2022 Management Track Peer Review Panel Report

Thomas Miller (Chair)
Chesapeake Biological Laboratory,
University of Maryland Center for Environmental Science
Solomons, MD

Yong Chen
School of Marine and Atmospheric Sciences
Stony Brook University
Stony Brook, NY

Yan Jiao
Department of Fish and Wildlife Conservation
Virginia Polytechnic Institute and State University
Blacksburg, VA

and

John Wiedenmann
Department of Ecology, Evolution and Natural Resources
Rutgers University,
New Brunswick, NJ

Executive Summary

In the spring 2022 Assessment Oversight Panel (AOP) meetings, both Atlantic herring (*Clupea harengus*) and southern New England / Mid-Atlantic winter flounder (*Pseudopleuronectes americanus*) were recommended for an enhanced peer review via a Management Track Peer Review. The Management Track meeting was conducted virtually on June 27-29, 2022. In addition to the reviews of the assessments for the two stocks, the Management Track Peer Review meeting was also briefed on progress on both the **C**atch **A**ccounting and **M**onitoring **S**ystem (CAMS) in the National Oceanic and Atmospheric Administration's (NOAA) northeast region, and on development of standardized area-swept indices derived from the NOAA Northeast Fisheries Science Center (NEFSC) spring and fall fishery-independent trawl surveys.

Atlantic herring

The Peer Review Panel (*hereafter, the Panel*) concluded that the 2022 assessment for Atlantic herring provides the Best Scientific Information Available as a basis for management decision making in the northeast. The Panel concluded that the assessment met each of the 5 terms of reference fully. Based on its review, the Panel supports the following statements. **Herring was assessed to be overfished.** Herring spawning stock biomass (SSB) in 2022 was estimated to be 61,645 mt after correcting for a retrospective bias, approximately 33% of the SSB proxy =185,750 mt. **Herring was assessed not to be experiencing overfishing.** The exploitation rate of the mobile fleet fishery was F=0.097 approximately 19% of the $F_{40\%}$=F_{MSY} proxy = 0.5.

In reaching these conclusions, the Panel made several recommendations for continued sampling and future work. The Panel highlights the four recommendations to be of particular significance.

1) NEFSC should continue the collection of direct age composition data from the summer shrimp trawl. The resulting age compositions from using direct observations are notably different from those developed from borrowed age length data, as shown in the comparison of data from 2018-2019 and 2021.
2) Missing data from 2020 affected the herring assessment and will likely similarly affect other assessments. A synthesis of the impacts and potential remedies that missing data from 2020 may have on the estimation of parameters in NEFSC assessment models is warranted.
3) A unified approach to representing natural mortality (M) in the assessment model should be considered. Over different iterations of the herring assessment, M has been represented as age- and time-invariant, age-dependent, or tuned to predator demand. This approach suggests the form and level of M has been selected as a way of resolving poor model fits. A systematic and foundational approach to modeling mortality in key forage species is warranted.
4) An analysis of herring recruits per spawner indicated that data from 1992 onwards was most representative of future productivities. This approach is appropriate for a pelagic species such as Atlantic herring that tend to be sensitive to changes in its environment. More research needs to be done to continue developing such a "dynamic reference points" approach to identify causal hypotheses explaining the patterns.

SNEMA Winter Flounder

The Peer Review Panel (Panel) concluded that the 2022 assessment for SNEMA winter flounder provides the Best Scientific Information Available as a basis for management decision making in the northeast. The Panel concluded that the assessment met each of the 5 terms of reference fully. Based on its review, the Panel supports the following statements. **SNEMA winter flounder was assessed to not be overfished and overfishing was not occurring.** This is a substantial change in the perceived status of the SNEMA winter flounder stock, resulting largely from the change in how reference points were calculated. SNEMA winter flounder spawning stock biomass (SSB) in 2022 was estimated to be 3,353 mt, approximately twice the biomass threshold of 1,657 mt. The exploitation rate experienced by SNEMA winter flounder was F=0.061 approximately 23% of the $F_{40\%}$=F_{MSY} proxy = 0.265.

In reaching these conclusions, the Panel made several recommendations for continued sampling and future work. The Panel highlights the four recommendations to be of particular significance.

1) The assessment considered the dynamics of the SNEMA winter flounder stock in isolation from the dynamics in other neighboring stocks of this species on Georges Bank and in the Gulf of Marine. The focus on SNEMA limits the ability to detect shifts in fishery activity, or in stock distributions among the three stock areas. These three stocks should be assessed at the same time, to the extent practicable.
2) A comprehensive evaluation of spatial processes in this species is warranted. The evaluation should include analysis of temporal changes in the distribution of thermal habitats, changes in movement phenology and changes in availability of fish to the fishery and to surveys. These analyses should consider correlation structure among potential predictor variables and population responses at the local scale as well as at regional scales. Such analyses may identify the causes resulting in systemic patterns in lack of model fit for the recent years for some state and inter-state coastal surveys.
3) The Panel discussed adoption of a moving recruitment window of the last 20 years of observations. The Panel recognized the attractiveness of this approach as it reflects current patterns of stock productivity. When coupled with the concept that recruitments in SNEMA winter flounder are driven by temperature, this approach would explicitly recognize the impacts of climate change on the productivity of this stock. However, the adoption of a moving window approach lacks a firm quantitative grounding that is provided by the current regression tree-based identification of the change point.

Introduction

In the spring 2022 Assessment Oversight Panel (AOP) meetings, both Atlantic herring (*Clupea harengus*) and southern New England / Mid-Atlantic winter flounder (*Pseudopleuronectes americanus*) were recommended for an enhanced peer review via a Management Track Peer Review. The assessments were prepared under guidelines provided by the Spring 2022 AOP. These guidelines provide a pathway for continuing development of previously accepted assessments for each species including incorporation of the most recent data and understanding of biology of the species.

The Management Track meeting was conducted virtually on June 27-29, 2022. In addition to the reviews of the assessments for the two stocks, the Management Track Peer Review meeting was also briefed on progress on both the **C**atch **A**ccounting and **M**onitoring **S**ystem (CAMS) in the National Oceanic and Atmospheric Administration's (NOAA) northeast region, and on development of standardized area-swept indices derived from the NOAA Northeast Fisheries Science Center (NEFSC) spring and fall fishery-independent trawl surveys. The meeting agenda is provided in Appendix A and a list of meeting attendees in Appendix B.

We thank Russ Brown (Population Dynamics Branch Chief) and Michele Traver (Assessment Process Lead) for their support during the meeting. We thank the staff of the Population Dynamics Branch at NEFSC for the open and collaborative spirit with which they engaged the Panel. Our thanks extend not only to the analysts for each assessment, but also to the rapporteurs for taking extensive notes during the meeting, to staff of the New England Fishery Management Council/NOAA Fisheries Greater Atlantic Regional Fisheries Office, and to representatives of the fishing industry who provide context and additional background.

The Panel has suggestions for improvements that should be made for future Management Track Assessments with respect to information needs:

1. It was very helpful to have all background documents, information, and presentations available prior to the beginning of a stocks' review. Provided materials should include the full AOP report and summary, documentation of the current assessment, documentation of the preceding assessments back to the most recent benchmark (including peer review reports and relevant SSC reports), the most recent benchmark research track assessment (if different from the preceding), a table of the stock's status and reference points, and at least a draft version of the PowerPoint presentations. These should be provided to the reviewers in a single folder, rather than available through an online search tool.
2. Assessment update reports should match the requirements laid out in the Management Track Assessment Terms of Reference. For example, the analyst should list and respond to any review panel or SSC concerns relevant to the most recent prior assessments.

Atlantic herring

The 2022 assessment for Atlantic herring (hereafter herring) is an operational assessment of the existing age-structured model approved at the 65th Stock Assessment Workshop in 2018. The model represents herring as a single well-mixed population occupying a region from southern Nova Scotia, Canada, throughout the Gulf of Maine, and into waters of southern New England. Herring is modeled to comprise age classes from ages-1 to age 8+. The existing model considers two fishing fleets as harvesting removals from the herring stock: a fixed gear fleet that comprises nearshore seine and weir fisheries, principally in Canadian waters, and a mobile-gear fleet that comprises mobile coastal boats that deploy gear, principally purse seines and midwater trawls. The dynamics of the population is derived from four principal fishery-independent surveys: the NEFSC spring and fall surveys, the NEFSC summer shrimp survey and an NEFSC acoustic survey conducted during the fall bottom trawl survey. A time and age invariant natural mortality rate (M=0.35) was assumed. The current model was used to derive management reference points: an F_{MSY} proxy = F40% = 0.54, and a SSB_{MSY} = 269,000mt. Based on the most recent analysis of stock status in 2020, herring is overfished (SSB=77,883 mt; 29 % of SSB_{MSY}), but is not experiencing overfishing (F=0.25; 46% F_{MSY} proxy)

The 2022 assessment update for herring underwent an enhanced review (Level 3 assessment) in accord with the decision at the spring 2022 AOP. The new assessment used the same general configuration of an age structured assessment model (ASAP Version 3.0). Changes to the model configuration included updates of US catch data up to 2021 inclusive, improvements to the reliability and accuracy of the Canadian catch data, incorporation of updated fishery-independent surveys, consideration of unprecedented low levels of recruitment evident in the stock since 2013, inclusion of exploitation by the fixed-gear fleet in calculation of reference points and incorporation of an autoregressive approach to estimate future recruitments in short-term forecasts.

The Peer Review Panel (*hereafter, the Panel*) concluded that the 2022 assessment for Atlantic herring provides the Best Scientific Information Available as a basis for management decision making in the northeast. **Herring was assessed to be overfished.** Herring spawning stock biomass (SSB) in 2022 was estimated to be a retro-adjusted level 61,645 mt, approximately 33% of the SSB proxy =185,750 mt. **Herring was assessed not to be experiencing overfishing.** The exploitation rate of the mobile fleet fishery was F=0.097 approximately 19% of the $F_{40\%}$=F_{MSY} proxy = 0.5.

In the sections that follow, the Panel reviews information provided during the Management Track review to evaluate the extent to which each Term of Reference was met. We also offer research recommendations that we believe will improve our understanding of herring population dynamics and fisheries.

Atlantic herring Terms of Reference

1. *Estimate catch from all sources including landings and discards.*

The Panel concluded that the work completed fully met this TOR. The assessment included commercial catch data from 1965 – 2021. Commercial discard data are generally only available since 1996. These data indicate that commercial discards are generally less than 1% the commercial landings. There are no appreciable recreational fisheries for herring. Thus, for the assessment catch and commercial landings were assumed as synonymous.

The evidence presented to the Panel indicates that the catch was fully accounted for, and the age-composition of the catch was estimated comprehensively.

The Panel makes the following observations and recommendations relative the ToR 1:

- *The Panel recommends that NOAA NEFSC provide more detail on the DFO Canada program for enhancing and standardizing the processing and reporting of catch data, particularly as there are several prominent fisheries that are shared between the two nations.*

2. *Evaluate indices used in the assessment (e.g., indices of relative or absolute abundance, recruitment, state surveys, age-length data, etc.).*

The Panel concluded that this TOR was addressed satisfactorily. Data from four fishery-independent surveys were updated to 2021with no surveys being conducted in 2020. The four surveys include NEFSC spring and fall trawl surveys (1965-2021), a shrimp summer bottom trawl survey (1983-2021) and an acoustic survey (1998-2021). The NEFSC spring and fall surveys were entered as six separate surveys to account for vessel and gear differences (RV Albatross – door type A, 1968 – 1984 spring survey and 1965-1984 fall survey; RV Albatross – door type B, 1985- 2008; RV Bigelow 2009 -2021). In these early time series of NEFSC surveys, every tow was assumed to be equivalent samples. Enhancements in net mensuration allowed the switch to an area-swept approach to index development for data after 2008.

One potential index based on seabird diet analysis was explored. However, it was not used in the final assessment model due to poor model fitting and a lack of understanding of ecological and sampling aspects of the data.

Improvements in age-composition data associated with the shrimp summer survey were a second significant improvement in the fishery-independent for the 2022 herring assessment. Prior 2019, age-composition for this survey borrowed data from the NEFSC spring and fall trawl survey and were estimated as the average of the spring and fall survey age compositions. This may introduce additional errors in the estimated age compositions because of mismatched seasons. In 2019, direct aging of summer survey catches was initiated. Clear differences exist between the estimated selectivity pattern from using the borrowed averaged survey approach and the direct aging approach.

The Panel makes the following observations and recommendations relative the ToR 2:

- *The Panel concluded that the swept area-based indices are a substantial improvement in the treatment of survey data derived from the NEFSC spring and fall surveys.*

- *Arithmetic means were used for all survey indices. The Panel suggests exploration of model based approaches to standardizing relative abundance indices. The Panel suggests also exploration of spatio-temporal dynamics of Atlantic herring. Such approaches can also test hypotheses on changes in phenology and distributions*

- *The Panel encourages NEFSC to continue the collection of direct age composition data from the summer shrimp trawl. The resulting age compositions from using direct observations are notably different from those developed from borrowed age length data, as shown in the comparison of data from 2018-2019 and 2021. The dataset may provide a good opportunity to explore ALK differences among the three surveys to model seasonal growth for the herring stock, which may be further used for the length frequency data between 1983-1998 that were not used in the current assessment.*

- *The Panel remains unclear why the change from average age composition to direct age composition data had the sizeable impact on assessment results that was observed. The influence is confounded further by the influence of the missing 2020 surveys. Hypotheses and mechanisms related to this pattern are worthy of further work. One hypothesis that the Panel suggested to explore is the influence of the old length compositions from the shrimp survey. The current assessment model used the age-composition from the three most recent years with direct observations in model fitting, which may influence the stability of the model.*

3. *Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) as possible (depending on the assessment method) for the time series using the approved assessment method and estimate their uncertainty. Include retrospective analyses if possible (both historical and within-model) to allow a comparison with previous assessment results and projections, and to examine model fit.*
   a. *Include bridge runs to sequentially document each change from the previously accepted model to the updated model proposed for this peer review.*
   b. *Prepare a backup assessment approach that would serve as an alternative for providing scientific advice to management if the analytical assessment were to not pass review*

The Panel concludes that the 2022 assessment provides a thoughtful, staged transition between the 2020 assessment and the final recommended data selections and model configurations accepted in the 2022 assessment.

Runs of the 2020 assessment with sequential improvements to reflect the adoption of area swept-based relative indices, directly estimated age composition data from the summer shrimp trawl survey and revision of Canadian catch-at-age time series suggest these improvements do not material affect assessment results. However, the model that included all three sources of improvements demonstrated pathological forensic features, including 70 parameters with high CVs (>0.5) and strong correlations (~ |1|) among 1,654 parameter pairs. The panel found that the use of results from these stepwise explorations to support a conclusion that their impacts were likely small somewhat incongruous with the poor model diagnostics of the final exploratory model. The analyst suggested that the poor diagnostics were the result of missing survey data from 2020 and its impacts on the ability of the model to estimate recruitment in 2020 and 2021. The Panel discussed the impacts of the missing survey data for 2020, expressing surprise that a single missing year of data could have such impacts on model fit.

Efforts to resolve the deficiencies in the exploratory models focused on improving recruitment estimates. The Panel found one approach that used indices of nest provisioning of seabirds, mostly terns, worthy of continued exploration, but insufficient for use at this time. The Panel found a second approach of including a penalty on deviations in estimated recruitments from the median value was more satisfactory. Model results indicated much improved model diagnostics, with substantially lower CVs and few strong correlations among parameter pairs. Although the model with penalized recruitments did improve a range of diagnostics related to parameter uncertainty, the model still demonstrated strong retrospective patterns of a magnitude that required post-model adjustments. The Panel concluded that despite the presence of retrospective patterns, this model represents an appropriate basis for management decisions.

A Plan B assessment was prepared but unnecessary because the current ASAP assessment model was accepted; however we appreciated having the option of a failsafe approach had the principal approach using ASAP not been successful.

The Panel makes the following observations and recommendations relative the ToR 3:

- *The Panel enquired whether parameter estimates reaching bounds of parameter space may account for some of the poor model performance in early runs. Answers suggested this may be the case in some model configurations.*

- *The Panel is unclear on why the presence of missing survey data for 2020 had such a sizeable impact on fits of early model runs, yet these effects were dampened by the addition of recruitment deviation penalties. The Panel was also unclear how missing data in 2020 seemed to have an impact on the model estimate of recruitment in 2021, given that these data do not provide any information on the size of the 2021 year class. To what extent do we understand the characteristics of input data sets that lead to the apparent stability in ASAP model outputs? Simulations designed to explore the parameter space more fully, e.g., runs with stronger and or weaker recruitment penalties, may help enhance understanding.*

- *Inclusion of a recruitment deviation penalty was novel for herring, but common in assessments for many other species in the region. The Panel suggested systematic exploration of the role of recruitment penalties in the performance over the range of species assessments that employ them.*

- *The Panel also recommended monitoring of the impact that missing data from 2020 has on other assessments in the region to understand better the impacts and potential remedies that missing data may have on the estimation of parameters in the assessment model.*

- *The Panel expressed interest in promoting the development of a unified approach to representing natural mortality (M) in the assessment model. Over different iterations of the herring assessment, M has been represented as age- and time-invariant, age-dependent, or tuned to predator demand. This approach suggests the form and level of M has been selected as a way of resolving poor model fits. The Panel recommends a more systematic and foundational approach to modeling mortality in a key forage species.*

4. Re-estimate or update the BRP's as defined by the management track level and recommend stock status. Also, provide qualitative descriptions of stock status based on simple *indicators/metrics (e.g., age-* and *size-structure, temporal trends in population size or recruitment indices, etc.).*

The Panel concluded that this TOR was satisfactorily addressed.

The Panel accepted the change point analysis that identified distinct phases in recruit-per-spawner time series, specifically the identification of a final 1992-2021 period.

The Panel also accepted the use of a fixed F for the fixed gear fleet in projections to account for Canadian catches, which are not under management control of the NEFMC but do nevertheless affect estimation of stock productivity.

The Panel accepted the biological reference points of:
F_{MSY} proxy = $F_{40\%}$ = 0.5
SSB_{proxy} = 185,750 mt

Applying the required retrospective corrections, the revised biological reference points indicate that herring is overfished, but is not experiencing overfishing.

The Panel makes the following observations and recommendations relative the ToR 4:

- *The Panel would have felt more confidence in the identification of these distinct phases in the recruit-per-spawner time series had there been causal hypotheses explaining the patterns.*

- *Improvements in estimation of reproductive status and condition of herring over time would improve our understanding of the patterns observed in recruits-per-spawner*

5. Conduct short-term stock projections when appropriate.

The Panel concluded that this TOR was met.

Short-term projections of herring were conducted under two scenarios. In one scenario, the method used for projections in earlier assessments was applied. In a second scenario, and the one accepted by the Panel, an autoregressive model of rank 1 was fit to the recent recruitments as a foundation to project future recruitments.

The projections accepted as the Best Scientific Information Available are given below:

	Mobile Fleet F	SSB	P(overfishing)	P(overfished)	OFL	ABC	SSB/SSBmsy	P(rebuild)
2022	0.097	61645	0.000	0.989	–	–	0.332	0.000
2023	0.232	79231	0.000	0.677	29138	16649	0.427	0.025
2024	0.327	76795	0.109	0.683	32233	23409	0.413	0.033
2025	0.313	103645	0.167	0.397	40727	28181	0.558	0.105

The Panel noted that these projections suggest that in 2025, herring will have a 10.5% chance of attaining their rebuilding biomass – a lower than expected probability estimated in the current rebuilding plan.

6. Respond to any review panel comments or SSC concerns from the most recent prior research or management track assessment.

The Panel commends the assessment team for addressing two key research recommendations from the 2020 assessment: Accounting for fishing mortality from the fixed-gear fleet in calculating reference points, and refine and consider autoregressive models for short-term projections.

Recommendations remaining from previous assessment reviews that the Panel believe have merit include:

1) Further research on the use of acoustic technology for inclusion in stock assessment
2) Evaluate data collected in a study fleet program for informing assessment data that may include information on the distribution of herring in the water column
3) Evaluate the ability of state space models to estimate reliably observation and process error variances under a range of scenarios.

The Panel offers these additional recommendations.

- *Work to understand the protocols used by DFO Canada to modify their landings and develop ALKS for their fixed gear fishery.*

- *Improve our understanding of fleet dynamics of the herring fishery and how it might be related to changes in the spatial dynamics of the herring population.*

- *Although there is no evidence suggesting that the herring is moving out of the survey area, possible directional change in phenology of Atlantic herring (e.g., movement, growth and maturation) may introduce additional errors in survey abundance indices and biological data, giving the relatively fixed survey schedule. Further research may be needed to evaluate the impacts of changes in phenology on the Atlantic herring stock assessment modeling. Developing model-based abundance indices may also be useful to remove possible uncertainty in survey indices introduced by the directional changes in the environments.*

- *Further research might be needed to evaluate how the missing year 2020 survey might impact the assessment outcome and why the model performance deteriorated so much while the assessment outcome was still relatively stable. Was this related to the built-in constraints for parameters and model structure (e.g., survey selectivity) in the ASAP? The Panel recommends a systematic exploration of the role of recruitment penalties in the performance of the range of species assessments that employ them.*

- *A change-point analysis was conducted for the recruits-per-spawner (R/S) values to identify different stanzas for stock productivity. The R/S was used, instead of recruitment alone, for isolating the influence of environmental drivers on the stock productivity. The latest R/S stanza was then used in the long-term projection to estimate* SSB_{MSY}*. This approach is appropriate for a pelagic species such as Atlantic herring that tend to be sensitive to changes in its environment. More research needs to be done to continue developing such a "dynamic reference points" approach. The assessment* *team may also consider the SSB level in the projection since the change point analysis is based on R/S not R.*

- *Further research is needed to analyze herring condition and growth data collected by the Maine Department of Marine Resources to understand temporal changes in Atlantic herring fecundity and condition better.*

- *Further research is needed to continue development of recruitment indices based on seabird diet data.*

- *Major sources of natural mortalities and their temporal changes need to be carefully evaluated and quantified, and should be incorporated in the stock assessment in a systematic way, instead of using them in an ad hoc way to address issues arising in model diagnostics.*

Winter Flounder

Winter flounder (*Pseudopleuronectes americanus*) has been distributed historically from Nova Scotia and as far south as Virginia. The species is divided into three stock areas for management purposes: the Gulf of Maine (GOM) stock, the Georges Bank (GB) stock and the southern New England - Mid Atlantic stock (SNEMA). The SNEMA stock of winter flounder was assessed as a part of the management track peer review meeting. The SNEMA winter flounder assessment is an operational assessment of the existing age-structured model approved at the 52nd Stock Assessment Workshop in 2011. The species was previously assessed at the 2020 management track peer review meeting during which assessment models for all three species were considered.

For the 2020 assessment, catch was derived from four different sources: commercial landings, commercial discards, recreational landings and recreational discards. The existing model considers a single fishing fleet partitioned into three selectivity blocks (1981- 1993, 1994 - 2009, 2010- present). Age-dependent selectivities differing among the three blocks, but all are constrained to have selectivities of q= 1 for fish of age 4 and older. The scale of the population is derived from multiple surveys including the synoptic Northeast Fisheries Science Center's spring, winter and fall surveys, the NEAMAP survey as well as a number of state surveys. A time and age invariant natural mortality rate (M=0.3) was assumed. The 2020 assessment provided management reference points: an F_{MSY} proxy = F40% = 0.284, and a SSB_{MSY} = 12,322 mt. Based on the most recent analysis of stock status in 2020, SNEMA winter flounder was overfished (SSB=3,638 mt, but was not experiencing overfishing (F=0.077).

The 2022 assessment update for SNEMA winter flounder was subject to an enhanced review (Level 3 assessment) in accord with the decision at the spring 2022 AOP. The new assessment used the same general configuration of the previous age structured assessment model (ASAP). Changes to the model included updates of catch data to include data to 2021 developed through the new NEFSC CAMS approach, incorporation of swept area-based indices of relative abundance for the NEFSC spring and fall surveys. The calculation of reference points was also changed, using a shorter period of recent recruitments reflective of a sustained period of low recruitments for longer than the last decade. This change resulted in a large reduction in the SSB_{MSY} reference point. The new estimate of SSB_{MSY} = 3,314 mt is approximately 25% of the previous estimated

The Peer Review Panel (Panel) concluded that the 2022 assessment for SNEMA winter flounder provides the Best Scientific Information Available as a basis for management decision making in the northeast. **SNEMA winter flounder was assessed to not be overfished and overfishing was not occurring.** This is a substantial change in the perceived status of the SNEMA winter flounder stock, resulting largely from the change in how reference points were calculated. SNEMA winter flounder spawning stock biomass (SSB) in 2022 was estimated to be 3,353 mt, approximately twice the biomass threshold of 1,657 mt. The exploitation rate experienced by SNEMA winter flounder was F=0.061 approximately 23% of the $F_{40\%}$=F_{MSY} proxy = 0.265.

In the sections that follow, the Panel review information provided during the Management Track peer review to evaluate the extent to which each Term of Reference was met. We also offer research recommendations that we believe will improve our understanding of winter flounder biology, ecology and fisheries.

SNEMA Winter Flounder Terms of Reference

1. *Estimate catch from all sources including landings and discards.*

Work completed fully met this TOR. The 2022 assessment for SNEMA winter flounder is the first assessment to use the new CAMS approach to estimating catch. Statistical area catches from CAMS were compared to equivalent estimates derived from the area allocation (AA) approach. The two approaches differed by approximately 50 mt, which although small in absolute magnitude, represents almost one third of the total catch for the stock area. CAMS catches were slightly more than 50 mt lower than those estimated by the AA approach, with the amount reallocated approximately evenly between the GOM and Georges Bank stocks. The specific reasons for these differences are not clear and remain under investigation.

Landings time series from all four sources show a broad pattern of decline from 1981- 2021. Commercial landings for SNEMA winter flounder declined from in excess of 10,000mt in 1981 to 87 mt in 2021. Commercial discards demonstrate a broadly similar pattern. Recreational landings and discards show initial increases early in the time series, but exhibit consistently low levels after 2010. Overall, total catch of SNEMA winter flounder declined from about 18,000 mt in 1981 to 216 mt in 2021, well below the time series average of 5,396 mt.

The catch composition was well characterized.

The Panel makes the following observations and recommendations relative the ToR 1:

- *The Panel concluded that the impacts of changes in catch reporting from AA to CAMS had been fully addressed in subsequent sensitivity model runs.*

- *Although small in absolute terms, the difference between the CAMS and AA estimates of catch in the stock area was a significant portion of the total SNEMA catch. The Panel recommend*s *that further evaluation and comparison of CAMS and AA estimates is essential to provide a fuller understanding of how CAMS derived data may alter our perception of stock status and resilience.*

2. *Evaluate indices used in the assessment (e.g., indices of relative or absolute abundance, recruitment, state surveys, age-length data, etc.).*

The Panel concluded that this TOR was addressed satisfactorily.

All the survey indices used in the last management assessment (NEFSC spring, fall and winter bottom trawl surveys, NEAMAP spring survey, MADMF spring trawl survey, RIDMF spring survey, CTDEP spring survey, NJDFW ocean and river survey, and the University of Rhode Island Graduate School of Oceanography (URIGSO) survey) were updated. Among these surveys, only RIDMF and URIGSO conducted surveys in 2020. Swept area adjustment relative indices of abundance for the NEFSC bottom trawl survey indices (2008-current) were implemented for this assessment. Two YOY indices were updated and included in the stock assessment from MADMF and CTDEP surveys. All the survey indices showed a declining trend over time, especially after the early 2000s but to different degrees.

The Panel makes the following observations and recommendations relative the ToR 2:

- *The Panel realized that some survey indices were not used in the assessment and suggested that indices to be considered or not may be documented and explained in the future.*

- *Several surveys used in the assessment are local and only cover a small part of the stock distribution area. The declining trends across surveys and likely ages (reflected in the residual patterns in the assessment results) are different. The Panel suggests exploring the spatio-temporal dynamics of winter flounder based on alternative model-based approaches to test hypotheses on phenology changes and distribution variation, including shift. Such suggestions should be considered during the upcoming Research Track Assessment for inclusion in future assessments. The Panel also suggests splitting the NEFSC surveys because of the change from the RV Albatross to the RV Bigelow should be explored in future assessments.*

3. *Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) as possible (depending on the assessment method) for the time series using the approved assessment method and estimate their uncertainty. Include retrospective analyses if possible (both historical and within-model) to allow a comparison with previous assessment results and projections, and to examine model fit.*
    a. *Include bridge runs to document sequentially each change from the previously accepted model to the updated model proposed for this peer review.*
    b. *Prepare a backup assessment approach that would serve as an alternative for providing scientific advice to management if the analytical assessment were to not pass review*

The Panel concluded that this TOR was addressed satisfactorily.

Output from the final accepted model indicates that stock biomass has declined from in excess of 50,000 mt in 1981 to 4,689 in 2021. The terminal estimate of the SSB was 3,353 mt. Similarly, forecasts of recruitment declined from close to 70 million in 1981 to 4.4 million in 2021. The consistency of the decline induces a pattern in which recruitments were exclusively above the average level of recruitment before 2000, and largely below average after 2000. Age compositions demonstrate a consistent pattern over the last decade in which the model under-predicted the abundance of recruits and over-predicted the abundance of older (7+) fish. Diagnostic plots for fits to the survey data were unremarkable. The final accepted 2022 assessment model did demonstrate retrospective patterns in biomass and exploitation – but the strength of the retrospective bias was less severe than that that characterized the results of the earlier 2020 assessment. The magnitude of the retrospective pattern was not sufficient to require adjustments to the terminal estimates of SSB and F. Evaluation of retrospective peels indicated that much of the retrospective pattern appeared to result from fits to the age composition in the catch data.

A Plan B assessment was available but unnecessary because the ASAP assessment model was accepted; however, the Panel app appreciated having the option of a failsafe approach had the principal approach using ASAP not been successful.

The Panel makes the following observations and recommendations relative the ToR 3:

- *Discussions with analysts during the review meeting led the Panel to recommend that evaluation of the flat-topped selectivity functions for commercial landings may have a role in the age-dependent patterns in bias in age composition fits.*

- *The Panel recommends evaluation of the selectivity blocks in the commercial catch time series, which may also influence the pattern of bias in the age composition data in model fits.*

- *The Panel noted consistent latitudinal patterns in the fits to survey data. These patterns suggest that common spatial processes, involving perhaps latitudinal shifts in distribution or changes in the phenology of seasonal movements have affected the availability of winter flounder to surveys.*

4. *Re-estimate or update the BRP's as defined by the management track level and recommend stock status. Also, provide qualitative descriptions of stock status based on simple indicators/metrics (e.g., age-* and *size-structure, temporal trends in population size or recruitment indices, etc.).*

The panel concluded that this TOR was addressed satisfactorily

The current approach to generating reference points draws from the entire 1981 - 2019 recruitment time series. This approach was highlighted as a cause for concern by the 2020 Management Track Assessment report. To address this concern, reference points in this assessment were based on a reduced set of recent recruitments from 2002 - 2021. This shorter time period is characterized by lower recruitments than were observed in the period 1981- 2021. As a result the calculated biological reference point for biomass is considerable lower in the 2022 assessment (Target = SSB_{MSY} = 3,314 mt, Threshold = ½ SSB_{MSY} = 1,657 mt) than in the earlier 2020 assessment (Target = SSB_{MSY} = 12,322 mt, Threshold = ½ SSB_{MSY} = 6,161 mt). In contrast, because M was unchanged, the F reference points were little changed (2022 F_{MSY} proxy = $F_{40\%}$ = 0.265 vs 2020 F_{MSY} proxy = $F_{40\%}$ = 0.284).

As a result of the lower SSB_{MSY} estimate, the imputed stock status changed markedly. Whereas the 2020 assessment indicated the SNEMA winter flounder stock was overfished, **the more recent 2022 assessment indicated that the SNEMA winter flounder stock is not overfished**.

Owing to the implications of the change in reference points on the management system, the Management Track Peer Review meeting considered in some detail the justification for the recruitment time series selected for calculating reference points. Three lines of evidence point to the selection of 2002 as the suitable base for the recent time series. First, recruitment estimates prior to 2000 were consistently above average, whereas those after 2000 were almost uniformly below average. This suggests years around 2000 represent a good "change point." The second line of evidence was derived from consideration of time series of the average winter water temperature (January - March) in five dominant estuarine ecosystems from the Chesapeake Bay

(MD and VA) to Buzzards Bay, MA .These time series were compared to a 5ºC isotherm. Evidence from Able et al. (Able et al, 2014[1]) suggests that winter flounder recruitments are markedly lower when temperatures exceed this threshold. An aggregate temperature index calculated as the average of all five time series indicates that this index rarely exceeded the 5ºC isotherm before 2000, but more regularly exceeded this threshold after 2000. The final line of evidence derives from a regression tree analysis of the entire recruitment time series that indicated the presence of a significant breakpoint in the recruitment time series at 2002.

The Panel makes the following observations and recommendations relative the ToR 4:

- *The Panel appreciated the multiple lines of evidence that led to the selection of 2002 as the anchor for the recent recruitment time series. The Panel believe that while this selection might be somewhat arbitrary it was not capricious and is grounded in mechanistic and empirical analysis. The Panel supports the reference points developed from this shortened time series.*

- *The Panel notes that application of the most recent biological reference points indicates that the SNEMA winter flounder stock has never been overfished based on current definitions. However, this conclusion ignores that under previous reference points, based on periods of time when recruitments were higher, it is highly likely that SNEMA winter flounder was overfished.*

- T*he Panel discussed whether to recommend adoption of a moving recruitment window of the last 20 years of observations. The Panel recognized the attractiveness of this approach as it reflects current patterns of stock productivity. When coupled with the concept that recruitments in SNEMA winter flounder are driven by temperature, this approach would explicitly recognize the impacts of climate change on the productivity of this stock. However, the adoption of a moving window approach lacks a firm quantitative grounding that is provided by the regression tree-based identification of the change point.*

5. *Conduct short-term stock projections when appropriate.*

The Panel concluded that this TOR was addressed fully.

Short-term projections indicated that SSB will likely increase slightly under current harvest policies. The projections are:

[1] Able, K. W., T. M. Grothues, J. M. Morson and K. E. Colement. 2014. Temporal variation in winter flounder recruitment at the southern margin of their range: Is the decline due to increasing temperatures? ICES Journal of Marine Science 71: 2186-2197.

Year	Catch (mt)	SSB (mt)	F_{Full}
2022	441	3,472 (2,859 - 4,222)	0.114

Year	Catch (mt)	SSB (mt)	F_{Full}
2023	1,142	3,447 (2,845 - 4,156)	0.265
2024	1,276	3,894 (3,367 - 4,491)	0.265
2025	1,256	4,186 (3,666 - 5,011)	0.265

6. *Research Recommendations*

The Panel commends the assessment team for addressing two key research recommendations from the 2020 assessment involving the calculation of reference points based on a shorter period of recent recruitments.

Recommendations remaining from previous assessment reviews that the Panel believe have merit include:

1. *Additional studies on maximum age to ground estimates of M*

2. *Additional studies of maturity, particularly with regard to latitudinal patterns*

3. *Update and investigate migration / movement rates. The recent tagging study was completed in 1960. Advances in tagging study design including acoustic tagging studies and utilizing natural tags, such as otolith microchemistry and next generation sequencing for single nucleotide polymorphisms may be useful for this species, and are currently underway.*

4. *Investigation of regional population structure using genetic tools*

5. *Incorporation of environmental influences on recruitment, mortality and / or survey catchability using state-space models.*

The Panel offers these additional recommendations in support of ToR 6:

- *The assessment considered the dynamics of the SNEMA winter flounder stock in isolation from the dynamics in other neighboring stocks of this species on Georges Bank and in the Gulf of Marine. The focus on SNEMA limits the ability to detect shifts in fishery activity, or in stock distributions among the three stock areas. The Panel recommends that, to the extent practicable, these three stocks be assessed at the same time.*

- *Related to the above recommendation, the Panel recommends a comprehensive evaluation of spatial processes in this species. The evaluation should include analysis of temporal changes in the distribution of thermal habitats, changes in movement phenology and changes in availability of fish to the fishery and to surveys. The Panel notes that these analyses should consider correlation structure among potential* *predictor variables and population responses at the local scale as well as at regional scales. Such analyses may identify the causes resulting in systemic patterns in lack of model fit for the recent years for some state and inter-state coastal surveys.*

- *The Panel recommends evaluation of alternative model structures that may be robust to the patterns of biases evident in age composition fits in commercial catch data and in survey time series.*

- *The Panel recognizes that the moving window approach proposed in this assessment is to address realistic realizations of future recruitments used in the long-term projections. However, the Panel feels that the 20-year window may appear arbitrary in future assessments, as it will no longer be grounded in the change point analysis presented in this assessment. As a result, the Panel recommends further research to identify the appropriate basis for selection of the time period from which the observed recruitments are drawn to calculate SSB_{MSY}.*

Appendix A: Agenda for the June Management Track Peer Review Meeting, June 27-29, 2022

Google Meet joining info: https://meet.google.com/gwr-scrv-roh
Or dial: (US) +1 563-277-0710 PIN: 969 498 725#

AGENDA (v. 6/16/2022)

**All times are approximate, and may be changed at the discretion of the Peer Review Panel chair. The meeting is open to the public; however, during the Report Writing sessions we ask that the public refrain from engaging in discussion with the Peer Review Panel.*

Monday, June 27, 2022

Time	Subject	Presenter
10 a.m. - 10:15 a.m.	Welcome/Logistics/Conduct of Meeting	Michele Traver, Russ Brown, Tom Miller, Chair
10:15 a.m. - 11:15 a.m.	CAMS Discussion/Questions	PopDy Panel
11:15 a.m. - 12:15 p.m.	Atlantic Herring	Jon Deroba
12:15 p.m. – 12:30 p.m.	Discussion/Questions	Panel
12:30 p.m. – 12:45 p.m.	Public Comment	Public
12:45 p.m. – 1:30 p.m.	Lunch	
1:30 p.m. – 3:30 p.m.	Atlantic herring cont.	Jon Deroba
3:30 p.m. - 3:45 p.m.	Break	
3:45 p.m. - 5:30 p.m.	Atlantic herring cont.	Jon Deroba
5:30 p.m. – 5:45 p.m.	Summary/Discussion	Panel
5:45 p.m. - 6 p.m.	Public Comment	Public
6 p.m.	Adjourn	

Tuesday, June 28, 2022

Time	Subject	Presenter
9 a.m. - 9:05 a.m.	Welcome/Logistics	Michele Traver Tom Miller, Chair
9:05 a.m. - 10:45 a.m.	Atlantic herring cont.	Jon Deroba

Time	**Subject**	**Presenter**
10:45 a.m. - 11 a.m.	Break	
11 a.m. - 12 p.m.	Atlantic herring cont.	Jon Deroba
12 p.m. - 12:30 p.m.	Summary/Discussion	Panel
12:30 p.m. - 12:45 p.m.	Public Comment	Public
12:45 p.m. - 1:45 p.m.	Lunch	
1:45 p.m. - 3:15 p.m.	Southern New England/Mid-Atlantic winter flounder	Tony Wood
3:15 p.m. - 4 p.m.	Break	
4 p.m. - 4:45 p.m.	Southern New England/Mid-Atlantic winter flounder cont.	Tony Wood
4:45 p.m. - 5:15 p.m.	Summary/Discussion	Panel
5:15 p.m. - 5:30 p.m.	Public Comment	Public
5:30 p.m.	Adjourn	

Wednesday, June 29, 2022

Time	**Subject**	**Presenter**
9 a.m. - 5 p.m.	Report Writing	Panel

Appendix B: Attendees at the June Management Track Peer Review Meeting, June 27-29, 2022.

NEFSC - Northeast Fisheries Science Center
GARFO - Greater Atlantic Regional Fisheries Office
MAFMC - Mid-Atlantic Fisheries Management Council
NEFMC - New England Fisheries Management Council
ASMFC - Atlantic States Marine Fisheries Commission
CLF - Conservation Law Foundation
SMAST - University of Massachusetts School of Marine Science and Technology
MADMF - Massachusetts Division of Marine Fisheries
MEDMR - Maine Department of Marine Resources
NC DMF - North Carolina Division of Marine Fisheries

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Tom Miller - Chair
Yong Chen - Panel
John Weidenmann - Panel
Yan Jiao - Panel
Russ Brown - NEFSC
Michele Traver - NEFSC

Alex Dunn - NEFSC
Alex Hansell - NEFSC
Angela Forristall - NEFMC Staff
Anthony Wood - NEFSC
Ashely Asci - GARFO
Benjamin Levy - NEFSC
Brad Schondelmeier - MADMF
Brian Linton - NEFSC
Cameron Day - NEFSC
Carrie Nordeen - GARFO
Charles Adams - NEFSC
Charles Perretti - NEFSC
Chris Legault - NEFSC
Daniel Caless - GARFO
Daniel Hocking - GARFO
David Mussina - NEFMC Herring Advisory Panel
Emilie Franke - ASMFC
Erica Fuller - CLF
Gerry O'Neill - Cape Seafoods
Jamie Cournane - NEFMC Staff
Jeff Kaelin - Lund's Fisheries
Jon Deroba - NEFSC
Kathy Sosebee - NEFSC
Katie Almeida - Town Dock
Kelly Whitmore - MADMF
Kiersten Curti - NEFSC
Larry Alade - NEFSC
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Liz Sullivan - GARFO
Melissa Smith - MEDMR
Maria Fenton - GARFO
Mary Beth Tooely - O'Hara Corporation (Maine)
Mark Terceiro - NEFSC
Matt Cieri - MEDMR
Megan Ware - MEDMR
Mike Celestino - New Jersey Fish and Wildlife
Pat Campfield, ASMFC Director of Fisheries Science Program
Paul Nitschke - NEFSC
Rachel Feeney - NEMFC Staff
Raymond Kane - Cape Cod Fishermen's Alliance
Richard Klyver - Maine stakeholder
Robin Frede - NEFMC Staff
Sara Weeks - NEFSC
Tara Dolan - NOAA QUEST program
Talya tenBrink - NEFSC (on detail)
Tom Nies - NEFMC Executive Director
Toni Chute - NEFSC
Tracey Bauer - NC DMF

draft working paper for peer review only

Atlantic Herring

2022 Management Track Assessment Report

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts

Compiled May 2022

This assessment of the Atlantic Herring (Clupea harengus) stock is a management track assessment of the existing 2020 management track assessment conducted using the ASAP model. Based on the previous assessment, the stock was overfished but overfishing was not occurring. This assessment updated fishery catch data, survey indices, life history parameters (e.g., weights-at-age), and the ASAP assessment model and reference points (BRPs) through 2021. Several notable changes were made and these were described more thoroughly below.

State of Stock: The methods used to derive BRPs and conduct short-term projections were changed as part of this management track assessment. Briefly, two notable changes were made to the methods used to calculate BRPs: 1) as recommended in the previous management track, long-term projections used to define BRPs accounted for mortality from the fixed gear fishery. The fishing mortality equaled the average of the estimated fishing mortalities from the most recent 10 years. 2) The recruitment stanza used to define BRPs was 1992-2019. The sequence of poor recruitments at the end of the time series suggested an unprecedented situation that made continued use of the entire time series (i.e., beginning 1965) untenable. It is likely that some combination of spawning stock size and environmental conditions are driving recruitment. A changepoint analysis (Killick and Eckley 2014) was applied to the recruitment and recruits/spawner time series to disentangle these effects. The analysis identified a changepoint in 1992 in the recruits/spawner time series that was not identified in the recruitment time series, suggesting a shift in environmental conditions effecting recruitment happened at that time. Thus the range of years used to define BRPs was 1992-2019 (2020-2021 estimates were not used due to uncertainty, as in previous assessments). Based on this management track assessment, the Atlantic Herring (*Clupea harengus*) stock is overfished and overfishing is not occurring (Figures 1-2). Retrospective adjustments were necessary (SSB Mohn's rho = 0.447 and F Mohn's rho = -0.21). Spawning stock biomass (SSB) in 2021 was estimated to be 39,091 (mt) which is 21% of the biomass target (SSB_{MSY} $proxy$ = 185,750; Figure 1). The 2021 average fishing mortality for ages 7-8 (fully selected ages for the mobile fleet) was estimated to be 0.153 which is 31% of the overfishing threshold proxy (F_{MSY} $proxy$ = 0.5; Figure 2).

Table 1: Catch and status table for Atlantic Herring. All weights are in mt, recruitment is in 000s, and $\bar{F}_{7-8}$ is the average fishing mortality on ages 7 to 8, which are fully selected by the mobile fleet. Model results are from the current updated ASAP assessment and the values in this table are not adjusted for the retrospective pattern.

	2014	2015	2016	2017	2018	2019	2020	2021
			Data					
US Catch	93,084	81,204	62,597	48,796	45,527	12,792	8,076	5,202
Canadian Catch	1,465	146	4,132	2,133	13,036	5,821	6,041	2,663
Total Catch	94,549	81,350	66,729	50,929	58,563	18,613	14,117	7,865
			Model Results					
Spawning Stock Biomass	292,370	228,600	145,350	105,790	65,529	53,441	51,749	56,566
$\bar{F}_{7-8}$	0.48934	0.48842	0.50347	0.53369	0.7291	0.3394	0.19665	0.1207
recruits (age1)	1,316,100	704,910	343,530	859,750	692,800	1,571,000	863,790	2,144,500

Table 2: Comparison of reference points estimated in an earlier assessment and from the current assessment. An $F_{40\%}$ proxy was used for the overfishing threshold, and the biomass proxy reference point was based on long-term, stochastic, projections. 95% CI were reported in parentheses.

	2020	2022
F_{MSY} *proxy*	0.54	0.5
SSB_{MSY} (mt)	269,000 (155,699 - 444,290)	185,750 (91,100 - 355,800)
MSY mt	99,400 (62,644 - 151,814)	68,980 (37,390 - 120,154)
Median recruits (age 1)	3,430,614 (915,478 - 10,132,087)	2,820,600 (578,900 - 10,441,500)
Overfishing	No	No
Overfished	Yes	Yes

Projections: The short-term projections presented here differed from the previous assessment in that they assumed recruitment followed an autoregressive process (AR(1)) rather than random draws from the cumulative distribution of estimated recruitments. The paramters defining the AR process were estimated using recruitment estimates from 1992-2019 using the R package arima (R Core Team 2020). The AR process was initiated using the rho adjusted 2021 recruitment estimate (i.e., 1,483,061). The projection results included here should be considered preliminary and subject to change based on future assessment and management decisions. This example projection applied the harvest control rule described in Amendment 8 of the hering Fishery Management Plan to the mobile fleet. The fixed gear catches are assumed constant during the projection period and equaled 4,238 mt. This fixed gear catch equals the sum of the ten year (2012-2021) averages of the Canadian (4,220 mt) and US (18 mt) fixed gear catches. The US fixed gear catches are those from stop seines, weirs, and pound nets. The reported $\bar{F}_{7-8}$ are those for the mobile fleet.

Table 3: Projection results. See above and supplementary document for details.

Year	Catch mt	SSB (mt)	$\bar{F}_{7-8}$
2022	8,767	61,645	0.097

Year	Catch mt	SSB (mt)	$\bar{F}_{7-8}$
2023	16,649	79,231	0.232
2024	23,409	76,795	0.327
2025	28,181	103,645	0.313

Special Comments:

- What are the most important sources of uncertainty in this stock assessment? Explain, and describe qualitatively how they affect the assessment results (such as estimates of biomass, F, recruitment, and population projections).

  A definitive explanation for the continued poor recruitment has not been identified. While identifying a causal mechanism for poor recruitment would be immensely beneficial, finding explanations for patterns in recruitment have been elusive in fisheries science for decades. Another uncertainty in this assessment is natural mortality. In this assessment, natural mortality was assumed constant among ages and years. Justifications for including age- or time-varying natural mortality in previous assessments have quickly deteriorated. Uncertainty in natural mortality affects the scale of abundance and fishing mortality estimates, but is unlikely to be related to the recent poor recruitments. Stock structure, particularly mixing with Nova Scotian herring, is also an uncertainty. Migration can be conflated with changes in mortality and contribute to retrospective patterns. Again, however, this is unlikely to explain recent poor recruitment.

- Does this assessment model have a retrospective pattern? If so, is the pattern minor, or major? (A major retrospective pattern occurs when the adjusted SSB or $\bar{F}_{7-8}$ lies outside of the approximate joint confidence region for SSB and $\bar{F}_{7-8}$).

This assessment model had a retrospective pattern that could be classified as major and required adjustments. While recent assessments have not had major retrospective patterns, these assessments also suggested that the lack of a retrospective pattern could be due to structural changes in the model (e.g., splitting the NMFS BTS survey in 2009 when the R/V Bigelow came into service; NEFSC 2018) and so the reemergence of a retrospective pattern was not suprising.

- Based on this stock assessment, are population projections well determined or uncertain? If this stock is in a rebuilding plan, how do the projections compare to the rebuilding schedule?

  The projections are uncertain, especially in regards to recruitment. The lack of 2020 survey data, and the fact that neither indices of abundance or the fishery consistently harvest age-1 herring, made estimation of the most recent two years of recruitment impossible without the addition of a likelihood penalty. Without other information about recruitment, the likelihood penalty has the effect of pulling the more recent recruitment estimates (i.e., 2020 and 2021) upwards towards the median. The upward increase in recent recruitments was partially offset in projections by applying a retrospective adjustment. Furthermore, assumptions about terminal year recruitment do not have much effect on projection results for 3 or more years because herring are 50% selected by the mobile fleet at about age-4, which causes a delay in the effect of terminal year recruitment assumptions. Just the same, recruitment is a significant uncertainty. Based on the projections done during this management track, the stock is behind the rebuilding schedule (See Framework 9 table 26). The rebuilding plan suggested the population would have a 43% chance of rebuilding by 2025, but this assessment projects only an 11% chance in that year. The rebuilding plan, however, used the full time series of recruitments when defining reference points and proejctions, which makes them more optimistic than the shortened time frame of recruitments and the AR(1) process applied in this assessment. A sensitivity using an AR(1) process was done during development of the rebuilding plan, but even those projections were more optimistic (25% chance of rebuilding in 2025) than those done during this assessment.

- Describe any changes that were made to the current stock assessment, beyond incorporating additional years of data and the effect these changes had on the assessment and stock status.

  NMFS bottom trawl indices of abundance since 2009 were calculated using tow-specific measured tow distance, instead of an assumed constant for all tows. This change had a negligible effect. The methodology used to calculate Canadian catches, age composition, and weights at age was revised, resulting in entirely new time series, but the effect on the assessment was negligible. The age composition of the NEFSC shrimp survey was previously based on an average of the NMFS spring and fall age-length keys. Three years of age data collected during this survey replaced the use of borrowed age-length keys, and this had a negligible effect on the assessment. The addition of a likelihood penalty on recruitment became necessary given the lack of information about recent cohort sizes (i.e., missing 2020 survey data). The likelihood penalty had the effect of increasing the estimates of recent recruitments toward the median level. The two most recent recruitments were still relatively poor, however, and were excluded when calculating BRPs and when estimating parameters of the AR(1) process used in short-term projections. Thus, the overall effect of the penalty on the assessment and stock status was negligible. An attempt was made to avoid using the likelihood penalty by deriving an age-1 recruitment index from seabird diet data. While an assessment that included such an index did not require a likelihood penalty, the model did not fit the index well (e.g., patterned residuals). Concerns about non-linearity between the seabird index and herring recruitment, and a lack of time to understand this novel data source, precluded its use in this assessment. An index derived from seabird diet data has promise, however, and could be persued in the future.

- If the stock status has changed a lot since the previous assessment, explain why this occurred.

  The stock status has not changed a lot since the previous assessment.

- Provide qualitative statements describing the condition of the stock that relate to stock status.

  Continued poor recruitment is the main issue driving stock status. Management decisions that reduced US catches had the effect of avoiding overfishing.

- Indicate what data or studies are currently lacking and which would be needed most to improve this stock assessment in the future.

Studies related to stock structure and movement would be beneficial, as this has been proposed as a possible explanation for retrospective patterns. While an explanation for drivers of recruitment would be beneficial, it would not directly effect the assessment, and as noted, such explanations are difficult to identify. An index of age-1 recruitment based on seabird diet data was attempted in this assessment, but was ultimately not included. This index could be especially informative because the fishery and indices based on bottom trawls do not consistently capture age-1 herring, and information on recent recruitments in this assessment was especially lacking due to the absence of 2020 bottom trawl surveys. The seabird diet data are collected by multiple entities (National Audubon Society, USFWS, University of New Brunswick, and University of New Hampshire). Collating this data and developing the index was a tremendous undertaking, only made possible by willing collaborators that collect the data and a volunteer student (Sean Hardison, University of Virginia). Continued consideration of this data would benefit from more formal and streamlined sharing agreements with NMFS.

- Are there other important issues?
  No other important issues were identified.

References:

NEFSC (Northeast Fisheries Science Center). 2018. 65^{th} Northeast Regional Stock Assessment Workshop (65^{th} SAW) Assessment Report. US Dept. of Commerce, NEFSC Ref. Doc. 18-11.

Killick, R. and I.A. Eckley. 2014. changepoint: an R Package for Changepoint Analysis. Journal of Statistical Software 58(3).

R Core Team. 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/ (last accessed 20 March 2020).

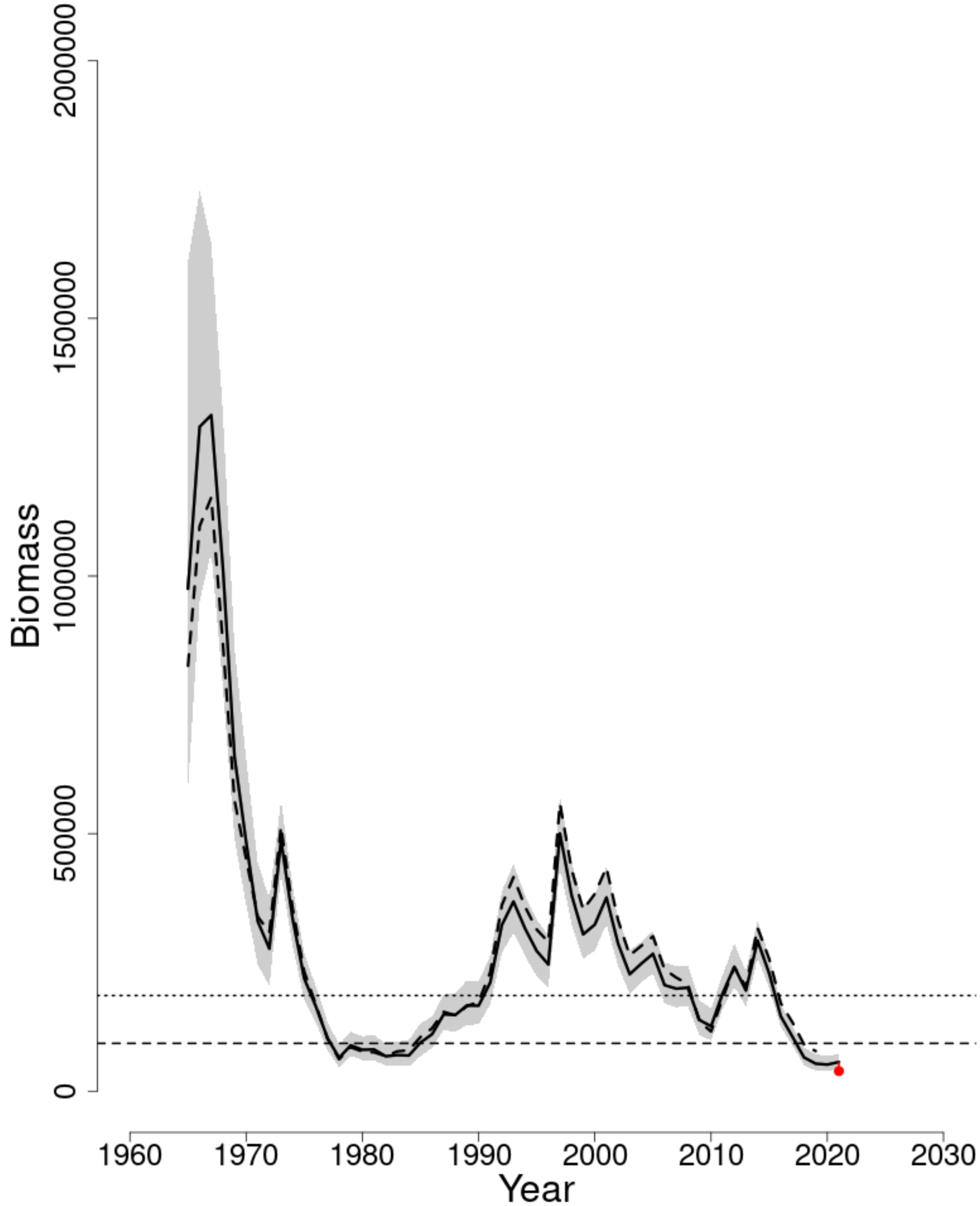

Figure 1: Trends in spawning stock biomass of Atlantic Herring between 1965 and 2021 from the current (solid line) and previous (dashed line) assessment and the corresponding $SSB_{Threshold}$ ($\frac{1}{2}$ SSB_{MSY} *proxy*; horizontal dashed line) as well as SSB_{Target} (SSB_{MSY} *proxy*; horizontal dotted line) based on the 2022 assessment. The approximate 90% confidence intervals are shown.

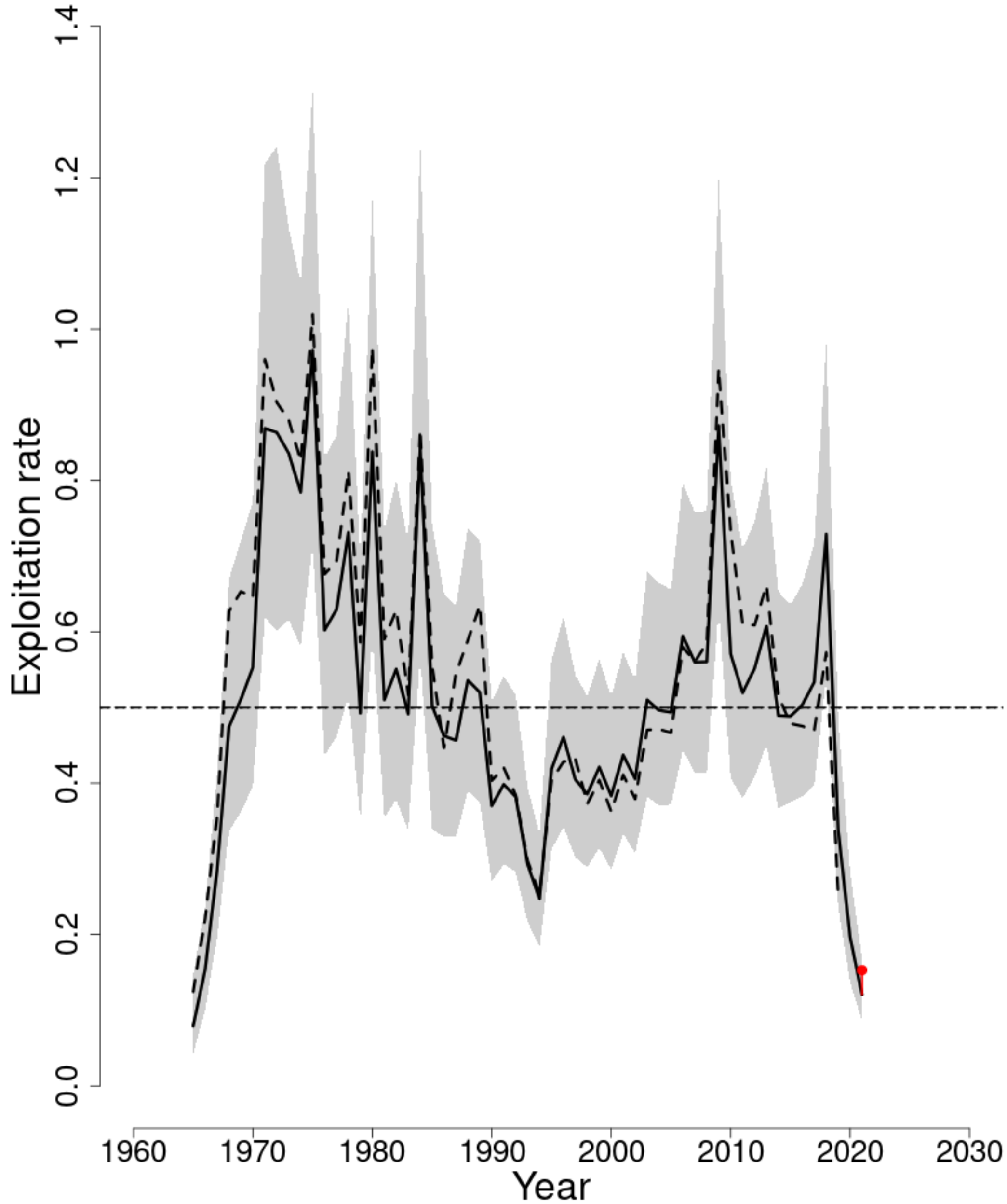

Figure 2: Trends in the average fishing mortality rate for ages 7-8, which are fully selected by the mobile fleet ($\bar{F}_{7-8}$), between 1965 and 2021 from the current (solid line) and previous (dashed line) assessment and the corresponding $F_{Threshold}$ (F_{MSY} *proxy*=0.5; horizontal dashed line). The approximate 90% confidence intervals are shown.

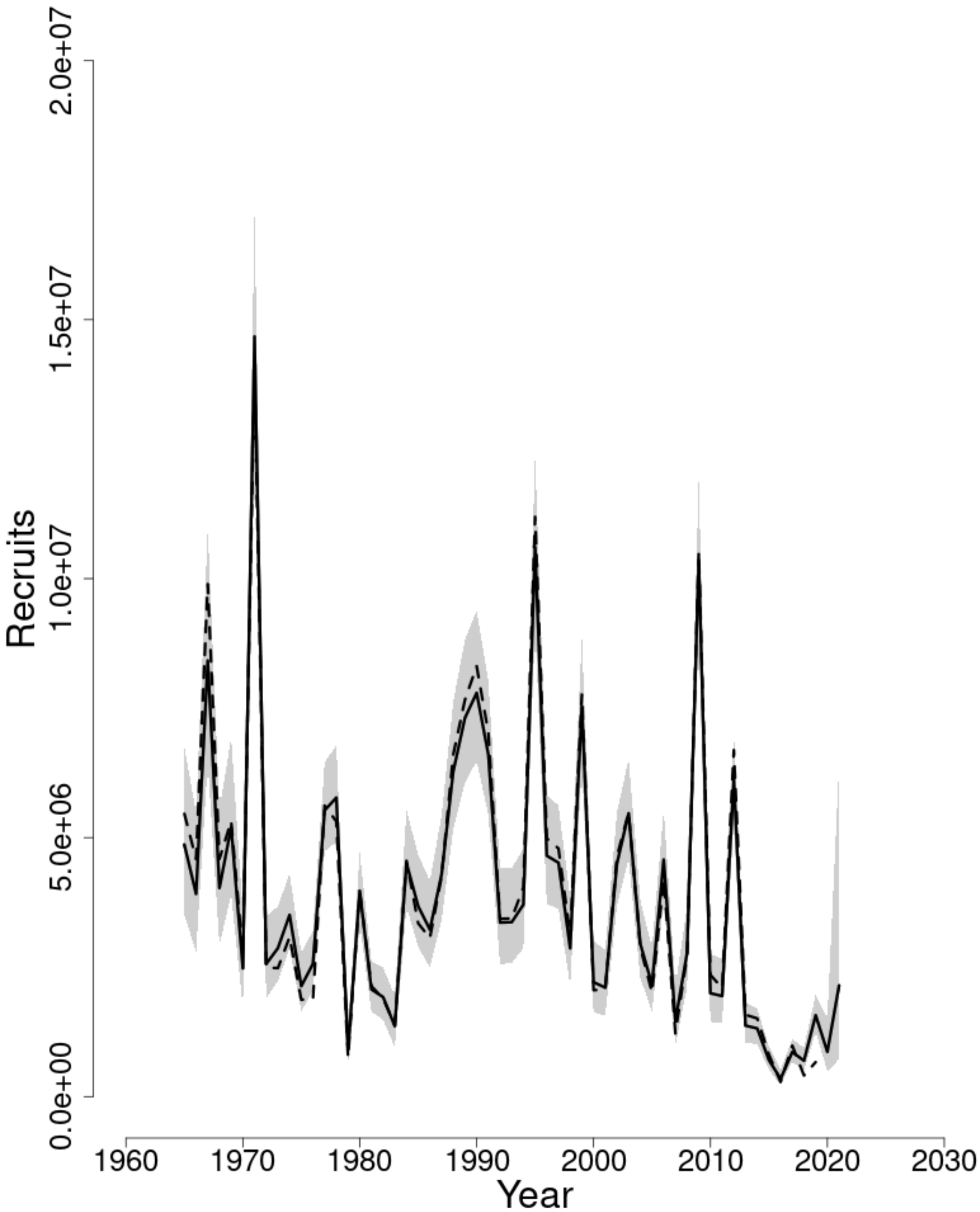

Figure 3: Trends in recruits (age-1)(000s) of Atlantic Herring between 1965 and 2021 from the current (solid line) and previous (dashed line) assessment. The approximate 90% confidence intervals are shown.

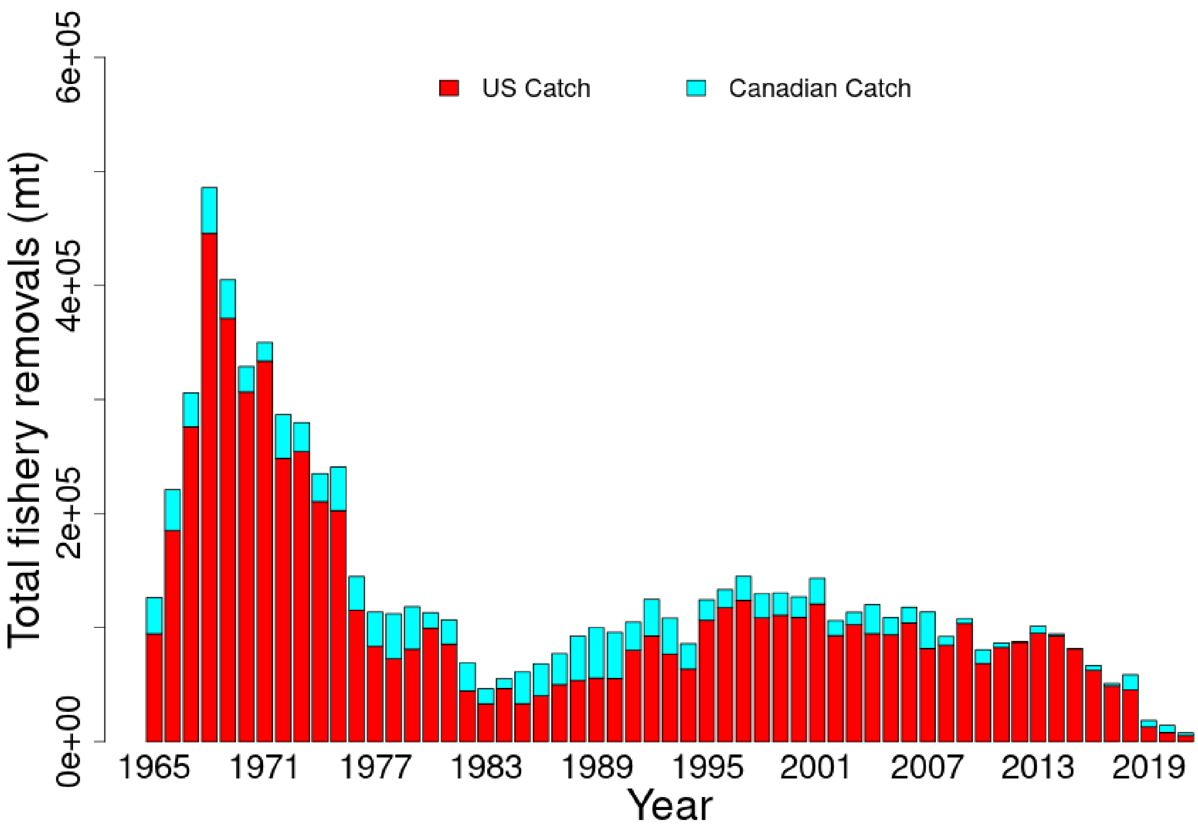

Figure 4: Total catch of Atlantic Herring between 1965 and 2021 by US and Canadian fleets.

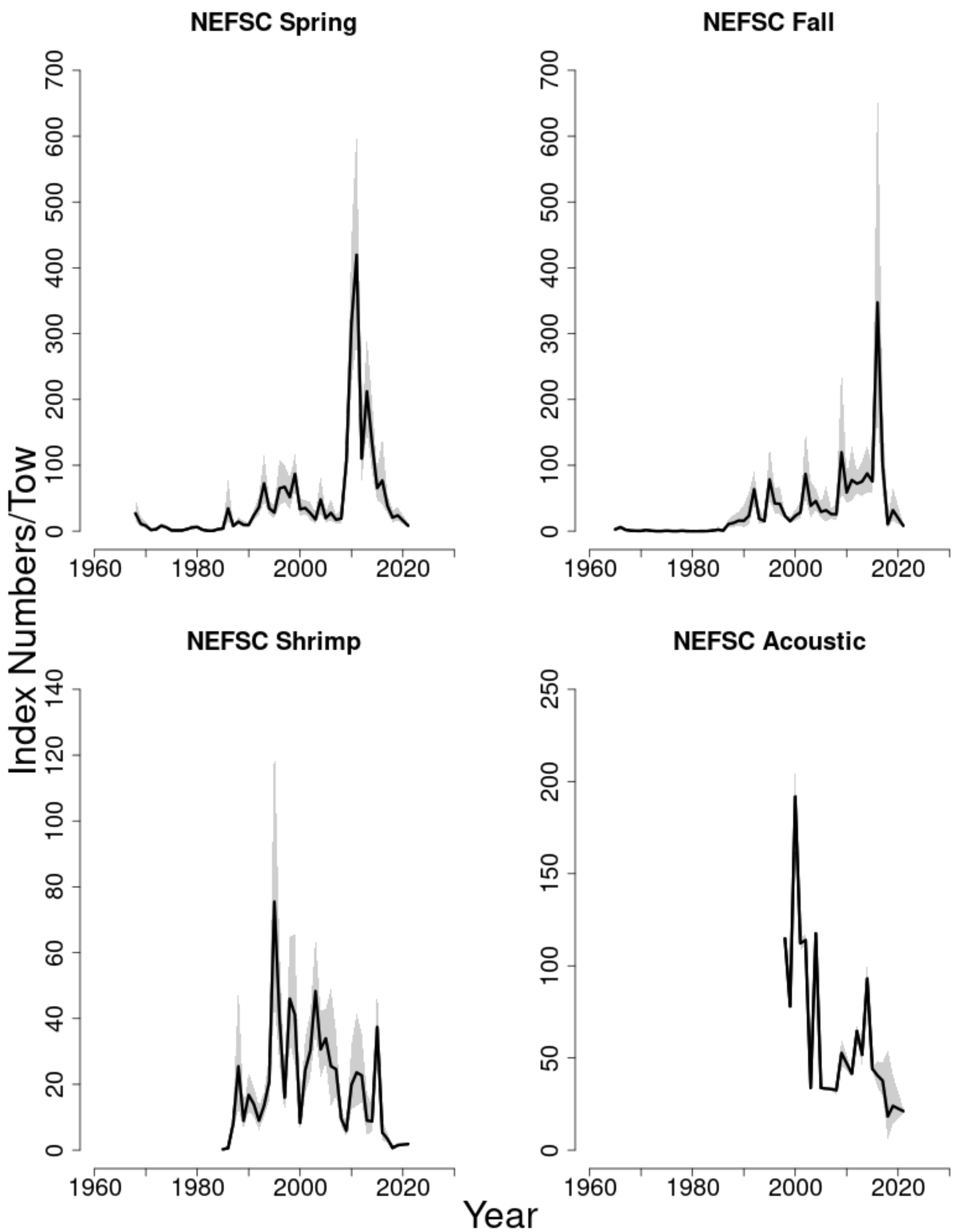

Figure 5: Indices of abundance for Atlantic Herring between 1965 and 2021 for the Northeast Fisheries Science Center (NEFSC) spring, fall, and shrimp bottom trawl surveys. The NEFSC acoustic index is collected during the fall bottom trawl survey and is in units of acoustic backscatter, not absolute numbers. The approximate 90% confidence intervals are shown.