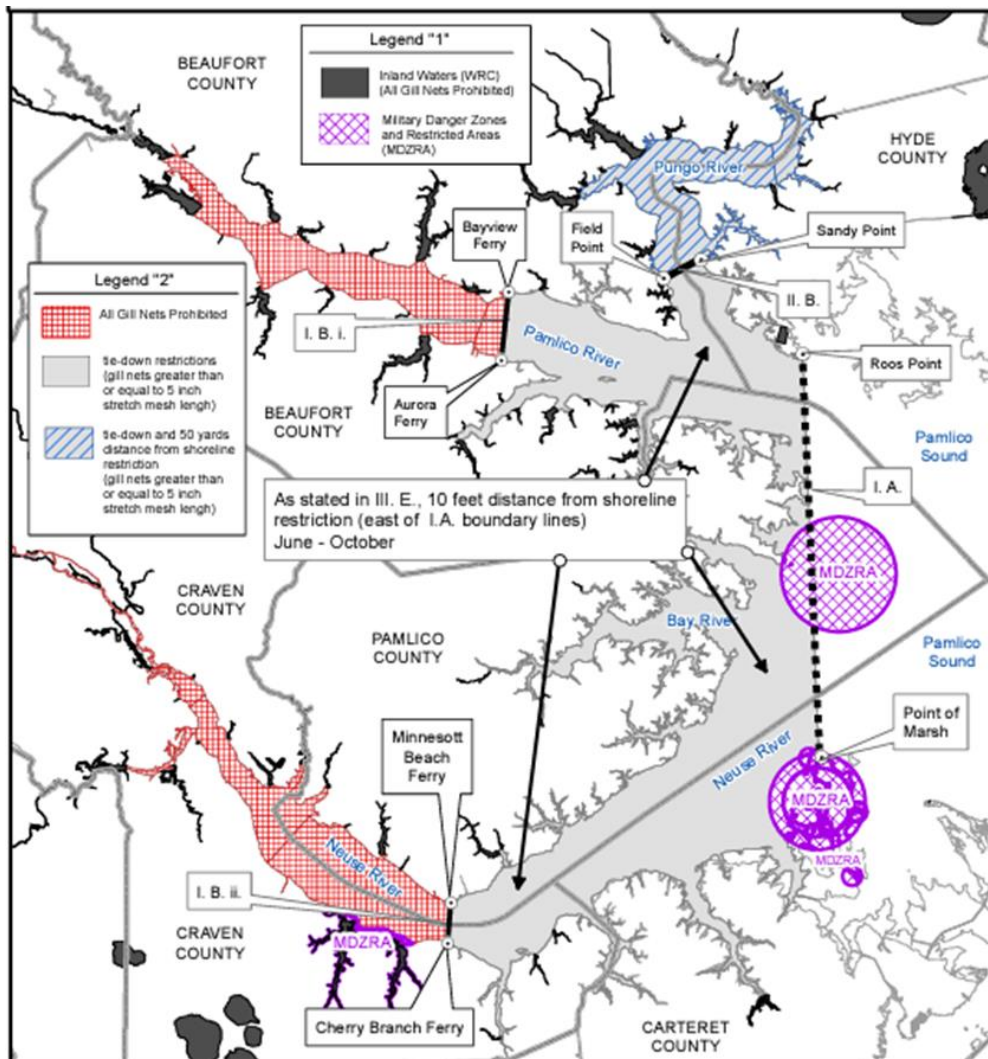


Figure 7. Map of the Pamlico and Neuse rivers showing existing gill net restrictions and the prohibition on the use of gill nets above the ferry line in each river.

Limited Entry

North Carolina General Statute 113-182.1 states the MFC can only recommend the General Assembly limit participation in a fishery in 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.

Reference Points and Adaptive Management

[The Striped Mullet FMP](#) (NCDMF 2006) adopted a fishing mortality overfishing threshold of $F_{25\%}$ spawning potential ratio (SPR) and a fishing mortality target of $F_{30\%}$ SPR. In [Amendment 1 to the Striped Mullet FMP](#), the fishing mortality target was raised from $F_{30\%}$ SPR to $F_{35\%}$ SPR. The F target was increased due to the fishery targeting female fish during the spawning season, the potential importance of striped mullet as a forage species, and because the small buffer between the target and threshold values could result in rebuilding plans with more restrictive harvest. The 2022 stock assessment maintained the F threshold and target from the prior assessment and complementary reference points for stock size were adopted based on female spawning stock biomass (SSB), with a threshold of $SSB_{25\%}$ and a target of $SSB_{35\%}$.

[In reviewing the 2022 striped mullet stock assessment](#) a peer review panel noted the use of F that maintains only 25% of the spawner biomass is relatively risky and suggested reference points set by determining F that maintain 30-40% SPR are commonly recommended (NCDMF 2022). Louisiana sets an $F_{30\%}$ SPR threshold (West et al. 2016) and Florida sets an $F_{35\%}$ target (Chagaris et al. 2014) for striped mullet. While an F Threshold of $F_{25\%}$ SPR is considered risky, an F Target of $F_{35\%}$ SPR is more consistent with how striped mullet are managed in other states and would be considered more risk averse.

[Amendment 2 to the North Carolina Estuarine Striped Bass FMP](#) (NCDMF 2022b) states estimates of F from stock assessments will be compared to F_{BRP} and if F “exceeds the F_{Target} reduce the TAL to achieve the F_{Target} through adaptive management”. Essentially, if overfishing is occurring in the striped bass fishery the total allowable landings (TAL) must be reduced to a level projected to lower F to the $F_{45\%}$ SPR target. Rather than change existing overfishing thresholds, a similar requirement could be adopted for striped mullet mandating F be maintained at the F target rather than at the threshold. Managing at the F_{Target} provides additional buffer to maintain sustainability given scientific uncertainty. This change, or mandate, could be carried out through adaptive management.

There is also a need to update the adaptive management framework and trigger in the striped mullet FMP. The 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 mean commercial landings from 1994-2002 in the FMP and the mean commercial landings from 1994-2011 in Amendment 1. If annual landings fall below the minimum trigger, the DMF would determine whether the decrease in landings is attributed to stock decline, decreased fishing effort, or both. If annual landings exceed the maximum trigger, 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 8). Commercial landings are a poor indicator of stock abundance because they can be affected 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.

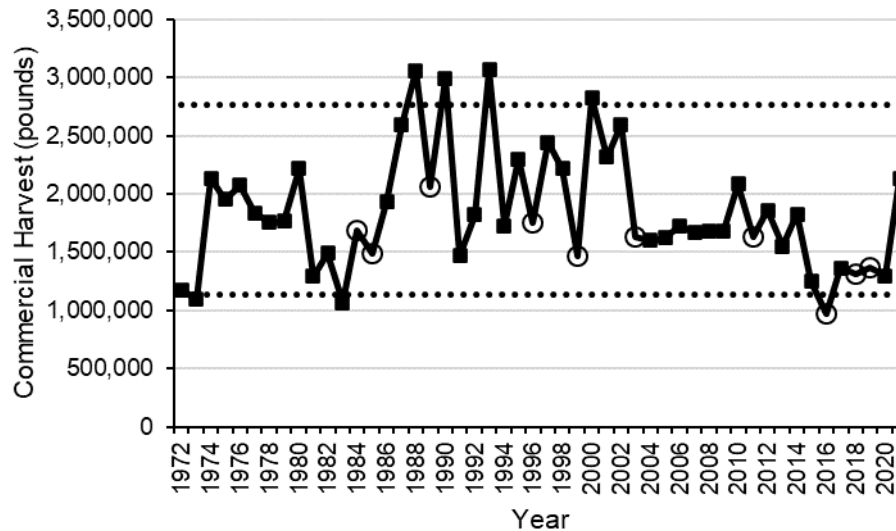


Figure 8. Striped mullet commercial landings (pounds) reported through the North Carolina Trip Ticket Program, 1972–2021 Lower dashed line (1.13 million lb.) and upper dashed line (2.76 million lb.) represent landings limits that trigger closer examination of data. Open circles represent years with significant hurricanes or storms.

Peer reviewed stock assessments and stock assessment updates should continue to be used to guide management decisions for the North Carolina striped mullet stock. Until the stock recovers the current peer reviewed stock assessment (NCDMF 2022) should be updated, at a minimum, every five years 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 late 2025. The intent of this update would primarily be to determine if overfishing has ended and to update SSB estimates to determine if adjustments to management measures via adaptive management are needed to meet the rebuilding schedule. Stock assessment updates do not typically undergo peer review, because the methodology and model specification do not change, only the data is updated. However, the DMF retains the ability to seek peer review of stock assessment updates if DMF staff deem it necessary.

The adaptive management framework will specify specific management objectives (e.g., F should be maintained at the F_{Target} , SSB should be maintained at the $SSB_{\text{Threshold}}$) to provide clear guidance about the management response to stock assessment updates. For example, if a statewide season closure is adopted as part of Amendment 2 and a stock assessment update

indicates F is still above the F_{target} the season would be adjusted based on the terminal year of the assessment to maintain F at the target. Conversely, if F is found to be below the target, the season would be adjusted to allow F to increase to the target. If a combination of management measures are adopted, the adaptive management framework will allow for specific measures to be adjusted to meet management objectives. For example, a seasonal trip limit or maximum size limit might be desirable measures to keep in place even as the stock recovers because of fishery benefits, but adjustments to season closures or day of week closures could still be used to meet sustainability objectives.

If a seasonal catch limit is adopted as part of Amendment 2, stock assessment updates would be used to adjust the seasonal catch limit to meet management objectives. However, if other measures are adopted as part of Amendment 2 and a stock assessment update indicates the stock will not meet recovery goals, it may be necessary to implement a striped mullet seasonal catch limit to directly control harvest. If this is done, a revision will be drafted by the Division, in conjunction with input from the Striped Mullet Advisory Committee about regional and gear specific allocations.

Finalization of the adaptive management framework is dependent on adoption of a directive to manage F at the target or some other level, and other management measures to control harvest. Essentially the adaptive management framework would allow for adjustment of management measures through revisions to Amendment 2 in response to stock assessment updates. Depending on management strategies implemented through Amendment 2, the following could be adjusted as part of a revision:

1. Fishing year and/or seasons
2. Catch controls, including bag and trip limits
3. Size limits
4. Effort controls, including fishing days and fishing times
5. Gear limitations, including minimum and maximum gill net mesh size, maximum yardage of gill nets, and specifications for any other gear used to harvest striped mullet
6. Reporting requirements
7. Measures to reduce or monitor bycatch
8. Measures to reduce or monitor user group conflict
9. Area closures
10. Any other management measures currently included in Amendment 2

Adaptive management options and associated positives (+) and negatives (-)

Do not allow for adaptive management of the striped mullet fishery, management changes will occur at the time of scheduled FMP reviews.

- + Consistent management in place
- Not risk adverse
- Could be overly restrictive
- Delayed management response could result in greater future harvest reductions

*Adopt adaptive management for the striped mullet fishery and manage the stock **at** the $F_{25\%}$ threshold.*

- + Prevents overfishing

- + Likely to achieve sustainability if recruitment is good
- + Clearly defined objective
- + Less immediate harvest reduction compared to managing at target
- Not risk averse
- Could result in additional future harvest reductions
- Management likely to change frequently

*Adopt adaptive management for the striped mullet fishery and manage the stock **at** the $F_{35\%}$ target.*

- + Prevents overfishing
- + Likely to achieve sustainability regardless of recruitment level
- + Clearly defined objective
- + Risk averse
- + Could have population and fishery benefits in future
- Greater immediate harvest reductions compared to managing at threshold
- Management likely to change frequently

*Adopt adaptive management for the striped mullet fishery and manage the stock **above** the $F_{25\%}$ threshold.*

- + Prevents overfishing
- + Likely to achieve sustainability regardless of recruitment level
- + Clearly defined objective
- + Risk averse
- + Could have population and fishery benefits in future
- Greater immediate harvest reductions compared to managing at threshold
- Management likely to change frequently

Future Adaptive Management

Once a stock assessment indicates the striped mullet stock has recovered and overfishing has ended the DMF will continue to monitor the stock using fishery-independent, fishery-dependent, and other data sources. Examples could include development of triggers for monitoring abundance indices or population characteristics or composite indices like a Traffic Light.

The Traffic Light Approach (TLA; Caddy and Mahoon 1995; Caddy 1998, 1999, 2002) is a precautionary management framework that is currently used to manage the Atlantic coast stocks of Atlantic croaker (ASMFC 2020a) and spot (ASMFC 2020b) and has been used in the past to assess the North Carolina blue crab stock (NCDMF 2013b). The TLA is preferred for fast-growing, early maturing species, where it is more important to respond to multi-year trends rather than annual changes. This method of monitoring would be done annually through FMP Updates. The results of any monitoring could be to undertake a stock assessment update or implement measures to reduce harvest.

MANAGEMENT OPTIONS

Option	Description	Reduction %
1	Seasonal Catch Limit	
	A. Statewide Seasonal Catch Limit	
1	1,072,065 lbs.	20.0
2	879,992 lbs.	33.0
	B. Regional Seasonal Catch Limit (Split at Highway 58 Bridge)	
1	North/South 1994-2021 Allocation	21.3
2	North/South 1994-2021 Allocation	35.4
3	North/South 2017-2021 Allocation	21.3
4	North/South 2017-2021 Allocation	35.4
5	North/South 2019 Allocation	21.3
6	North/South 2019 Allocation	35.4
2	Size Limit	
	A. Minimum Size Limit	?
	B. Maximum Size Limit	?
	C. Seasonal Maximum Size Limit	?
	D. Implement w/Mesh Size Restrictions	?
3	Season Closure	
	A. Statewide Season Closure	
1	October 29-December 31	33.7
2	November 7-December 31	22.1
	B. Regional Season Closure	
1	North: October 28-December 31 South: October 30-December 31	35.6
2	North: November 7-December 31	21.7

Option	Description	Reduction %
South: November 10-December 31		
4	Trip Limits	
	1	50
	2	75
	3	100
	4	150
	5	200
	6	300
	7	400
	8	500
	9	600
5	Day of Week Closures	
	1	Saturday-Sunday
	2	Friday-Sunday
	3	Saturday-Monday
	4	Friday-Monday
6	Combination of Measures	(see Table 16)
7	Adaptive Management	
	1	Status Quo
	2	Manage at F25% Threshold
	3	Manage at F35% Target
	4	Manage above F25% Threshold

RECOMMENDATIONS

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