
Image courtesy of Brian Gratwicke

Introduction

Atlantic menhaden have supported one of the largest fisheries in the U.S. since colonial times and are also an important prey species for a variety of predators, including striped bass, bluefish, marine mammals, and sea birds. Ecological reference point (ERP) models are needed to quantify the effects of Atlantic menhaden harvest on its predators, to examine the impact of predators on Atlantic menhaden removal targets, and to quantitatively evaluate the tradeoffs between menhaden harvest and predator biomass. The importance of Atlantic menhaden as a forage fish and the need for ERPs has been long recognized. In 2015, the Atlantic States Marine Fisheries Commission's (ASMFC) Atlantic Menhaden Management Board formally requested the development of ERPs that account for Atlantic menhaden's role as a forage fish for use in management.

This document presents a summary of two reports: the 2019 Atlantic Menhaden Single-Species Benchmark Assessment and the Ecological Reference Points Stock Assessment. These assessments were peer-reviewed and approved by an independent panel of scientific experts through the 69th 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 for use in fisheries management and acknowledge the role of Atlantic menhaden as a forage fish.

Management Overview

The Atlantic menhaden stock is currently managed under Amendment 3 (2017) to the Interstate Fishery Management Plan (FMP). Amendment 3 changes fishery allocations from Amendment 2 (2012) in order to strike a better balance between gear types and jurisdictions. The Amendment allocates a 0.5% baseline quota to each jurisdiction and then allocates the rest of the annual total allowable catch (TAC) based on landings between 2009 and 2011. The Amendment also maintains the quota transfer process, prohibits the rollover of unused quota, maintains the 6,000-pound trip limit for non-directed and small-scale gears following the closure of a directed fishery, and sets aside 1% of the TAC for episodic events in the states of New York through Maine. For the 2018-2020 fishing years, the Board set the TAC at 216,000 mt with the expectation that these assessments and menhaden-specific ERPs will guide the TAC-setting process going forward.

What Data Were Used?

The Atlantic menhaden assessments used both 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 and a new fecundity study for Atlantic menhaden revised the values of natural mortality and fecundity 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. 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

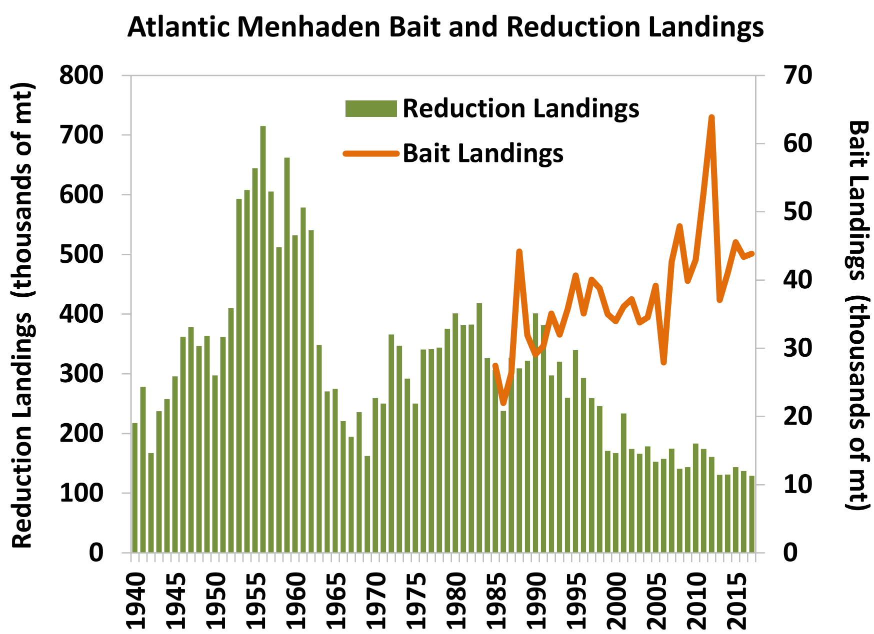
Life History

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 2010-2012, reduction landings averaged 172,600 mt. The first coastwide TAC for Atlantic menhaden was implemented in 2013 at 170,800 mt. The TAC has increased incrementally up to 216,000 mt for the 2018 to 2020 seasons, although annual coastwide landings have remained under 200,000 mt. In 2017, the terminal year of the assessments, reduction landings were 128,900 mt and accounted for approximately 74% of coastwide landings. Landings in the reduction fishery are currently at their lowest levels in the time series (1955-2017). Numerous portside samples are taken to obtain information about the weight, length, and age distribution of the fished population.

The Bait Fishery

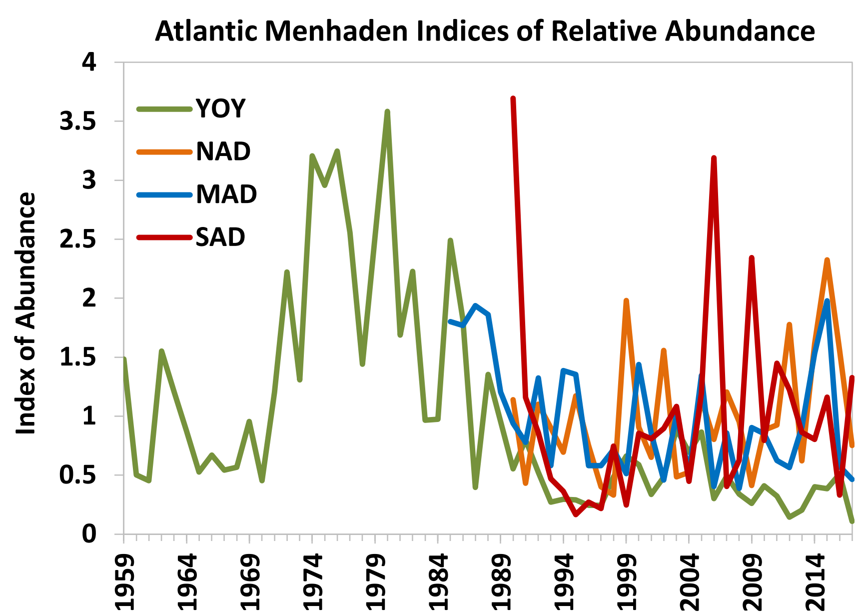
While reduction landings have declined since the mid-2000s, menhaden landings for bait have become increasingly important to the total coastwide landings of menhaden. Commercial bait landings occur in almost every Atlantic coast state. A majority of bait landings are used commercially in crab, lobster,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

Total bait landings along the Atlantic coast averaged 53,000 mt annually in 2010-2012. Following the implementation of the coastwide TAC, landings in 2013 were 37,000 mt. 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, peaking in 2012 at 63,900 mt. In 2017, bait landings were 43,900 mt and comprised 25% of coastwide landings. Recreational landings (menhaden caught by recreational anglers and used as bait on a single trip) comprised 1% of the 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 notable year classes in the mid-2000s and in 2016. 2017 had the lowest YOY abundance of the time series (1959-2017).

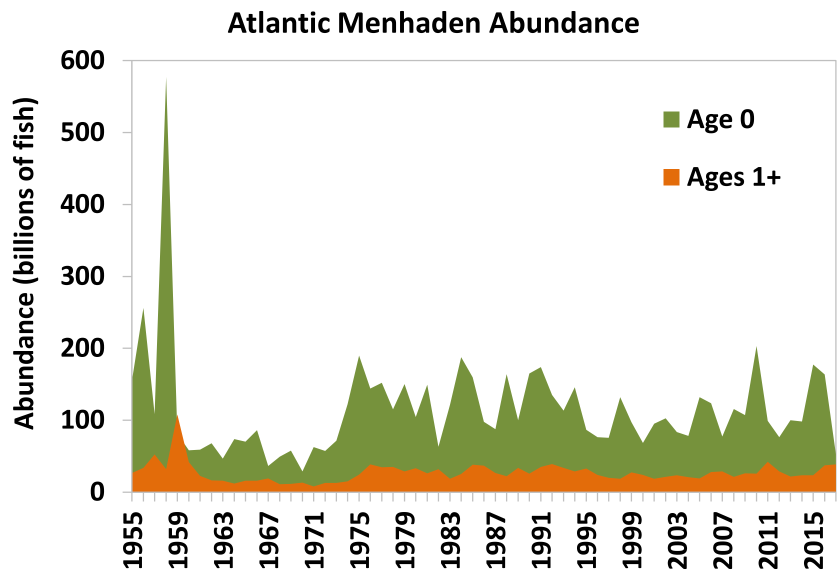
Three coastwide indices of adult abundance were developed from eight fishery-independent survey data sets: northern (NAD; age-2+), Mid-Atlantic (MAD; age-1+), and southern (SAD; age-1) adult indices. SAD was developed from surveys from North Carolina to Georgia and indicated that age-1 abundance was high in 1990 and low in recent years, with a notable increase in 2017. MAD was developed from surveys in the Chesapeake Bay and showed high relative abundance in the late 1980s, with variable abundance and then peaks in 2014 and 2015 followed by low abundance in 2017. NAD was developed



from surveys from Connecticut to Delaware and indicated that age-2+ relative abundance has been variable, but abundance was high in 2014, 2015, and 2016, followed by a decline in 2017.

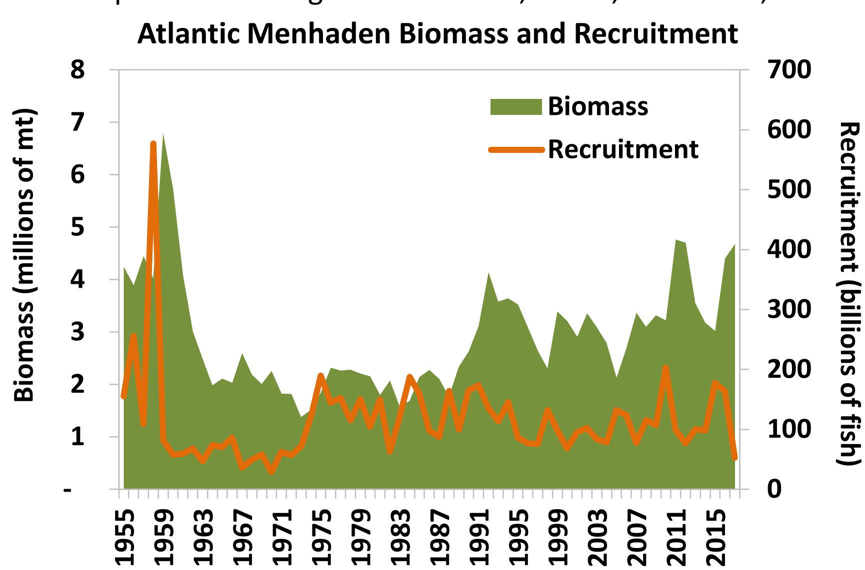
What Models Were Used?

Single-Species Model



The Beaufort Assessment Model (BAM), which was used for providing management advice during the 2015 benchmark stock assessment and the 2017 stock assessment update, was used again in the single-species assessment. 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. BAM was configured to be a fleets-as-areas model with the bait and reduction fleets broken into northern and southern regions to reflect differences in the way the fisheries operated along the coast and through 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 lower in the 2000s. Adult abundance in 2017 was relatively high. Juvenile abundance follows a similar pattern with highs in the 1950s, 1970s, and 1980s, a decline in the 1990s, and a slight increase through the late 2010s, with low juvenile abundance in 2017.



Similarly, model results indicate recruitment was highest in the late 1950s and while it has been variable over time, 2017 saw one of the lowest recruitment events in the time series. Biomass of age-1+ Atlantic menhaden also indicated biomass 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 was relatively high in 2017.

ERP Model

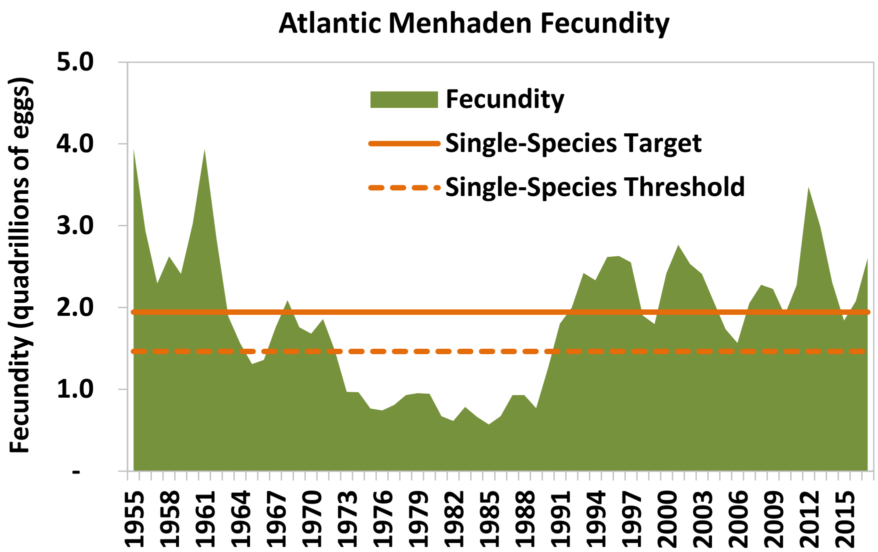
The ERP Workgroup explored a suite of different models, ranging from very simple models with minimal data requirements and few assumptions, to complex full-ecosystem models with extensive data needs and many detailed assumptions. The ERP Workgroup evaluated these models on the basis of their performance, their strengths and weaknesses, and their ability to meet the ecosystem management objectives that the Commission identified during a workshop held in 2015.

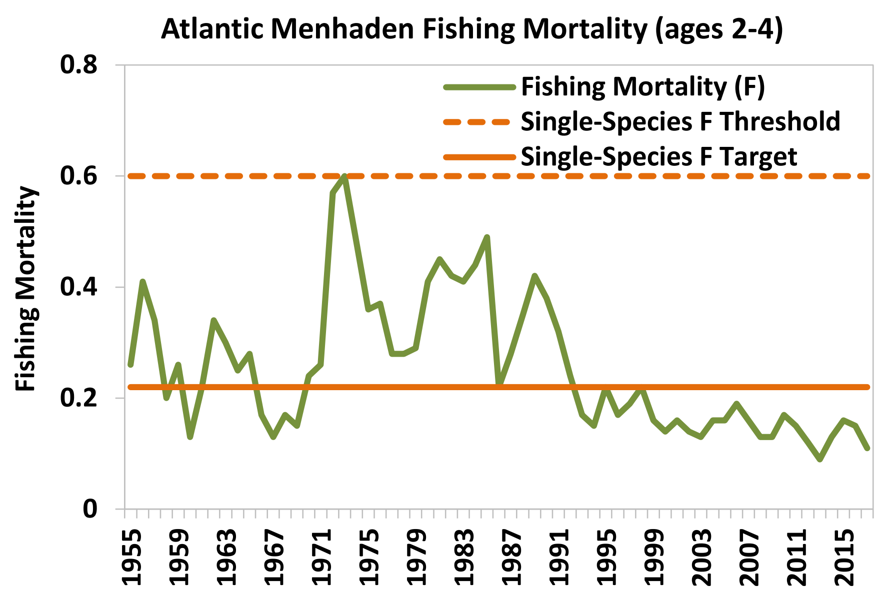
The ERP Workgroup chose the Northwest Atlantic Coastal Shelf Model of Intermediate Complexity for Ecosystems (NWACS-MICE) to develop Atlantic menhaden ERPs because it was the only model that could explore both the impacts of predators on menhaden biomass and the effects of menhaden harvest on predator populations, while being updateable in the management timeframe. The NWACS-MICE is an intermediate complexity Ecopath with Ecosim (EwE) model that focused 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 species 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.

What is the Status of the Stock?

The single-species assessment indicates the stock is not overfished nor experiencing overfishing relative to the single-species reference points in Amendment 3. These reference points used historical performance of the population during the 1960-2012 time frame, a period during which the Technical Committee considers the population to have been fished sustainably. Fishing mortality rates (*F*) have remained below the overfishing threshold (0.6) since the mid-1970s, and below the overfishing target (0.22) since the mid-1990s. Fishing mortality was estimated to be 0.11 in 2017 (the last year in the assessment). However, the ERP assessment indicates that the fishing mortality reference points for menhaden should be lower in order to account for menhaden's role as a forage fish.

Population fecundity, a measure of reproductive capacity (i.e., number of mature egg in the population), was highest in the early 1960s and from the 1990s to the present. In 2017, fecundity was above the single-species threshold and target.

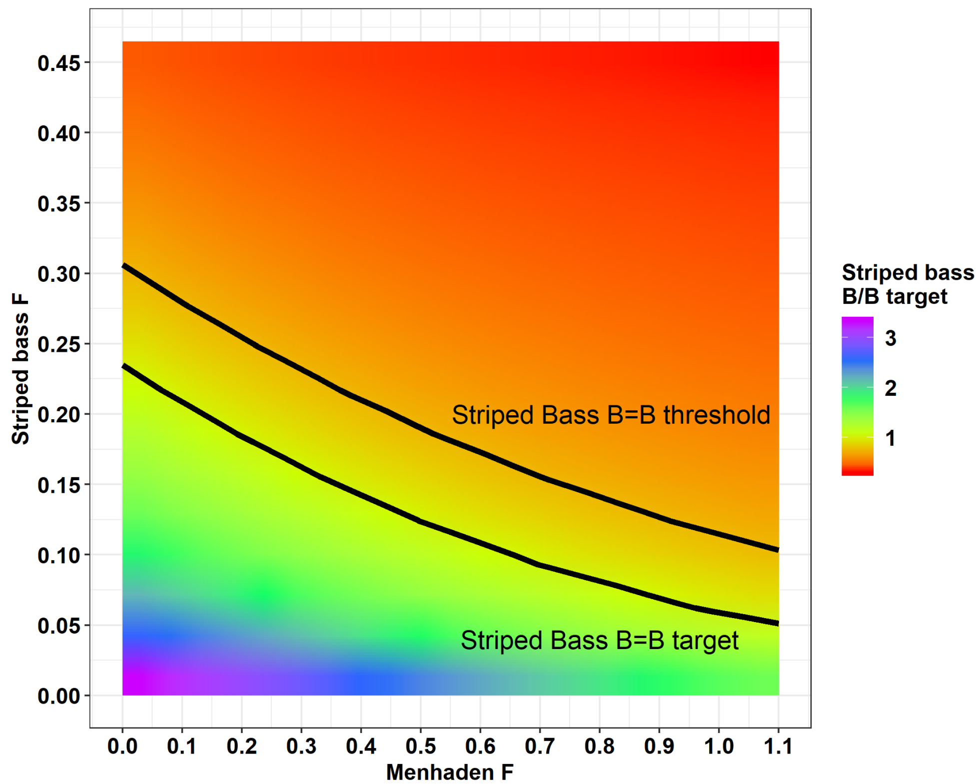




Ecological Reference Points

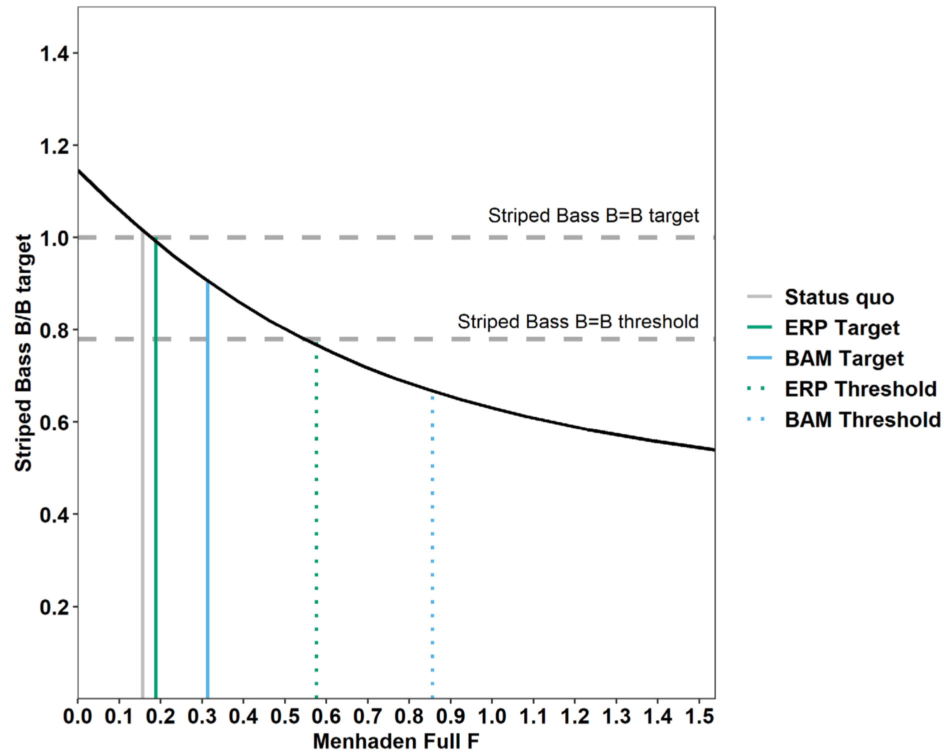
There is no one right ERP for Atlantic menhaden. The final definition and values for the ERP target and threshold will be a management decision that takes into account the management objectives of both Atlantic menhaden and their predators. The ERP Workgroup developed an example ERP target and threshold to show how this approach would work based on existing management objectives for Atlantic striped bass. Atlantic striped bass was the focal species for this analysis 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 sustained striped bass would likely not cause additional declines for other predators in the model. The example ERP target was defined as the maximum *F* on Atlantic menhaden that would sustain striped bass at its biomass target when striped bass are fished at its *F* target. The example ERP threshold was defined as the maximum *F* on Atlantic menhaden that would sustain striped bass at its biomass threshold when striped bass are fished at its *F* target. In the example scenarios, all other species were fished at status quo.

The accompanying rainbow surface plot from the NWACS-MICE illustrates a set of tradeoffs that could be evaluated by managers. 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. The solid black lines indicate 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 in order to keep striped bass at its biomass target, and vice versa.



The following description provides *example values* to illustrate a specific management scenario, where all species, except menhaden and striped bass, are fished at F_{2017} values. The example ERP target and threshold were lower than the current single-species target and threshold. The example ERP target was estimated at a full *F* of 0.19, compared to a full *F* of 0.31 for the single-species target. The example ERP threshold was estimated at a full *F* of 0.57, compared to a full *F* of 0.86 for the single-species threshold. The current estimate of full *F* from the single-species model is 0.16, below both the example ERP target and threshold.

This example was based on the *F* and biomass targets established in the 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.



Research Needs

The single-species 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.

Next Steps

Implementing reference points and tools to address ecosystem issues is a complex and multifaceted process. The full implementation of ecosystem-based fisheries management will require significant process and cultural changes to traditional fisheries management practices beyond simply new reference points for Atlantic menhaden. However, these new reference point methods for Atlantic menhaden are a critical next step in that implementation. While the Commission continues to refine the ERP models, collect better data, and consider changes to its management structure and process, managers can set harvest strategies for Atlantic menhaden that take into account its role as a forage fish in a transparent and quantitative way.

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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