## Introduction

This document summarizes the 2022 Stock Assessment Update for Atlantic herring, which was completed by NOAA Northeast Fisheries Science Center (NEFSC) and peer-reviewed in June 2022. The 2022 assessment is an update using the Age-Structured Assessment Model (ASAP) from the 2018 benchmark assessment that was peer-reviewed at the 65th Northeast Regional Stock Assessment Workshop/Stock Assessment Review Committee (SAW/SARC 65) meeting. The 2022 assessment update reflects the latest and best information available on the status of the Atlantic herring stock for use in fisheries management.

## Management Overview

Atlantic herring (*Clupea harengus*) are oceanic, plankton-feeding fish that occur in large schools and inhabit coastal and continental shelf waters from Labrador to Virginia. Juveniles (called sardines) undergo seasonal inshore-offshore migrations and are abundant in shallow, inshore waters during the warmer months of the year. Adults (age three and older) migrate south from summer and fall spawning grounds in the Gulf of Maine and Georges Bank to spend the winter in Southern New England and the Mid-Atlantic.

The Atlantic herring fishery is an important source of bait, particularly for the American lobster fishery. Because Atlantic herring can be found in both state waters (0-3 miles) and federal waters (3-200 miles), there are complementary management plans between the Atlantic States Marine Fisheries Commission (ASMFC) and the New England Fishery Management Council (NEFMC). Both the ASMFC and NEFMC fishery management plans set annual catch limits (ACLs) for three management areas and two sub-areas. The ACLs for these areas are set based on the maximum sustainable yield that allows for a sustainable harvest but leaves enough herring for fish, birds, and marine mammals. While the plans for state and federal waters share management boundaries, there are a few differences between the plans. The federal plan prohibits mid-water trawling from June 1 - September 30 in Area 1A (inshore Gulf of Maine). The ASMFC plan includes spawning closures and a "days out" provision for Area 1A. During a spawning closure or a "day out" of the fishery, vessels participating in other fisheries may possess no more than 2,000 pounds of Atlantic herring per trip and must stow all gear when traveling through Area 1A.

The 2022 assessment was used to inform specifications for the 2023-2025 fishing seasons. For the 2023 fishing season, ASMFC and NEFMC set the total ACL at 12,429 metric tons (mt) (27.4 million pounds). The ACL is further subdivided into sub-ACLs by the Atlantic herring management areas as follows: Area 1A = 3,592 mt (7.9 million pounds), Area 1B = 534 mt (1.2 million pounds), Area 2 = 3,455 mt (7.6 million pounds), and Area 3 = 4,847 mt (10.7 million pounds). ASMFC's Atlantic Herring Management Board established the following seasonal allocations for the 2023 Area 1A sub-ACL: 72.8% available from June 1 – September 30 and 27.2% available from October 1 – December 31. Directed fisheries within a management area close when 92% of the sub-ACL has been harvested, and the stock-wide fishery closes when 95% of the ACL is projected to be reached.

### Life History

Herring spawn as early as August in Nova Scotia and eastern Maine and during October and November in the southern Gulf of Maine, Georges Bank, and Nantucket Shoals. Spawning habitat consists of rock, gravel, or sand bottoms, ranging in depth from 50-150 feet. Females can produce between 30,000 and 200,000 eggs each. By their fourth year, fish are about 10" in length and may grow to about 15" (1 ½ pounds) by 15 to 18 years old. Herring are filter feeders preying entirely on plankton. They usually feed at night following the massive vertical migrations of zooplankton that inhabit deep waters by day and surface waters by night.

## What Data Were Used?

The Atlantic herring stock assessment used fishery-dependent and -independent data collected through state, federal, and academic research programs. Fishery-dependent data are collected from fish caught by commercial fisheries. Only data from commercial fisheries are used because the Atlantic herring fishery is predominantly commercial; only a very small percentage of harvest is recreational. Fishery-independent data are collected from fish caught through biological surveys that are operated independently from commercial fisheries. The 2022 assessment update includes data through 2021.

### Commercial Data

The stock assessment used commercial fishery landings and discards data. Commercially landed herring in the US are caught using mobile gear (e.g., purse seines and mid-water trawls). Commercially landed herring in Canada and a small portion of US-caught herring are caught using fixed gear (e.g., weir fishery). The mobile gear fishery catches a relatively broad range of ages, while the fixed gear fisheries harvest almost exclusively age-2 herring.

US catch data were reported for two aggregate gear types, fixed and mobile gears, for 1965-2021 (Figure 1). The reported catch is a sum of landings and self-reported discards. Available discard estimates are generally less than 1% of landings and do not represent a significant source of mortality. New Brunswick, Canada weir catches were provided for the years 1965-2021 and were combined with US fixed gear catches for the purposes of the assessment.

Catch in the mobile gear fishery peaked in the late 1960s and early 1970s, largely due to foreign fleets. Catch in the US fixed gear fishery has been variable, but has been relatively low since the mid-1980s. In the 2000s, total US landings were fairly stable around 207 million pounds (94,000 mt) but have been decreasing since 2013. In 2020 and 2021, US landings were around 17.8 million pounds (8,000 mt) and 11.4 million pounds (5,200 mt), respectively, which are the lowest landings in the time series.

**Figure 1. Atlantic Herring Commercial Landings**
Source: Northeast Fisheries Science Center, 2022
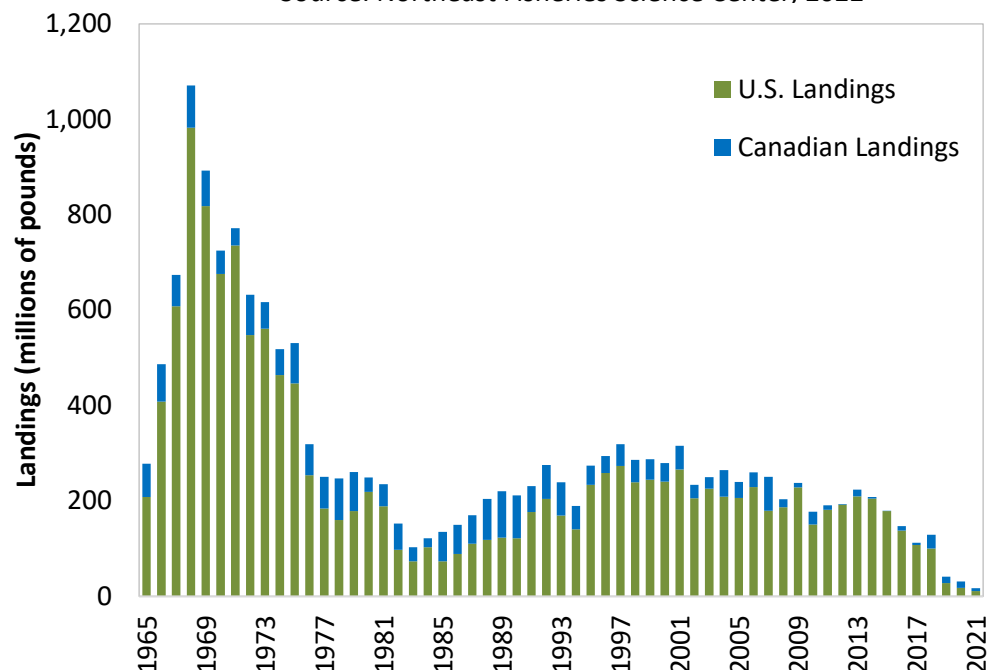
US landings are closely monitored throughout the year against the ACLs set for each area. After the fishing year ends, NOAA Fisheries reviews final landings and catch accounting. Canadian landings are monitored and reported by Fisheries and Oceans Canada.

### Fishery-Independent Surveys

Atlantic herring abundances (i.e., mean numbers per survey tow) from the NOAA Fisheries Summer Shrimp Survey, and the Spring and Fall Multispecies Bottom Trawl Surveys were used in the assessment model along with age composition data when available. The spring and fall surveys had three time periods: 1965-1984, 1985-2008, 2009-2021 to account for the changes in vessel and gear type. An acoustic time series collected during the NOAA Fisheries Fall Bottom Trawl Survey was also used as an index of age 3+ herring abundance. Several other indices of abundance were considered, but not used in the final assessment model. These indices included: NOAA Fisheries Winter Survey, Massachusetts state surveys (spring and fall), joint Maine/New Hampshire state surveys (spring and fall), and an index based on food habits data.

## How Were the Data Analyzed?

The Age-Structured Assessment Program (ASAP) model is the accepted model for the Atlantic herring stock assessment. The ASAP model uses fishery landings-at-age, as well as indices of abundance, to estimate annual stock size and fishing mortality rates. Indices of abundance indicate relative changes in abundance over time, while catch data provide information on the magnitude of abundance and the proportion of abundance removed by fishing. Age composition data link the information provided by indices of abundance and catch to specific year classes. Stock abundance is tracked by the model as new year classes recruit to the stock and then decline over time due to mortality (both natural and fishing).

The 2022 assessment used the ASAP model from the peer-reviewed 2018 benchmark assessment with two notable method updates for calculating the biological reference points and projections. First, the 2022 assessment accounted for mortality from the fixed gear fishery by using the most recent 10-year average of fixed gear fishing mortality. In previous assessments, only fishing mortality from the mobile gear fishery was included. Second, the 2022 assessment applied a subset of the recruitment time series (1992-2019) instead of the entire recruitment time series (1965-forward). A changepoint analysis identified 1992 as a changepoint in the recruits per spawner data, which suggests a shift in environmental conditions affecting recruitment at that time. The most recent recruitment estimates for 2020-2021 were not used due to uncertainty, as in previous assessments.
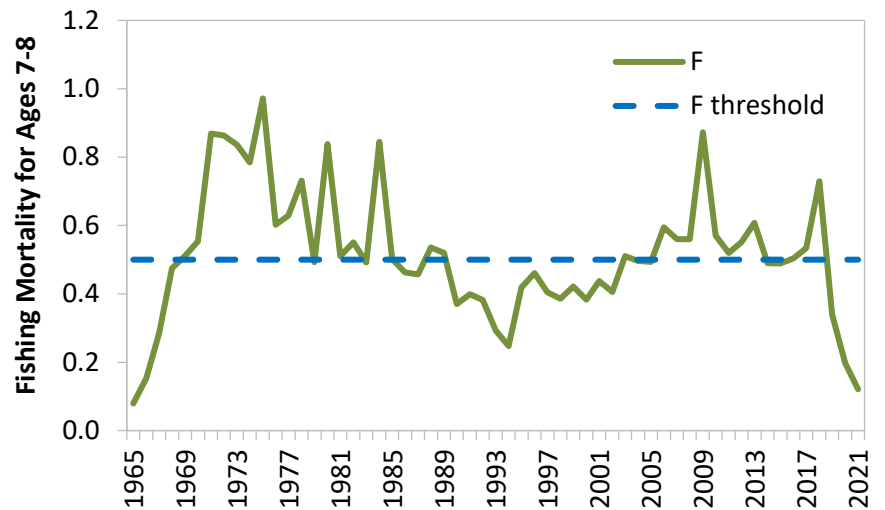
## What is the Status of the Stock?

The 2022 assessment indicates the Atlantic herring stock is overfished but not experiencing overfishing.

### Biological Reference Points

The reference points used for management are based on fishing mortality ($F$) and spawning stock biomass (SSB). The $F$ overfishing threshold is 0.5, which is calculated as a proxy associated with maximum sustainable yield (MSY). The corresponding SSB biomass target is 185,750 mt. The overfished threshold is ½ of the SSB target (92,875 mt).

*F* in 2021 for herring ages 7-8 was estimated to be 0.153 (accounting for retrospective pattern adjustment), which is well below the overfishing threshold of 0.5 (Figure 2). *F* for herring ages 7-8 is used for evaluation against the reference points because these ages are fully available to the mobile gear fishery which accounts for a majority of landings. *F* in 2021 was the lowest value since the mid-1960s.

SSB in 2021 was estimated to be 39,301 mt (accounting for retrospective pattern adjustment), which is only 21% of the SSB target of 185,750 mt and is below the overfished threshold of 92,875 mt (Figure 3). SSB has been declining since 2014, and the SSB estimates for 2020-2022 are the lowest values in the time series.



Figure 2. Atlantic Herring Fishing Mortality for Ages 7-8

### Recruitment

Continued poor recruitment is one of the main factors driving the current stock status of Atlantic herring. Age-1 recruitment has been below average since 2013. The all-time high of 1.4 billion fish occurred in 1971. While the 2009 and 2012 cohorts were relatively strong, recruitment has been consistently low since 2013 (Figure 3). The four lowest recruitment estimates in the time series occurred consecutively from 2015 through 2018.



Figure 3. Atlantic Herring Spawning Stock Biomass and Recruitment
Source: Northeast Fisheries Science Center, 2022
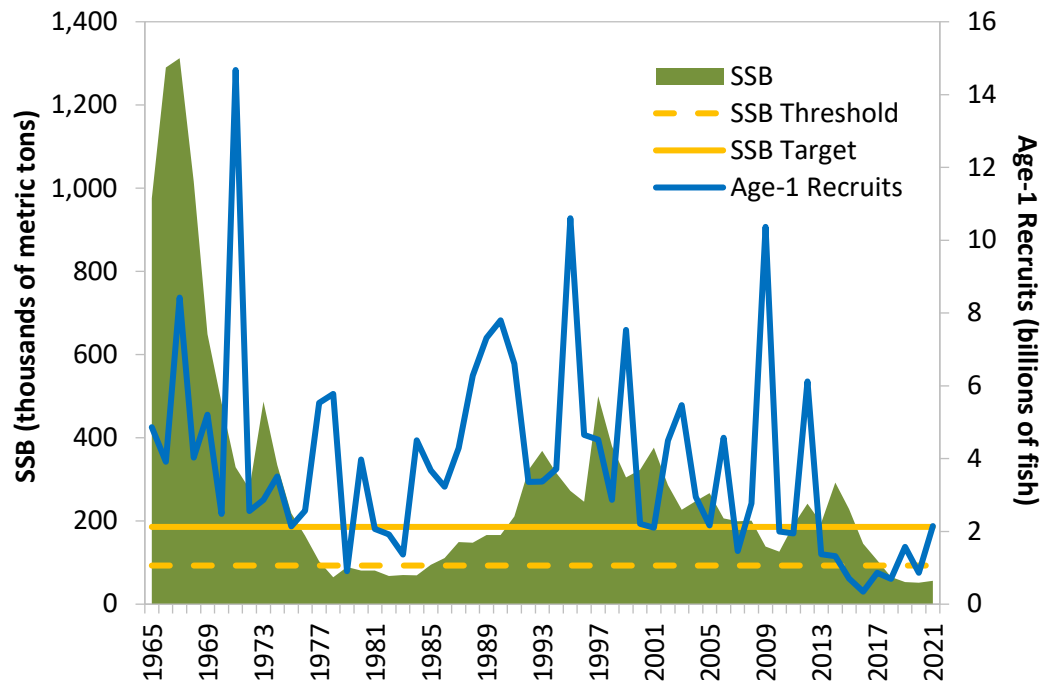
## Data and Research Priorities

The 2022 assessment and peer review report included several recommendations for future assessments. The Peer Review Panel highlighted four particular recommendations. First, direct age composition data from the Summer Shrimp Trawl Survey should continue to be collected to inform age data for future assessments. Second, a synthesis of the impacts of missing 2020 data (due to COVID-19) on the assessment model should be conducted. Third, a unified approach to representing natural mortality (M) in the assessment model should be considered to address the different representations of M throughout different herring assessments over time.

Fourth, more research should be done to continue developing a "dynamic reference points" approach (i.e., recruits per spawner data indicate a change from 1992 onwards) to identify causal hypotheses, such as environmental changes, to explain those patterns.

The assessment team also noted that studies related to stock structure and movement would be beneficial to potentially explain retrospective patterns. Additionally, the team noted that an index of herring age-1 recruitment based on seabird diet data should be further considered for future assessments to inform the recruitment index since current data do not consistently capture age-1 herring.

## Future Stock Assessments

The next management track assessment for Atlantic herring is scheduled for 2024, which will be used to set 2025-2027 specifications. The next research track (i.e., benchmark) assessment is scheduled for 2025.

## Glossary

**Age structure:** the separation of a fish population into distinct age groups

**Age-Structured Assessment Program (ASAP):** an age-structured stock assessment model that works forward in time to estimate population size and fishing mortality in each year

**Fishing mortality rate:** the instantaneous rate at which fish are killed by fishing

**Maximum Sustainable Yield (MSY):** The largest average catch that can be taken from a stock over time under existing environmental conditions without negatively impacting the reproductive capacity of 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. For this stock assessment, recruitment refers to the number of age-1 fish entering the population

**Retrospective pattern:** a pattern where the previous years' estimates of fishing mortality/abundance/ spawning stock biomass are over- or underestimated. Analysis of this pattern can indicate the model's sensitivity to the terminal year data.

**Spawning stock biomass (SSB):** the total weight of the mature females within a stock of fish; frequently used instead of total biomass as a better measure of the ability of a stock to replenish itself

**Stock assessment update:** also referred to as 'management track assessment'; incorporates data from the most recent years into a peer-reviewed assessment model to determine current stock status (abundance and overfishing levels)

**Year class:** All of the individuals in a given stock spawned or hatched in the same year; also known as an 'age class' or 'cohort'.

## References

ASMFC. 2009. Guide to Fisheries Science and Stock Assessments. Arlington, VA.
http://www.asmfc.org/uploads/file/GuideToFisheriesScienceAndStockAssessments.pdf

NEFSC, 2018. 65th Northeast Regional Stock Assessment Workshop (65th SAW) Assessment Report, Northeast Fisheries Science Center, Woods Hole, Massachusetts.

NEFSC, 2022. Atlantic Herring Management Track Assessment Report, Northeast Fisheries Science Center, Woods Hole, Massachusetts.

Miller, T., Y. Chen, Y. Jiao, and J. Wiedenmann, 2022. 2022 Management Track Peer Review Panel Report, Northeast Fisheries Science Center, Woods Hole, Massachusetts.