ASMFC Stock Assessment Overview: Atlantic Menhaden

Introduction

Atlantic menhaden have supported one of the largest commercial fisheries in the US since colonial times and are also an important prey species for a variety of predators, including striped bass, bluefish, marine mammals, and sea birds. The Commission and its member states have long recognized the importance of Atlantic menhaden as a forage fish and have worked to develop ecological reference point (ERP) models to quantify the effects of Atlantic menhaden harvest on its predators, examine the impact of predators on Atlantic menhaden removal targets, and quantitatively evaluate the tradeoffs between menhaden harvest and predator demand. In 2020, the Commission formally adopted ERPs based on a peer-reviewed ecosystem model, representing the first time on the Atlantic coast that a forage fish was managed with quantitative ecological reference points. Since then, the Commission has continued to develop and refine the ERP models to improve our understanding of Atlantic menhaden population dynamics and its role in the ecosystem.

This document presents a summary of two reports: the 2025 Atlantic Menhaden Single-Species Update Assessment and the ERP Benchmark Assessment. The ERP Benchmark Assessment was peer-reviewed and approved by an independent panel of scientific experts through the 102nd SouthEast, Data, Assessment and Review (SEDAR) workshop. The reports represent the latest and best information available on the status of the coastwide Atlantic menhaden stock and the role of Atlantic menhaden as a forage fish for use in fisheries management.

Management Overview

Atlantic menhaden are currently managed under Amendment 3 (2017) and Addendum I to Amendment 3 (2022) to the Interstate Fishery Management Plan (FMP). Addendum I responded to changes in the commercial fishery by aligning state quotas with recent landings and resource availability while maintaining access to the resource for all states; reducing dependence on quota transfers; and minimizing regulatory discards. It created a three-tiered system for minimum allocations to the states, with Pennsylvania receiving 0.01%; South Carolina, Georgia, Connecticut, Delaware, North Carolina, and Florida receiving 0.25%; and the remaining states continuing to receive a minimum of 0.5%. Furthermore, the Addendum allocates the remainder of the TAC, excluding the 1% reserved for the Episodic Event Set Aside (EESA) Program, on a state-by-state basis based on landings history of the fishery from 2018, 2019, and 2021. Regarding the Incidental Catch/Small-Scale Fishery (IC/SSF) provision, the Addendum codifies the ability for states to elect to divide their quotas into sectors, enabling individual sectors to utilize this provision at different times. Additionally, the Addendum removes purse seines as a permitted small-scale directed gear, thereby, prohibiting them from harvesting under the IC/SSF provision. Finally, the Addendum counts IC/SSF landings against the TAC and if IC/SSF landings cause the TAC to be exceeded, then the Board must take action to modify one or both of permitted gear types and trip limits under the provision. For the 2023-2025 fishing years, the Board set the TAC at 233,550 mt based on the results of the 2022 stock assessment update and the ERPs adopted in 2020.

What Data Were Used?

Both assessments used fishery-dependent and -independent data as well as information about Atlantic menhaden biology and life history. Fishery-dependent data come from the commercial reduction and bait fisheries, while fishery-independent data are collected through scientific research and surveys. A re-analysis of historical tagging data for Atlantic menhaden revised the values of natural mortality used in previous assessments.

For the ERP models, fishery-dependent and -independent datasets were compiled for predator and prey species from the most recent stock assessments for each species. New data on the abundance of other important prey like anchovies and zooplankton, and high-profile predators like osprey, bluefin tuna, and marine mammals were incorporated. Diet data were also compiled from fishery-independent surveys to calculate the proportion of Atlantic menhaden and other species in predators' diet.

Single-Species Assessment Overview

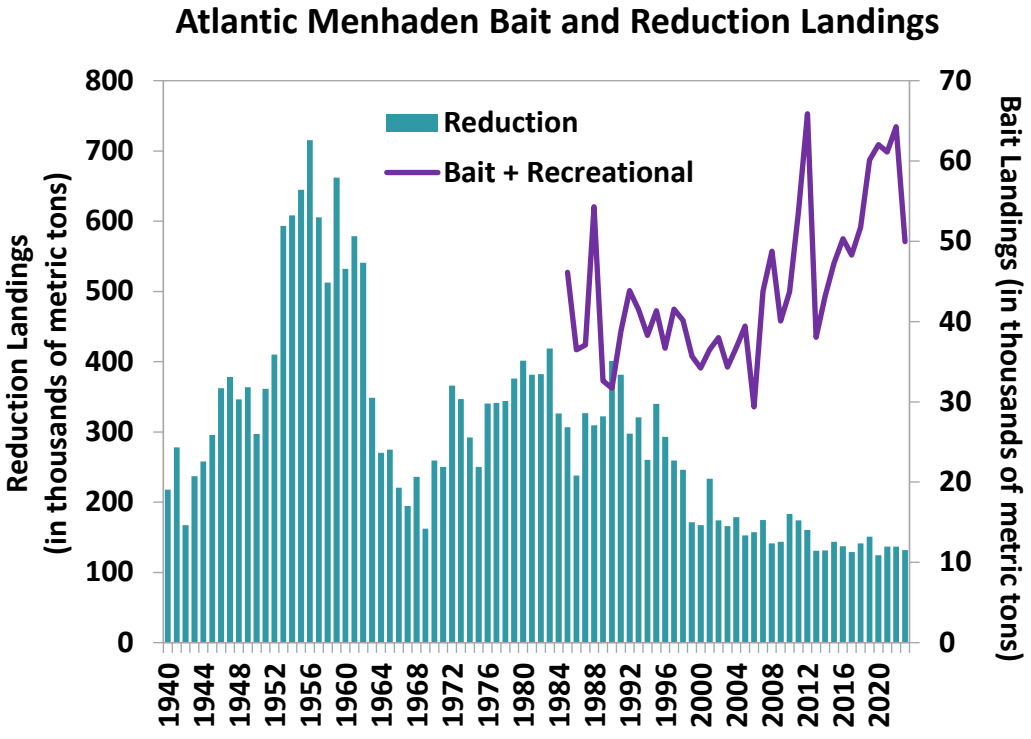
Life History

Atlantic menhaden undergo extensive north-south migratory movements and are believed to consist of a single population. Adults move inshore and northward in the spring, grouping by age and size along the Atlantic coast. During the summer, older and larger menhaden are typically found in northerly habitats, whereas immature menhaden are typically found in estuarine and inshore areas from Chesapeake Bay southward. The population extends as far north as the Gulf of Maine, although abundance in the northern extent of its range can significantly fluctuate from year to year. Spawning occurs along the continental shelf as well as in coastal sounds and bays. Eggs hatch at sea and larvae are carried by inshore currents to estuaries where they grow to the juvenile stage. Adults typically overwinter off the coast of North Carolina. Atlantic menhaden start reaching sexual maturity at age-1 and can live up to 10 years; however, fish older than age-6 have been uncommon in the fishery-dependent data since the mid-1960s. Natural mortality varies by age with the highest mortality on the youngest fish.

Commercial Data

The Reduction Fishery

The majority of Atlantic menhaden harvest is reduced to fish meal, oil, and solubles (which is used in animal feed, fertilizer, health supplements for human consumption, and other products). The reduction fishery grew with the advent of purse seine gear in the mid-1800s. Purse seine landings peaked in 1956 at 715,200 mt. At the time, over 20 menhaden reduction factories were in operation from southern Maine to northern Florida.



In the 1960s, the stock contracted geographically, and many of the fish factories north of Chesapeake Bay closed because of a scarcity of fish. Reduction landings dropped to a low of 162,300 mt in 1969.

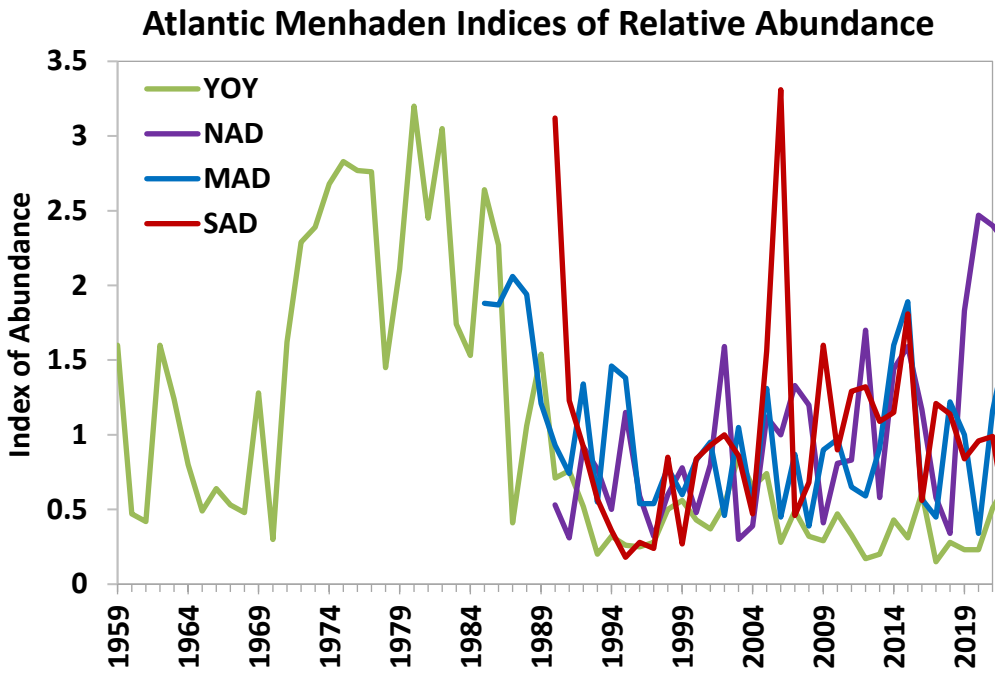
In the 1970s and 1980s, the menhaden population began to expand (primarily because of a series of large year classes entering the fishery), and reduction landings rose to around 300,000-400,000 mt. Adult menhaden were again abundant in the northern portion of its range and as a result reduction factories in New England and Canada began processing menhaden again. However, by 1989 all shore-side reduction plants in New England had closed, mainly because of odor abatement regulations.

During the 1990s, the stock contracted again, mostly due to a series of poor year classes. Over the next decade, several reduction plants consolidated or closed, resulting in a significant decrease in fleet size and fishing capacity. Since 2005, there has been one operational reduction factory processing Atlantic menhaden on the Atlantic coast. From 2005-2012, reduction landings averaged 160,900 mt. Reduction landings have been relatively steady since the implementation of the TAC in 2013, averaging 135,800 mt. In 2023, the terminal year of the assessments, reduction landings were 131,800 mt and accounted for approximately 70% of coastwide landings. Numerous portside samples are taken to obtain information about the weight, length, and age distribution of the fished population.

The Bait Fishery

While reduction landings have declined since the mid-2000s, menhaden landings for bait have become increasingly important to the total coastwide landings of menhaden. Commercial bait landings occur in almost every Atlantic coast state. A majority of bait landings are used commercially in crab, lobster, and hook-and-line fisheries. Recreational fishermen also catch Atlantic menhaden as bait for various game fish.

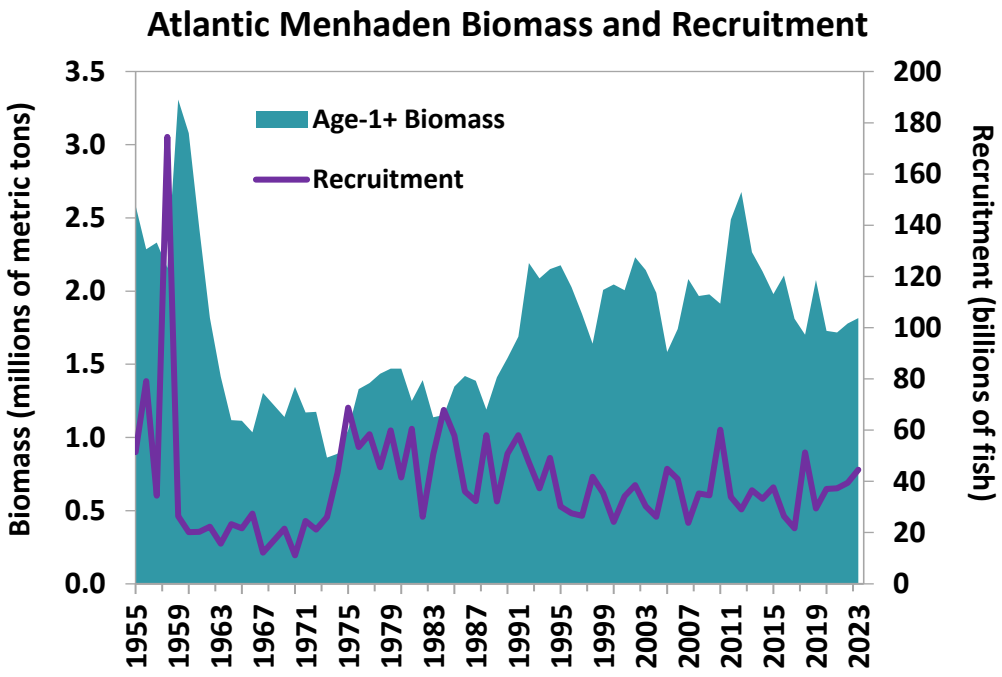
In contrast to reduction landings, bait landings have increased in recent years due to higher demand and increased menhaden availability in the northern part of the species' range. Total bait landings along the Atlantic coast averaged 44,600 mt from 2005-2012 prior to the implementation of the TAC and have averaged 50,000 mt since then. Recreational landings (menhaden caught by anglers on recreational fishing trips, usually for bait) comprised 1% of the coastwide landings over that time period. In 2023, bait and recreational landings were 50,000 mt and comprised 30% of coastwide landings.



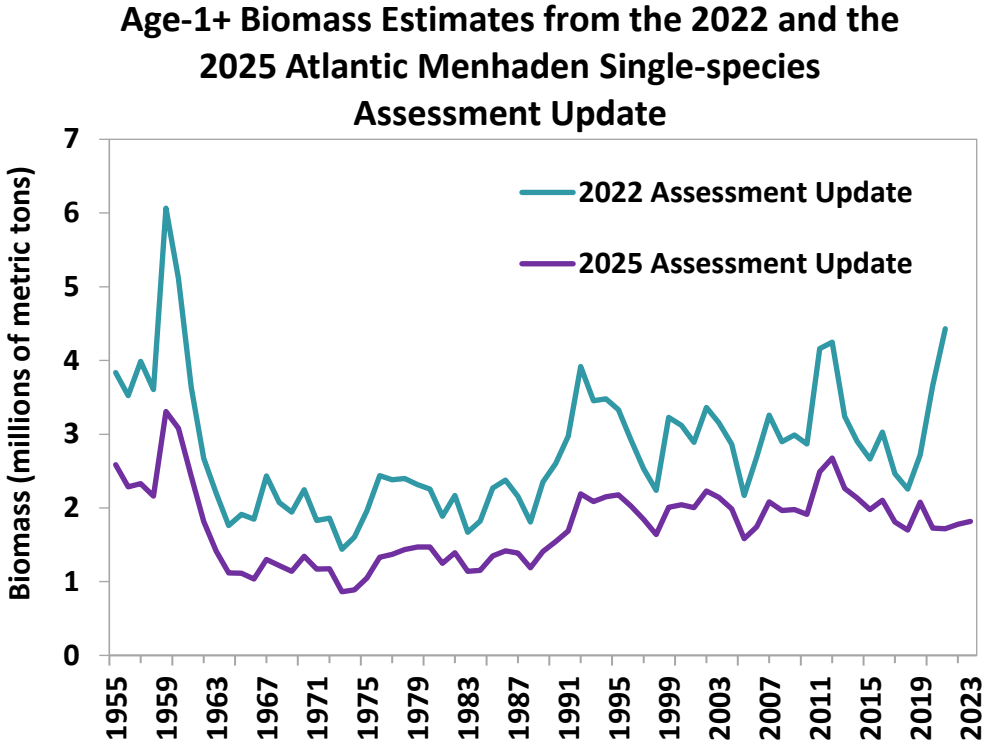
Fishery-Independent Surveys

Data collected from several different surveys were used in these stock assessments. These data were used to inform both juvenile and adult abundance within the models. Data used to develop an index of relative abundance for juvenile

menhaden (young-of-the-year or YOY) were collected from 16 surveys conducted in Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, Virginia, North Carolina, and South Carolina. Data from the surveys were statistically combined into one coastwide index. The index increased from historic lows in the 1960s to highs in the 1970s and 1980s.



Abundance has since been lower with moderate increases in year classes in the mid-2000s, 2016, and from 2021-2023. The three coastwide indices of adult abundance were updated based on eight fishery-independent survey data sets: the northern adult index or NAD (age-2+), the Mid-Atlantic adult index or MAD (age-1+), and the southern adult index or SAD (age-1). The NAD index was developed from surveys from Connecticut to Delaware and indicated that age-2+ relative abundance has been variable with high abundance occurring in the recent years of 2019-2022 before declining somewhat in 2023. The MAD index was developed from surveys in the Chesapeake Bay and showed high relative abundance in the late 1980s, with variable abundance throughout the rest of the time series, with 2021-2023 showing an increase from a time series low in 2020. The SAD was developed from surveys from North Carolina to Georgia and has been highly variable over time but generally showed an increasing trend since the early 1990s.

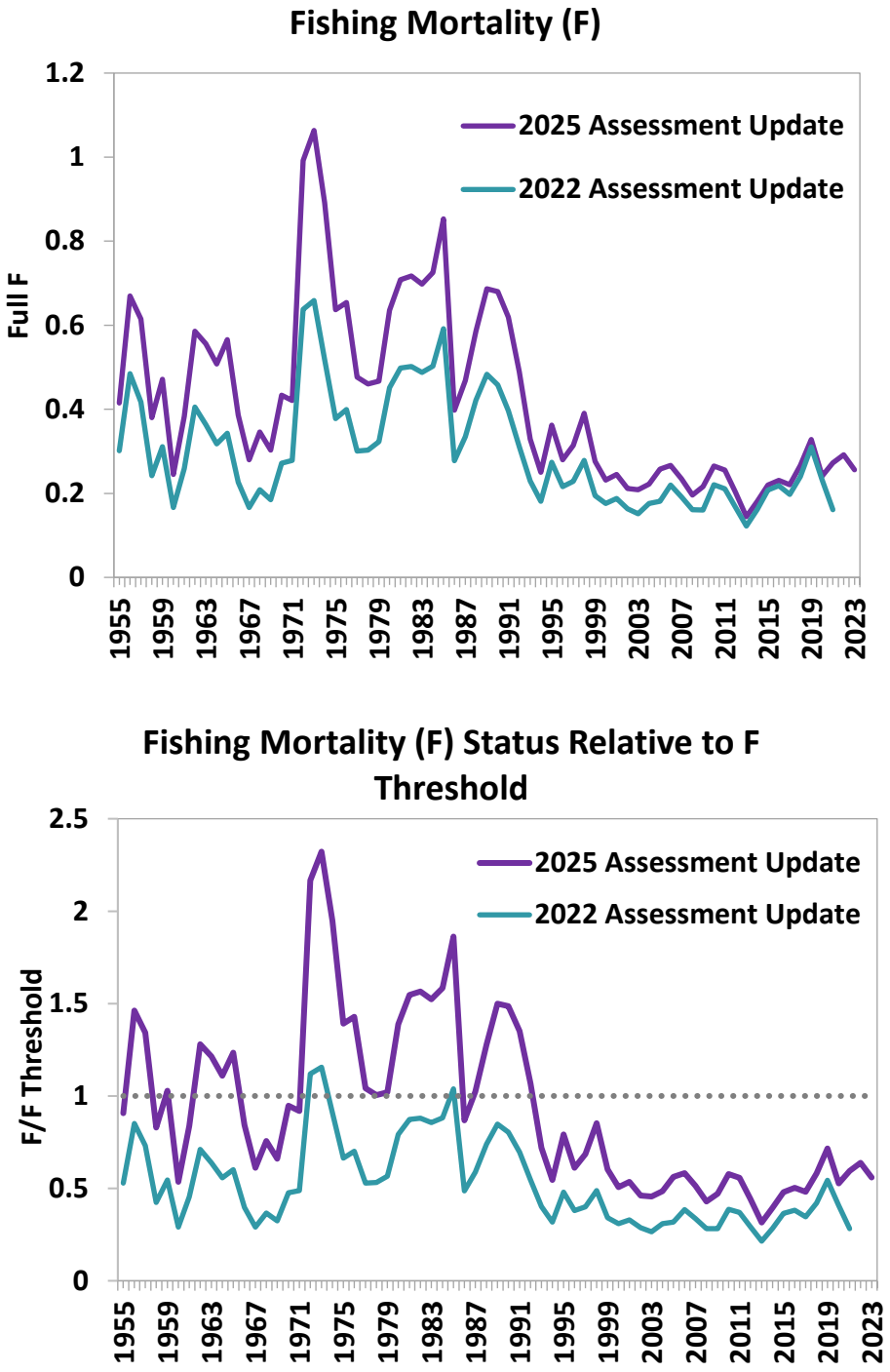


What Models Were Used?

Single-Species Model

The Beaufort Assessment Model (BAM), which was used for providing management advice during the 2020 benchmark stock assessment and the 2022 stock assessment update, was used again in the single-species update assessment. BAM is a statistical catch-at-age model that estimates population size-at-age and recruitment starting in 1955. The model estimates trends in the population, including abundance-at-age, recruitment, spawning stock biomass, egg production, and fishing mortality rates. BAM models the fishery as four separate fleets, separating the bait and reduction fleets into northern and southern regions to reflect differences in the way the fisheries have operated along the coast over time.

Model results indicate the population has undergone several periods of both high and low abundance. Following a peak in the late 1950s, adult abundance declined through the 1960s. Adult abundance increased in the late-1970s, was high until the mid-1990s, and then was somewhat lower in the 2000s, although not as low as in the 1960s. Adult abundance in 2023 was estimated at 14.8 billion age-1+ fish, slightly above the average of the past 20 years.



The estimates of fishing mortality F from the 2025 update (top) and the ratio of F to the ERP F threshold (bottom) were higher than the estimates from the 2022 update in all years, but the ratio was still less than one in recent years, indicating overfishing was not occurring.

Similarly, model results indicate recruitment was highest in the late 1950s followed by a period of very low recruitment in the 1960s. Recruitment has been variable but without a strong trend since the mid-1970s. Recruitment in 2023 was estimated at 44.5 billion age-0 fish, slightly above the average of the past 20 years. Biomass of age-1+ Atlantic menhaden was high in the 1950s, with lower values through the 1960s, 1970s, and 1980s. Biomass increased in the 1990s and was variable through the

2000s. Biomass of age-1+ menhaden has trended downward somewhat since a high in 2012, and was estimated at 1.82 million metric tons, just below the 20 year average.

The 2025 single-species assessment used a revised value of natural mortality that was lower than the value used in the 2020 benchmark and 2022 update. Natural mortality is the rate at which fish die from causes other than fishing; for menhaden, this includes things like predation, disease, and die-offs caused by low oxygen and warm water. This change was reviewed as part of the 2025 ERP Benchmark Assessment, and the Peer Review Panel agreed it represented the best available scientific information on natural mortality for Atlantic menhaden. As a result of this change, the estimates of recruitment, biomass, and fecundity were lower in the 2025 assessment update than the 2022 update, and the estimates of fishing mortality were higher.

ERP Model

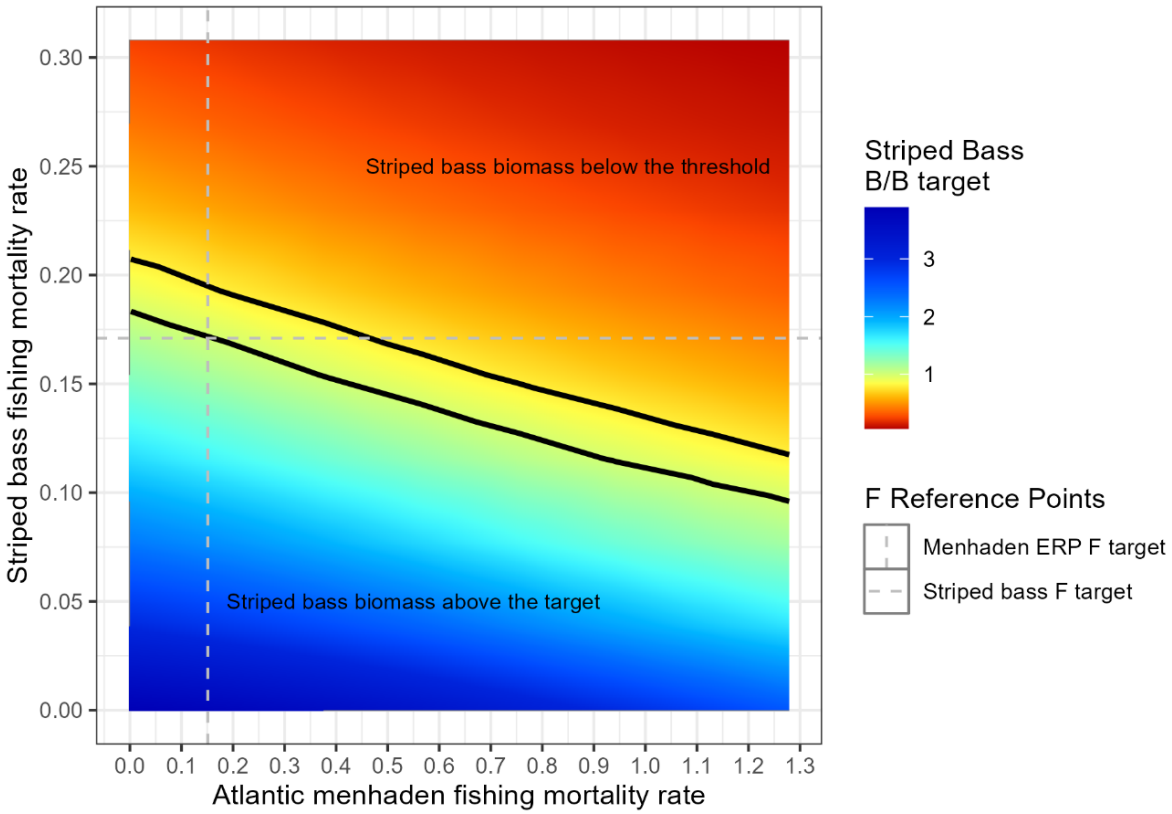
The 2025 ERP Benchmark Assessment focused on refining the Northwest Atlantic Coastal Shelf Model of Intermediate Complexity for Ecosystems (NWACS-MICE) used to develop Atlantic menhaden ERPs in 2020. The NWACS-MICE is an intermediate complexity Ecopath with Ecosim (EwE) model that focuses on four key predator species (striped bass, bluefish, weakfish, and spiny dogfish), and three key prey species (Atlantic menhaden, Atlantic herring, and bay anchovy). These predators were chosen because diet data indicated they were top predators of Atlantic menhaden and there were many available datasets to describe their population dynamics. The output from the NWACS-MICE model can be used in conjunction with the single-species (BAM) model to set the annual TAC for Atlantic menhaden and evaluate status relative to ERPs.

Ecological Reference Points

There is no one right ERP for Atlantic menhaden. The final definition and values for the ERP target and threshold is a management decision that accounts for management objectives of both Atlantic menhaden and their predators. In 2020, the Board defined the ERP target and threshold for Atlantic menhaden using the results of the ERP benchmark. The **ERP *F* target** was defined as the maximum rate of fishing mortality (*F*) on Atlantic menhaden that would provide adequate forage for striped bass at its biomass target when striped bass are fished at its *F* target. The **ERP *F* threshold** was defined as the maximum *F* on Atlantic menhaden that would provide adequate forage for striped bass at its biomass threshold when striped bass are fished at its *F* target. All other species were fished at status quo. Atlantic striped bass was the focal species for the reference points because it was the most sensitive predator fish species to Atlantic menhaden harvest in the NWACS-MICE model, so an ERP target and threshold that would provide adequate forage for striped bass would likely not cause declines for other predators in the model.

The ERP target and threshold for fecundity (a measure of the number of eggs the stock can produce in a year) were developed from the single-species model and defined as the long-term egg production expected if Atlantic menhaden is fished at the ERP *F* target and threshold, respectively.

However, the Board can re-evaluate those definitions at any time, using the tool developed through the 2025 ERP Benchmark Assessment. The accompanying rainbow surface plot from the NWACS-MICE model illustrates the tradeoffs between menhaden fishing mortality, striped bass fishing mortality, and striped bass biomass that could be evaluated by managers. Striped bass biomass is affected by both the fishing mortality rate from the striped bass fishery, and by the biomass of menhaden, which is affected by the fishing mortality rate from the menhaden fishery. The colors indicate where striped bass biomass would be in the long-term (relative to its target value) under different combinations of striped bass and Atlantic menhaden fishing mortality. Warmer, redder colors indicate lower striped bass biomass, while cooler, bluer colors represent higher striped



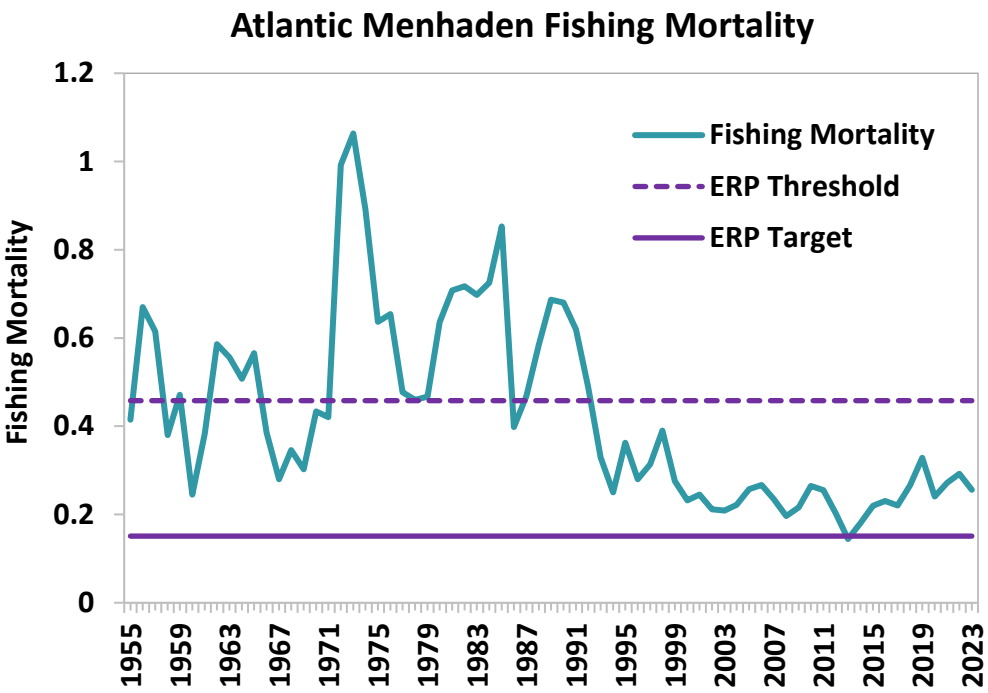
bass biomass. The lower left corner of the plot is where both striped bass fishing mortality and menhaden fishing mortality is low, and that corner is blue, indicating striped bass biomass would be well above the target in that scenario. Conversely, the upper right corner of the plot is where fishing mortality for both striped bass and menhaden is high; that corner is red, indicating striped bass biomass would be low, below both the target and the threshold. The solid black lines show combinations of striped bass *F* and Atlantic menhaden *F* that would maintain striped bass at its biomass target and threshold, respectively. There are many possible combinations to achieve these goals, but there are trade-offs: if *F* on striped bass increases, the *F* on Atlantic menhaden would need to decrease to keep striped bass at its biomass target, and vice versa. The horizontal grey dashed line indicates the striped bass *F* target, and the vertical dashed grey line is the menhaden ERP *F* target. They intersect on the solid black line where striped bass biomass is at the biomass target, meaning that if Atlantic menhaden are fished at the ERP *F* target and striped bass are fished at their *F* target, in the long run, striped bass will remain at their biomass target.

The current ERPs were based on the *F* and biomass targets established in the Amendment 7 to Atlantic Striped Bass Interstate FMP. Higher or lower reference points for striped bass will result in different reference point values for Atlantic menhaden. Similarly, this example maintained the other species at their current *F* rates, including some species that were experiencing overfishing. Higher or lower *F* rates on these other species would also result in different reference point values for Atlantic menhaden. Using the ERP approach (NWACS-MICE + BAM), managers and stakeholders can evaluate the tradeoffs between Atlantic menhaden harvest, predator harvest, and resulting biomass for all modeled species quantitatively and transparently in order to set the final ERP definitions, values, and subsequent TAC for menhaden.

What is the Status of the Stock?

Using the current definition of the ERPs as adopted by the Atlantic Menhaden Board in 2020, Atlantic menhaden are not overfished and not experiencing overfishing. Fecundity in 2023 was estimated at 1.2

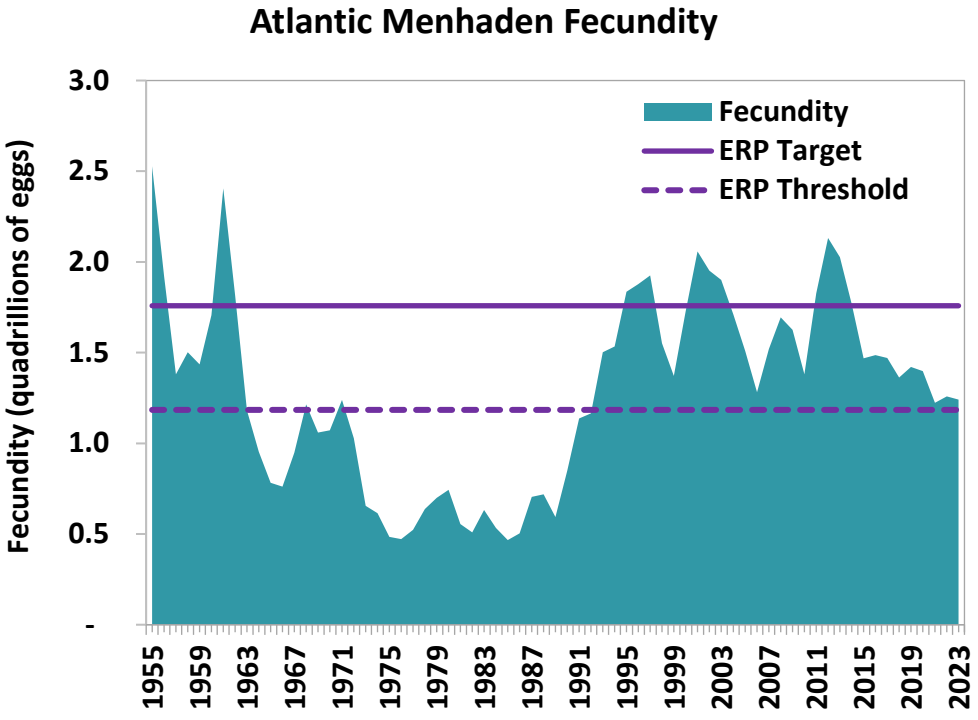
quadrillion eggs, above the ERP fecundity threshold but below the fecundity target. Fishing mortality in 2023 was estimated at 0.26, above the ERP *F* target but below the ERP *F* threshold. Although the change in natural mortality resulted in lower estimates of fecundity and higher estimates of fishing mortality in this assessment compared to the 2022 assessment update, stock status remains unchanged.



Research Needs

The single species update assessment identified a number of data and research needs for future Atlantic menhaden stock assessments. In particular, the Atlantic menhaden stock assessment would be substantially improved by the development of a coastwide fishery-independent survey to replace or supplement the existing indices, as well as the development of a Management Strategy Evaluation. There are several research recommendations specific to model diagnostics and data inputs to the existing model.

The ERP WG identified a number of research recommendations dealing with data collection and modeling. The ERP WG recommended expanding the collection of diet and condition data along the Atlantic coast to provide annual, seasonally- and regionally-stratified year-round monitoring of key predator diets, as well as improving the collection of diet data and monitoring of population trends for non-finfish predators (e.g., birds, marine mammals) and data-poor prey species (e.g., bay anchovies, sand eels, benthic invertebrates) to better parameterize the full ecosystem models. In addition, the ERP WG recommended further development of the multispecies statistical catch-at-age and the NWACS models to improve the spatial



and seasonal dynamics of the models and to incorporate additional predator feedback and environmental recruitment drivers. The ERP WG supported continued development of a spatial NWACS-MICE model using Ecospace to better address manager and stakeholder priorities but recommended that a spatial ecosystem objectives workshop be conducted first to explicitly identify those priorities.

Glossary

Age class – All of the individuals in a stock that were spawned or hatched in the same year. This is also known as the year class or cohort.

Beaufort Assessment Model (BAM) – BAM is a statistical catch-at-age model that estimates population size-at-age and recruitment, using 1955 as the base year, and then projects the population forward in time. The model estimates trends in the population, including abundance-at-age, recruitment, spawning stock biomass, egg production, and fishing mortality rates.

Biological reference point (BRP) – A particular value of stock size, catch, fishing effort, or fishing mortality that may be used as a measure of stock status or management plan effectiveness. BRPs can be categorized as limits, targets, or thresholds depending on their intended use.

Ecological reference points (ERPs) – As it is used for Atlantic menhaden, ERPs provide a method to assess the status of menhaden not only with regard to its own sustainability, but also with regard to its interactions with predators and the status of other prey species. This method accounts for changes in the abundance of several species when setting an overfished and overfishing threshold for menhaden. The benefit of this approach is that it allows fishery managers to consider the harvest of menhaden within a broad ecosystem context.

Fecundity (FEC) – The number of eggs produced per female per unit time (e.g., per spawning season).

Fishing mortality (*F*) – The instantaneous (not annual) rate at which fish are killed by fishing

MAD – Mid-Atlantic adult abundance index

Maximum spawning potential (MSP) – The estimated egg production from female spawning stock biomass that would occur in the absence of fishing. A percentage of this value (%MSP) can be used as a measure of the health of a fish stock.

Northwest Atlantic Continental Shelf Model of Intermediate Complexity for Ecosystem (NWACS-MICE) – NWACS-MICE is an intermediate complexity ecosystem model that focuses on four key predator species, striped bass, bluefish, weakfish, and spiny dogfish, and three key prey species, Atlantic menhaden, Atlantic herring, and bay anchovy. The model was used to develop Atlantic menhaden ERPs because it was the only model that could explore both the impacts of predators on menhaden biomass and the effects of menhaden harvest on predator populations, while being updateable in the management timeframe.

NAD – Northern adult abundance index

Overfishing – A condition in which the rate of removal of fish by the fishery exceeds to the ability of the stock to replenish itself.

Overfished – A condition in which there is insufficient mature female biomass or egg production to replenish the stock.

Recruitment – A measure of the weight or number of fish that enter a defined portion of the stock, such as the spawning stock or fishable stock.

SAD – Southern adult abundance index

Statistical catch-at-age (SCAA) model – An age-structured stock assessment model that works forward in time to estimate population size and fishing mortality in each year. It assumes some the catch-at-age data have a known level of error.

Young-of-the-year (YOY) – An individual fish in its first year of life; for most species, YOY are juveniles.

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