STRIPED MULLET
FISHERY MANAGEMENT PLAN
AMENDMENT 2

NC Division of Marine Fisheries
3441 Arendell St. P.O. Box 769
Morehead City, NC 28557

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ACKNOWLEDGMENTS

Amendment 2 to the North Carolina (NC) Striped Mullet Fishery Management Plan (FMP) was developed by the NC Department of Environmental Quality (NCDEQ), Division of Marine Fisheries (NCDMF) under the auspices of the NC Marine Fisheries Commission (NCMFC) with the advice of the Striped Mullet Advisory Committee (AC). Deserving special recognition are the members of the Striped Mullet AC and the NCDMF Plan Development Team (PDT) who contributed their time and knowledge to this effort.

Striped Mullet Advisory Committee

Barry Hodawanic
Eric Bregman
Janey Nye
Joey Frost
Sammy Corbett
Steve Edens
Walter Rogers

Striped Mullet Development Team

Alan Bianchi
Amos Williams
Barbie Byrd
Brandi Salmon
Daniel Zapf (Mentor)
David Behringer
Jacob Tyler
Jason Parker
Jason Rock
Jason Walsh
Jeffrey Dobbs (Co-lead)
Kimberlee Harding
Laura Lee
Lee Paramore
Lucas Pensinger
Marc Hamric
Mclean Seward
Melinda Lambert
Morgan Paris
Nolen Vinay
Steve Poland
Jeffrey Moore
Vicky Thayer
Willow Patten (Co-lead)

The following division staff were also invaluable in assisting with the development of this document: Corrin Flora, Debbie Manley, Carter Witten, Casey Knight, Steve Poland, Tina Moore, and Catherine Blum.

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EXECUTIVE SUMMARY

*** added before secretarial review***

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 (NCDMF) 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 NCDMF prepares FMPs for adoption by the North Carolina Marine Fisheries Commission (NCMFC) 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 NCMFC adopts rules and policies and implements management measures for the striped mullet fishery in Coastal Fishing Waters in accordance with 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) indicated that striped mullet in North Carolina are overfished and that overfishing is occurring in 2019, the terminal year of the assessment. An external peer review panel and NCDMF concluded that 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 Fishery Management Plan (NCDMF 2006), Amendment 1 to the Striped Mullet Fishery Management Plan (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: https://www.deq.nc.gov/about/divisions/marine-fisheries/managing-fisheries/fishery-management-plans.

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 NCDMF website: https://www.deq.nc.gov/about/divisions/marine-fisheries/managing-fisheries/fishery-management-plans

Management Unit

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

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.

DESCRIPTION OF THE STOCK

Biological Profile

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).

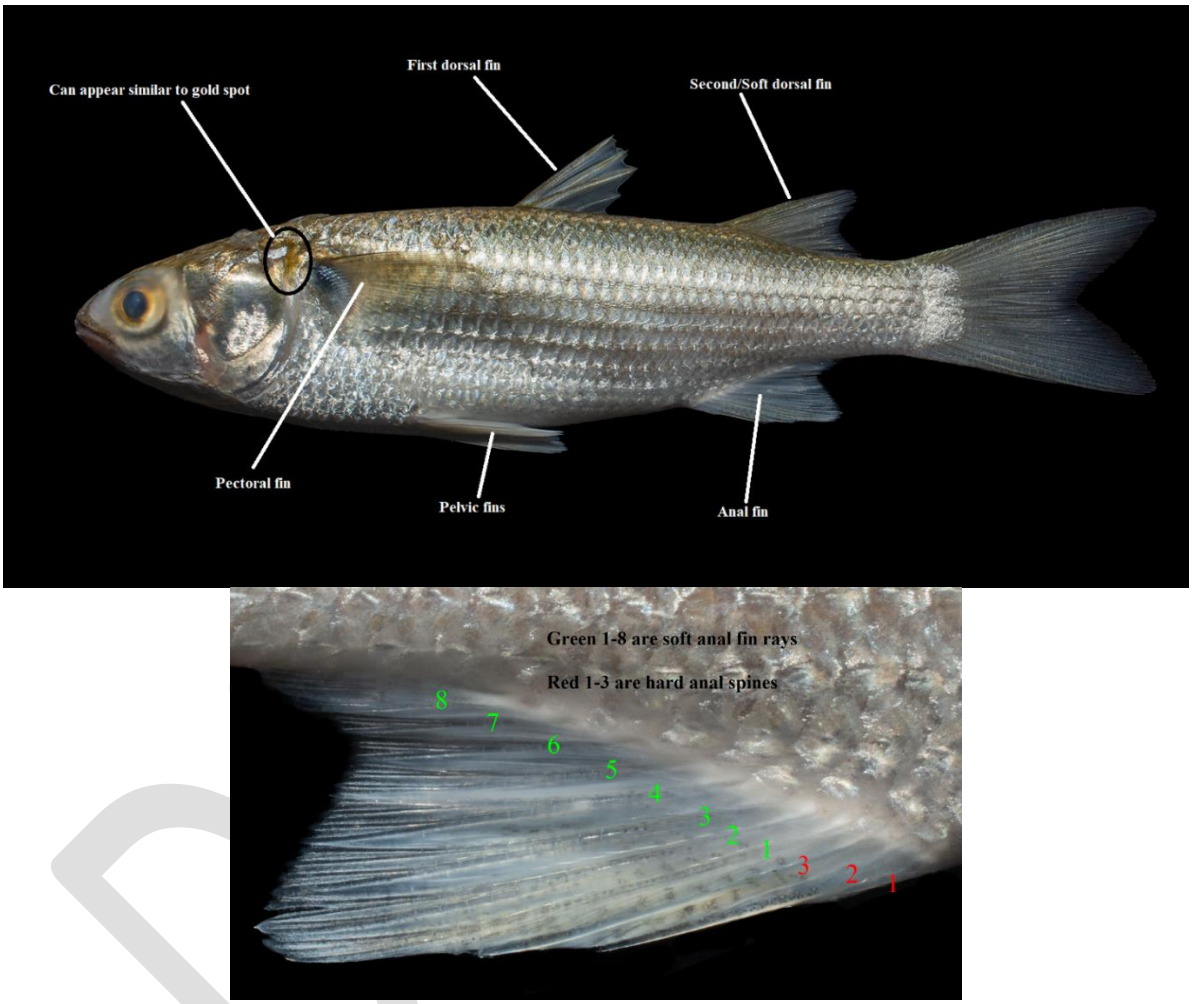

Figure 1. Identifying features for striped mullet. Striped mullet have eight soft anal fin rays and do not have a gold spot on the opercle that white mullet sometimes have. Photo By Scott Smith.

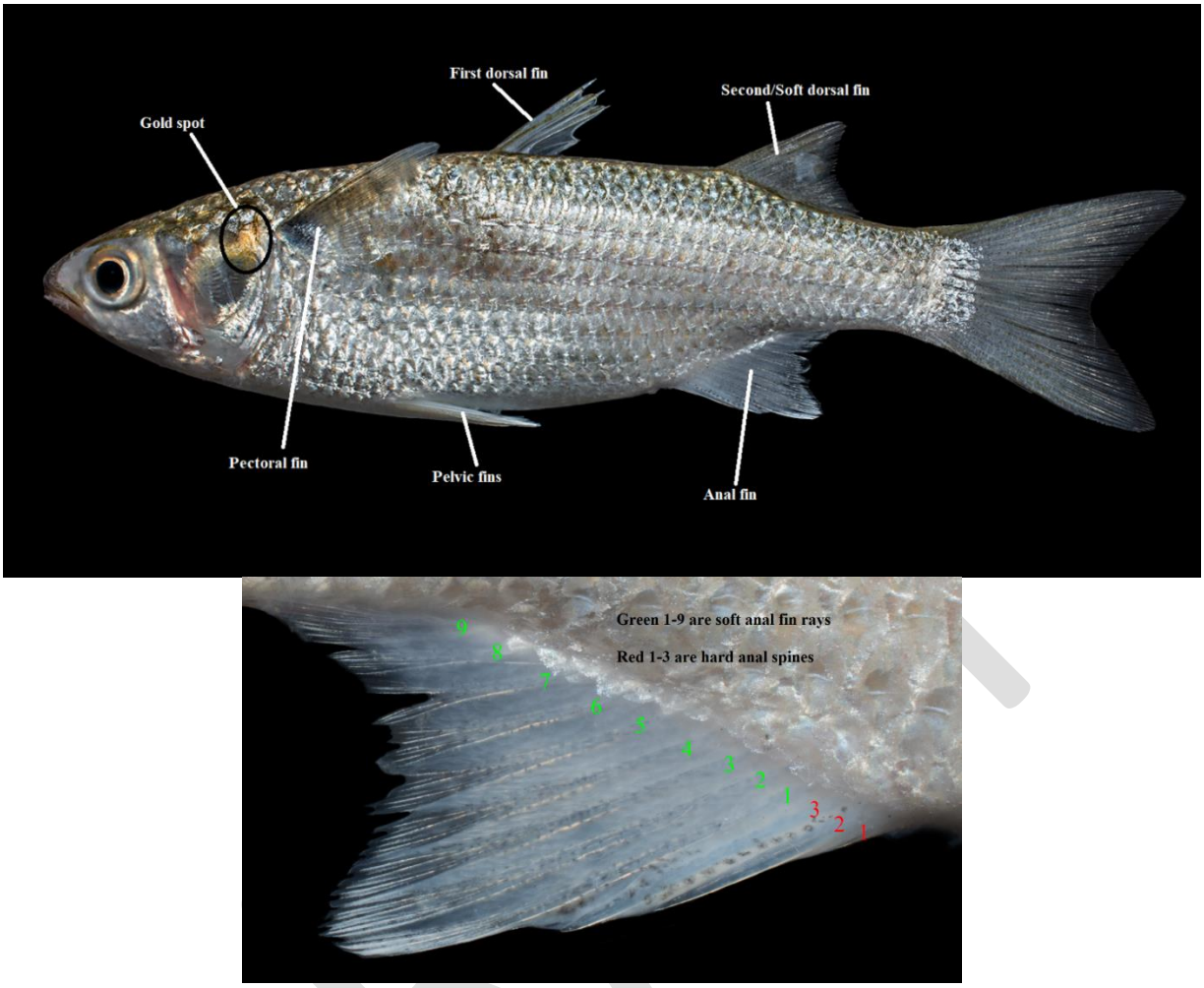

Figure 2. Identifying features for white mullet. White mullet have nine soft anal fin rays and a gold spot on the opercle. Photo By Scott Smith.

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 NCDMF, 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).

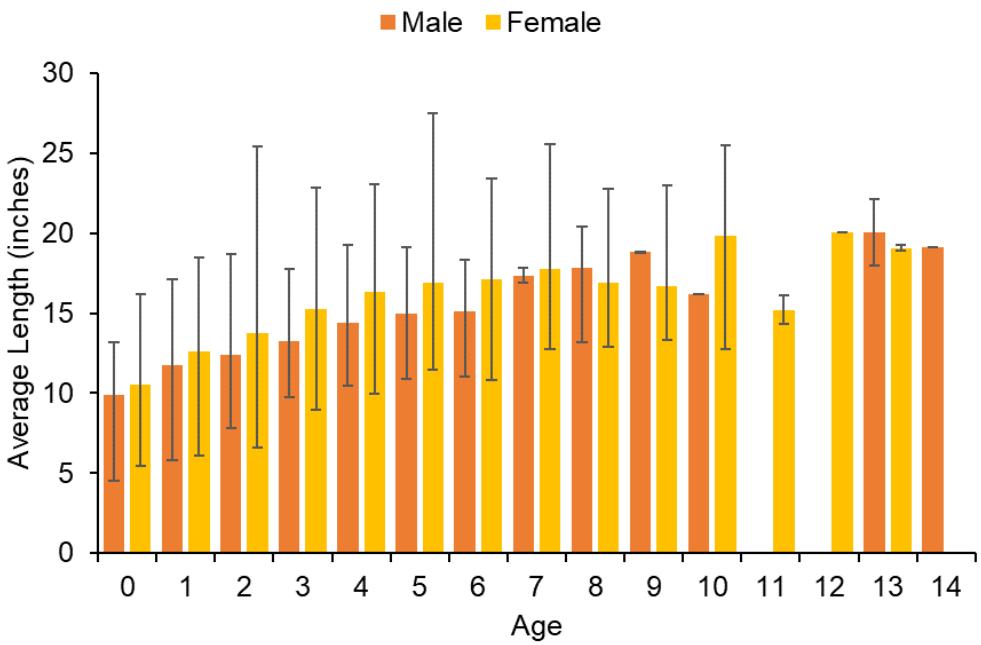

Figure 3. Average length at age for male and female striped mullet from NCDMF data. For some ages, only one sex or one specimen has been observed. Error bars show the range of lengths observed at each age by sex.

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, fishes, 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 (YOY) 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 data were collected by NCDMF as part of several fishery-independent and fishery-dependent data collection programs. Following completion of the stock assessment, an external peer review workshop was held in April 2022. The NCDMF 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.

Current (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 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).

Stock Status

The North Carolina striped mullet stock is overfished and overfishing is occurring in 2019, the terminal year of the stock assessment, completed in 2022 (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 highest risk for overfishing.

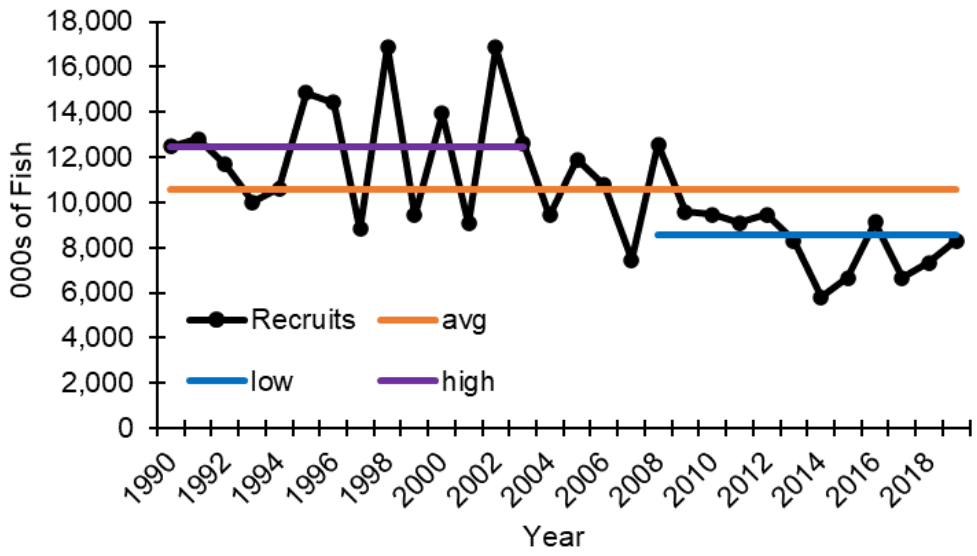

Figure 4. Estimates of striped mullet recruitment from the 2022 striped mullet stock assessment (NCDMF 2022). Average recruitment is the average number of recruits from 1990 to 2019, high recruitment is the average number of recruits from 1990 to 2003, and low recruitment is the average number of recruits 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.

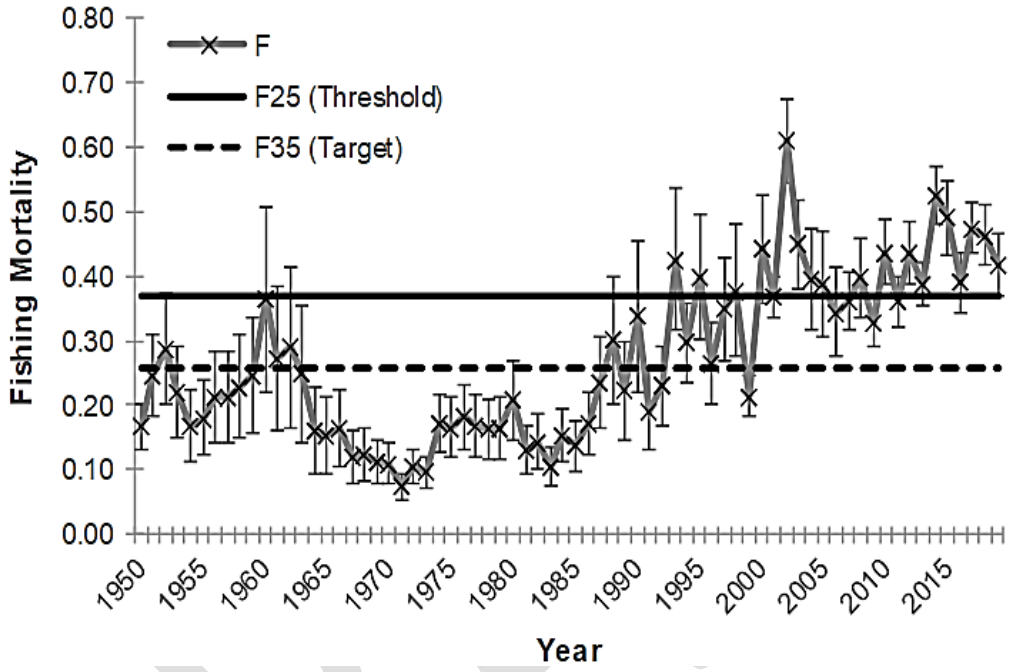

Figure 5. Comparison of annual estimates of fishing mortality (numbers weighted, ages 1-5) to the fishing mortality target (F35%) and threshold (F25%). Error bars represent plus or minus 2 standard deviations.

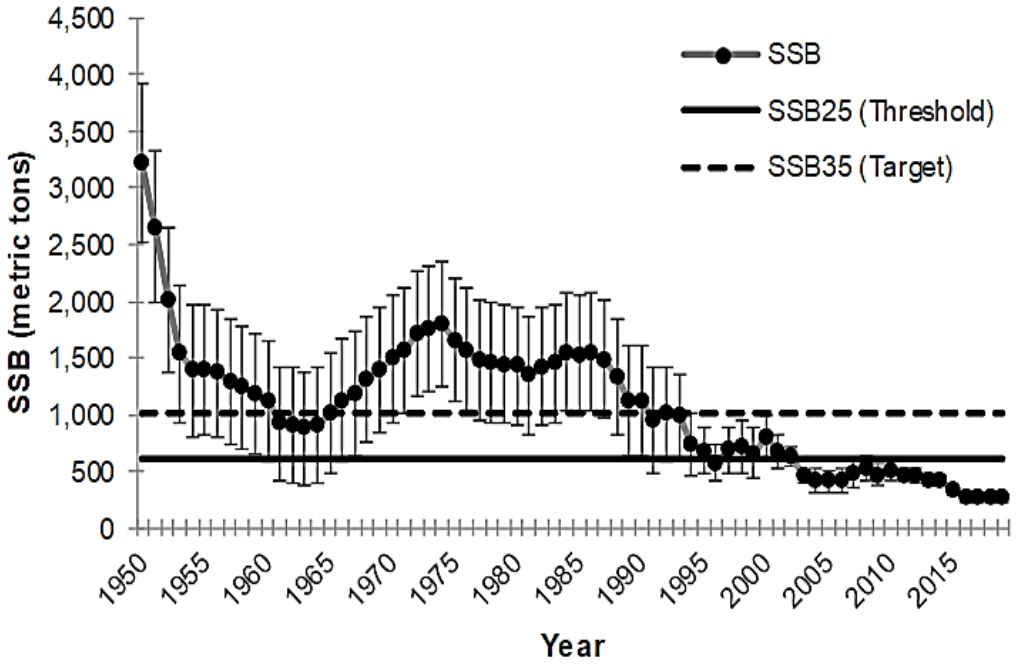

Figure 6. Comparison of annual estimates of female spawning stock biomass (SSB) to the SSB target (SSB35%) and threshold (SSB25%). Error bars represent plus or minus 2 standard deviations.

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 and Amendment 1 (NCDMF 2006, NCDMF 2015). Commercial and recreational landings can be found in the License and Statistics Annual Report (NCDMF 2022) which can be found on the NCDMF Fisheries Statistics webpage: NCDMF Fishery Statistics.

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 FMP's are included to help inform decision-making regarding the long-term viability of the states commercially and recreationally significant species and fisheries. For detailed explanation of the methodology used to estimate economic impacts, please refer to the division's License and Statistics Section Annual Report (NCDMF 2022).

Commercial Fishery

COLLECTION OF COMMERCIAL HARVEST DATA

NCDMF instituted a mandatory, dealer-based, trip-level, reporting system known as the North Carolina Trip Ticket Program (NCTTP) for all commercial species in 1994. 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 division's 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).

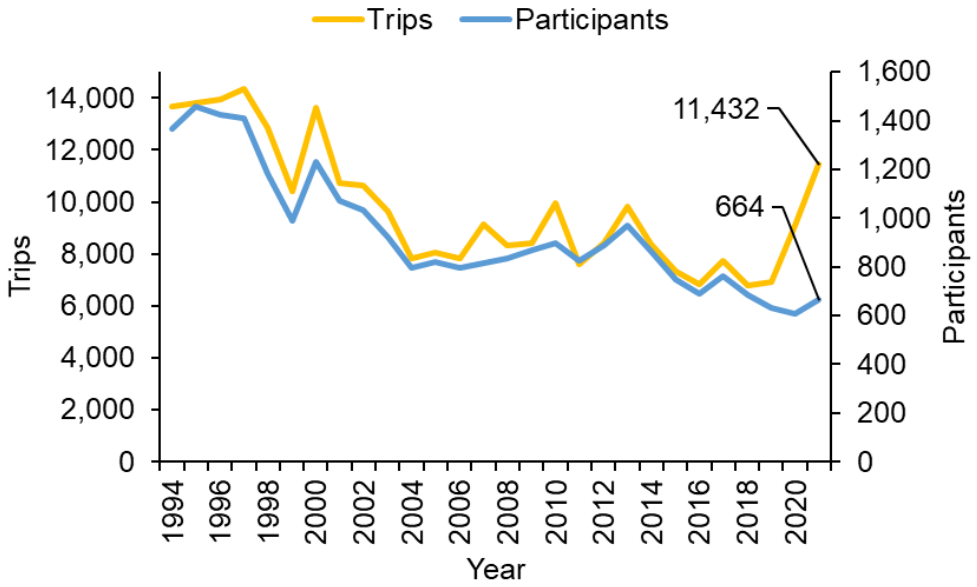

Figure 7. Annual number of trips and participants for the North Carolina striped mullet commercial fishery from 1994 to 2021.

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 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).

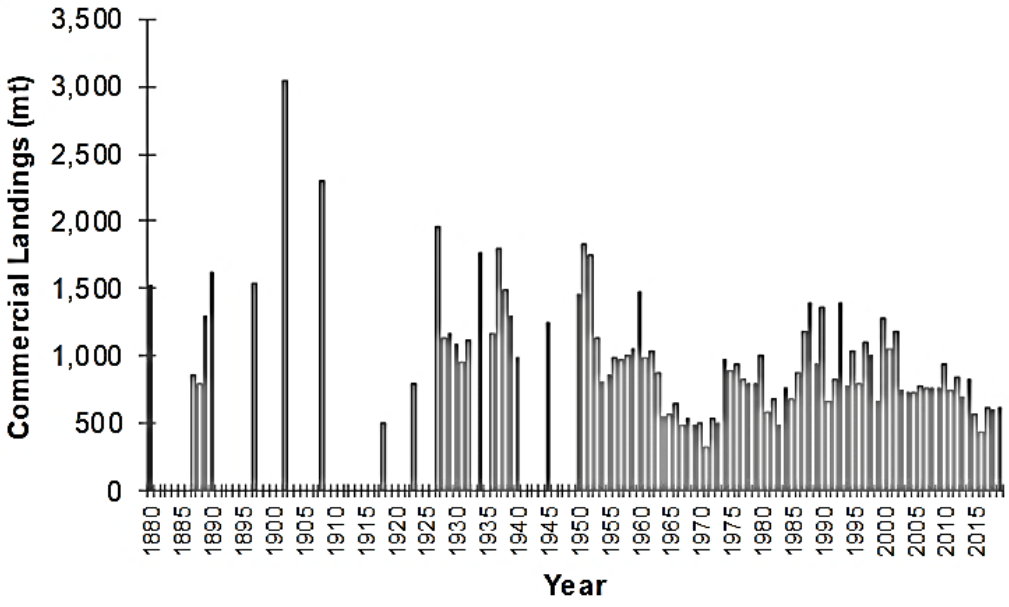

Figure 8. Historical striped mullet landings in the North Carolina commercial striped mullet fishery, for 1880 to 2021.

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.

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 around 1.5 to 2.0 million pounds annually, with the exception of 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).

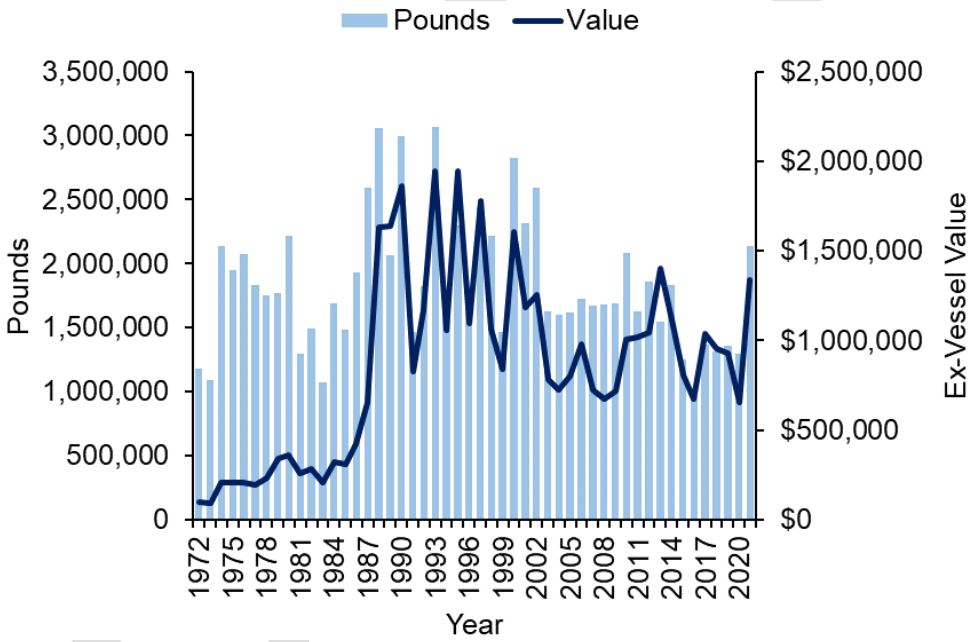

Figure 9. North Carolina annual striped mullet commercial landings and ex-vessel value for 1972 to 2021. Values include all market grades and are not adjusted for inflation.

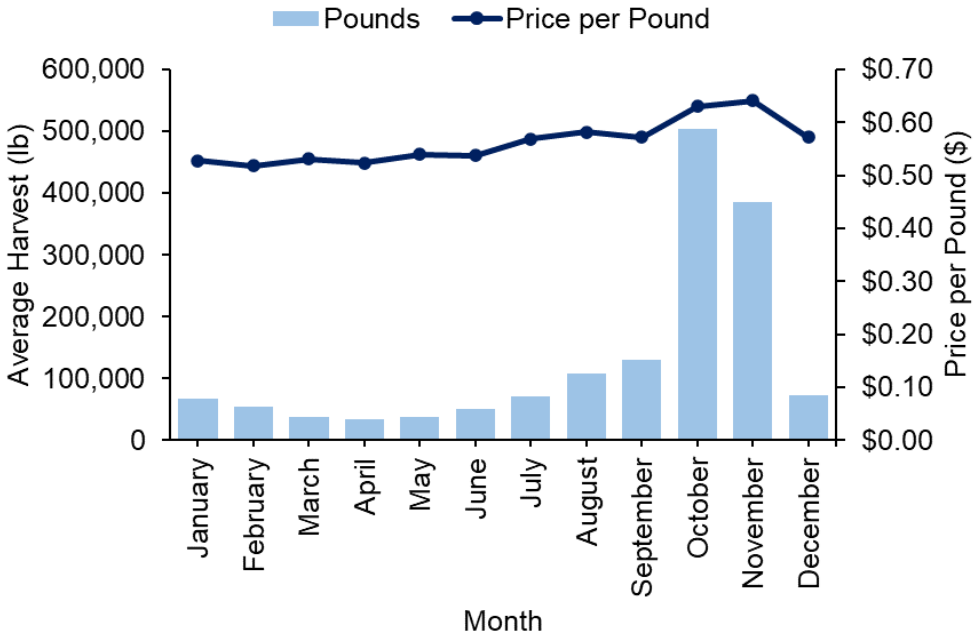

Figure 10. North Carolina striped mullet average monthly landings and average price per pound for 2010 to 2021. Averages include all market grades and are not adjusted for inflation.

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.

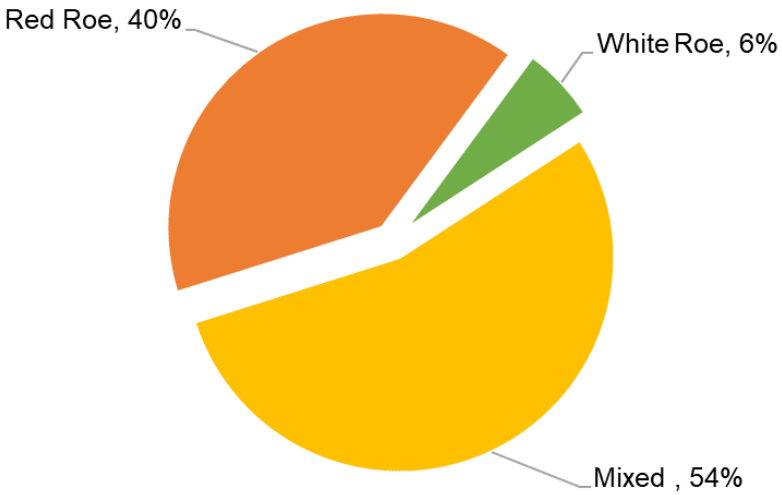

Figure 11. Percent of total landings by market grade in the North Carolina striped mullet commercial fishery, for 1994 to 2021. Landings reported as extra small, small, medium, large, jumbo, and mixed were combined into the “Mixed” market grade category. Landings reported as roe or red roe were combined into the “Red Roe” market grade category.

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 has 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).

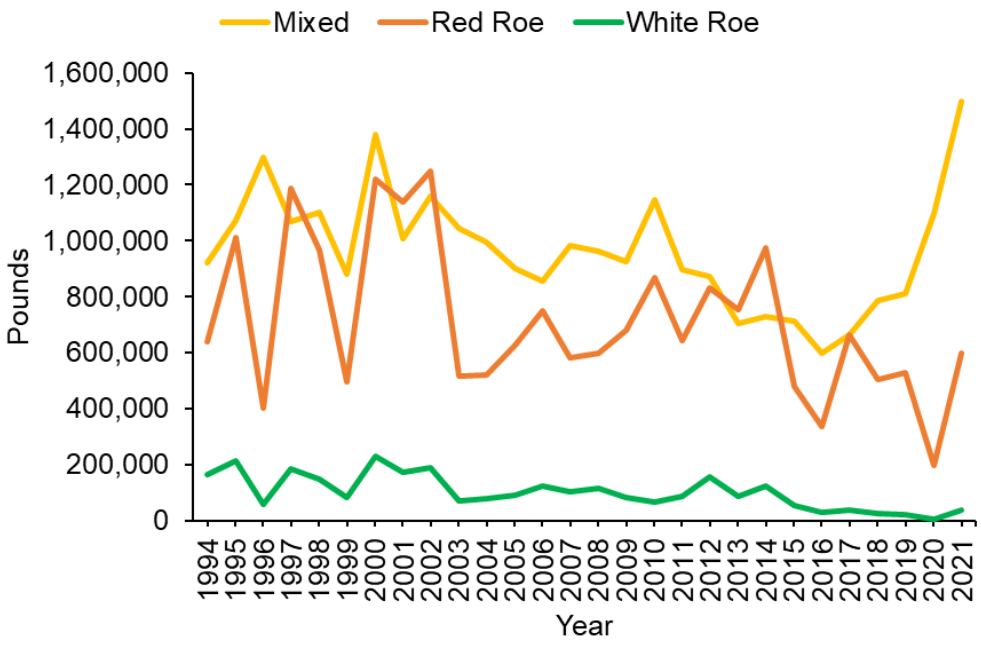

Figure 12. Annual landings by major market grade in the North Carolina striped mullet commercial fishery for 1994 to 2021. Landings reported as extra small, small, medium, large, jumbo, and mixed were combined into the "Mixed" market grade category. Landings reported as roe or red roe were combined into the "Red Roe" market grade category.

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 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. An NCDMF study completed in the early 2000s indicated that the majority of these landings may be white mullet, depending 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).

The vast majority of commercial striped mullet landings in North Carolina come from gill net fisheries and are landed in Dare and Carteret counties.

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. Since then, gill net landings have averaged around 91% of striped mullet landings through 2021 (Figure 15). 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.

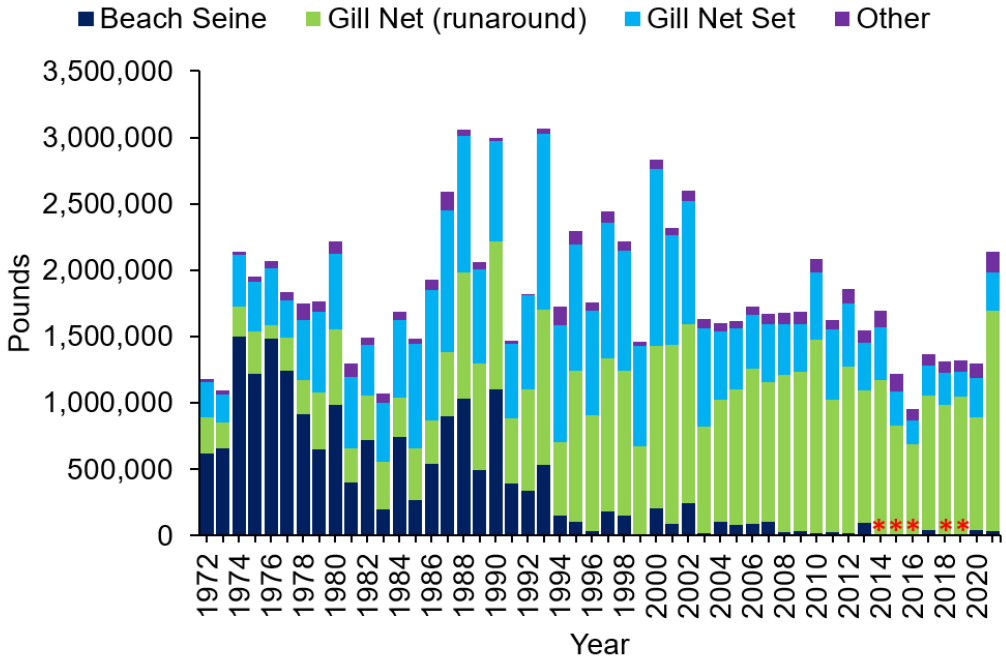

Figure 15. Total landings in pounds by dominant gear type in the North Carolina striped mullet commercial fishery for 1972 to 2021. Beach seine landings for 2014 through 2016 and 2018 through 2019 are confidential and therefore not presented, indicated by asterisks.

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-1990's. 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).

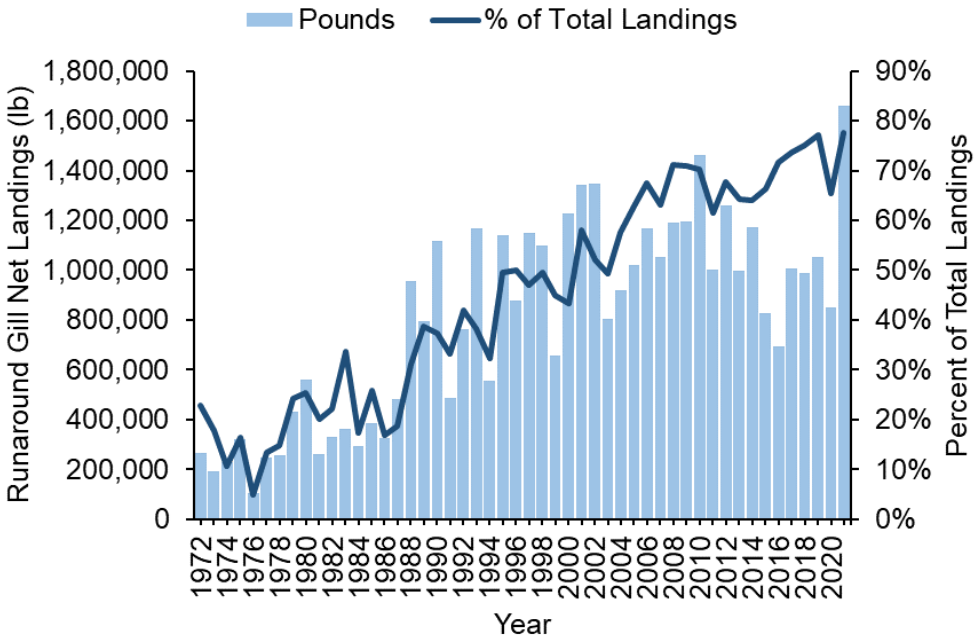

Figure 16. Pounds harvested by runaround gill nets by year and percent of total landings harvested by runaround gill nets by year in the North Carolina striped mullet commercial fishery for 1972 to 2021.

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 has not increased since the mid-1980's (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).

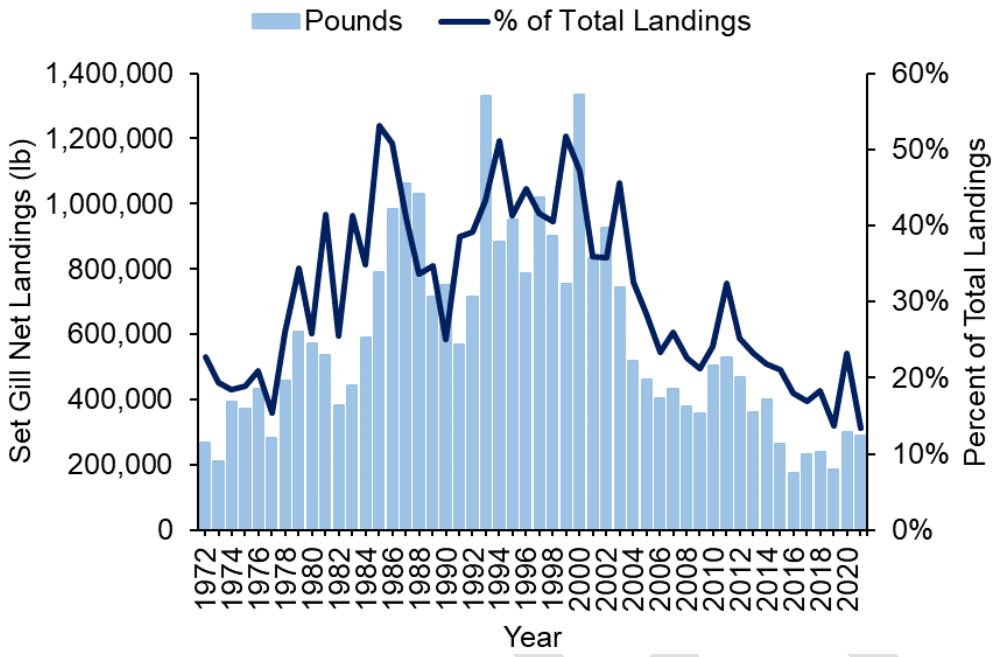

Figure 17. Pounds harvested using set gill nets and percent of total landings harvested using set gill nets by year in the North Carolina striped mullet commercial fishery for 1972 to 2021.

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 tractor in later years. Stop nets (stationary nets not intended to gill fish but used to impede the movement of schooling fish so that they can be harvested with a seine) were employed 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 1990's and 2000's may have resulted from fall hurricanes and strong weather conditions, which can have a particularly profound effect on stop net harvest because of it's 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.

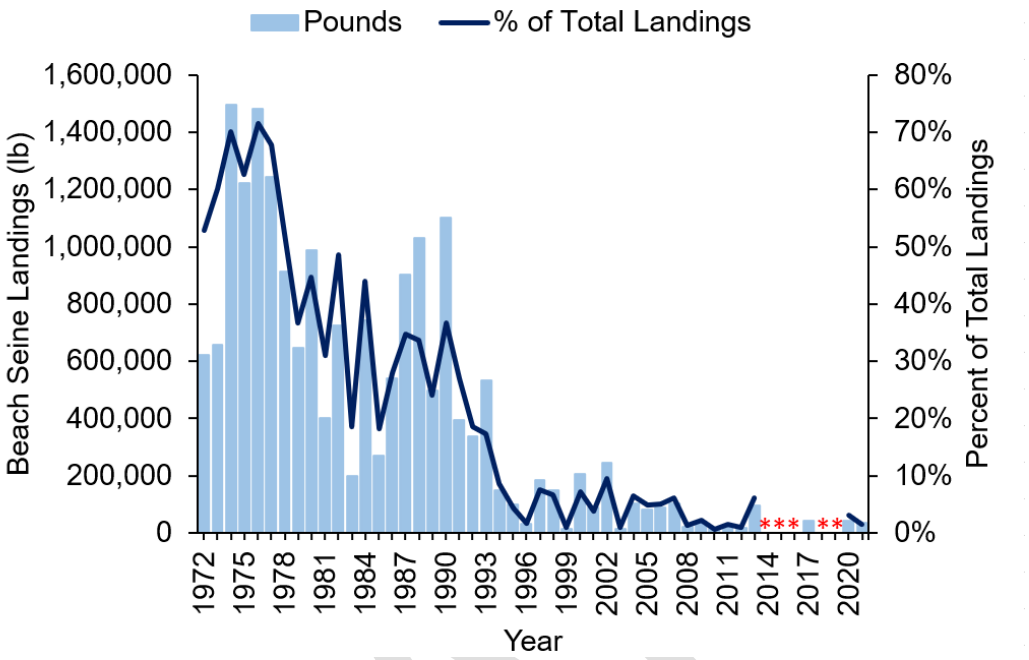

Figure 18. Pounds harvested using beach seins and percent of total landings harvested using beach seines by year in the North Carolina striped mullet commercial fishery for 1972 to 2021. Values for 2014 through 2016 and 2018 through 2019 are confidential and therefore not presented, indicated by asterisks.

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 as striped mullet 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 the majority of 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%).

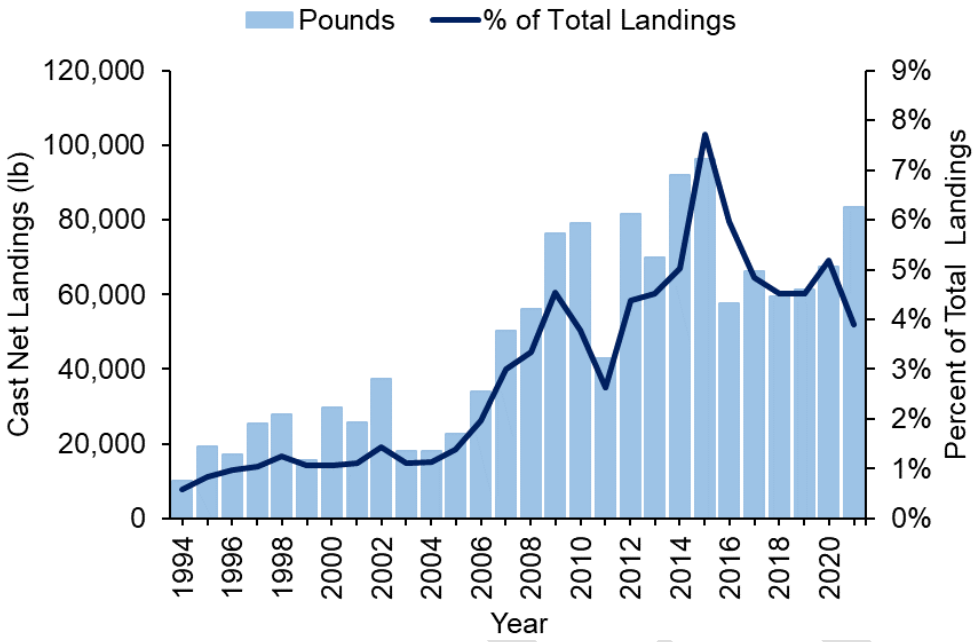

Figure 19. Pounds harvested using cast nets and percent of total landings harvested using cast nets by year in the North Carolina striped mullet commercial fishery for 1972 to 2021.

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 cause 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).

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 NCDMF 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 time 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 no longer make up the majority of beach seine landings in North Carolina. In both targeted striped mullet fisheries, the species most 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.

Recreational Fishery

Few anglers target striped mullet by hook and line; 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 (YOY) mullets, commonly known as finger mullet. At the end of each fishing trip, anglers typically discard dead and unused bait mullet. Cast netting for mullet generally occurs during the summer and fall, with the majority caught in September and October, coinciding with the southward migration of YOY striped and white mullet. For more information about North Carolina's 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 NOAA's 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's 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 NCDMF License and Statistics Annual Report.

From 2011 to 2021 striped mullet economic ex-vessel value has been about $1 million dollars, impacting about 9,000 jobs annually (**Error! Reference source not found.**). Annual sales impacts have varied over the described decade but have averaged $3.5 million from 2011 to 2021 (**Error! Reference source not found.**). It is estimated that the striped mullet fishery contributes to about 1% of commercial fishing sales impact.

Table 1 Annual commercial estimates of annual 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 commercial estimates of annual 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

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 (**Error! Reference source not found.**).It is difficult to determine the economic impact and importance of North Carolina's 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 NCMFC. The NCMFC 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 NCMFC authority (e.g.,

water quality management, shoreline development) can be addressed by the other commissions through the CHPP process. The CHPP helps to ensure consistent actions among these commissions as well as their supporting NCDEQ divisions. The CHPP also summarizes the economic and ecological value of coastal habitats to North Carolina, their status, and potential threats to their sustainability (NCDEQ 2016).

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. Inlets are also hydraulically dredged on a regular basis, potentially entraining marine animals, particularly eggs and larval fish that cannot avoid the suction field of the gear (Todd, et al. 2015).

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 removing benthic infauna from the areas, reducing food availability to bottom-feeding fish such as striped mullet. Soft bottom habitats in the surf zone of shallow ocean waters are also used by juvenile striped mullet and may act as a transient habitat, orienting fish larvae into estuaries (Kinoshita, et al. 1988, Fujita, et al. 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 the 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.

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.

Gear Impacts on Habitat

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 have impacts of bycatch while in operation and can have negative impacts if the gear is abandoned or lost.

The primary gears used in the 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 considered static gear (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 NCDMF monitors interactions between protected species and commercial fisheries, please refer to the NCDMF Observer Program webpage: https://www.deq.nc.gov/about/divisions/marine-fisheries/science-and-statistics/observer-program#ProtectedSpecies-4366. 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 to North Carolina's climate in this century will be larger than anything experienced historically (Kunkel, et al. 2020). It is predicted that average annual temperatures will continue to increase, sea level will continue to rise, the intensity of hurricanes will increase, total annual precipitation from hurricanes and severe thunderstorms will increase resulting in increased flooding events, while severe droughts will also likely increase due to higher temperatures (Kunkel, et al. 2020). Flood events can flush contaminated nutrient-rich runoff into estuaries causing degraded water quality. Runoff from flood events can cause eutrophication resulting in fish kills due to hypoxia, algal blooms, and alteration of the salinity regime. Flood events can also cause erosion of shorelines resulting in loss of important coastal habitats, such as SAV, 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 the coastal communities, but to coastal habitats and the fisheries they support. While the risks and hazards associated with climate change and extreme weather events cannot be completely eliminated, the effects can be decreased by improving coastal resilience, which can be broken down into two parts: 1) community resiliency – the ability of a community to withstand, respond to, and recover from a disruption, and 2) ecosystem resiliency – the ability of

the natural environment to withstand, respond to, and recover from 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 AMENDMENT TWO MANAGEMENT STRATEGY

****Section will be completed when the MFC selects preferred management and prior to DEQ secretary and legislative committees review****

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.

- Increase sampling of recreational mullet catches to determine the proportion of striped versus white mullet and improve estimates of recreational landings
- Improve characterization of the length and age structure of recreational fisheries removals by increasing the number of age samples and number of trips sampled for lengths and ages from fisheries-dependent sources
- Develop a reliable fisheries-independent abundance index for larger juveniles, to characterize trends in recruitment
- Consider expanding Program 915 to include the northern part of the state (Albemarle Sound and major tributaries)
- Evaluate the current sampling methodology of Program 146 and effectiveness for sampling striped mullet. Since this survey was not considered useful for the assessment of striped mullet, consider dropping this survey, and focusing effort elsewhere if it is not contributing to management of other species
- Consider running a simpler, single-sex version of the stock assessment model

MANAGEMENT FROM PREVIOUS PLANS

The original Striped Mullet FMP (NCDMF 2006) implemented a possession limit of 200 mullets (striped and white combined) per person in the recreational fishery to eliminate anglers from taking large amounts of bait mullets from North Carolina and selling them in other states without impinging on normal fishing practices. It also allowed Marine Patrol to distinguish between commercial and recreational fishing operations.

Supplement A to Amendment 1 to the N.C. Striped Mullet FMP (NCDMF 2023) implemented a season closure for both the commercial and recreational striped mullet fisheries from November 7 through December 31 north of the highway 58 bridge to Emerald Isle, and from November 10 through December 31 south of the highway 58 bridge to Emerald Isle. Supplement A to

Amendment 1 management will remain in place until adoption of Amendment 2 to the N.C. Striped Mullet FMP.

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