draft working paper for peer review only

Atlantic Herring

2024 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

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This assessment of the Atlantic Herring (Clupea harengus) stock is a management track assessment of the existing 2022 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 2023. No significant changes were made to the methods in this assessment.

State of Stock: Based on this management track assessment, the Atlantic Herring stock is overfished and overfishing is not occurring (Figures 1-2). Retrospective adjustments were necessary (SSB Mohn's rho = 0.563 and F Mohn's rho = -0.261.). Adjusted spawning stock biomass (SSB) in 2023 was estimated to be 47,955 (mt) which is 26% of the biomass target (SSB_{MSY} *proxy* = 186,367; Figure 1). The 2023 adjusted average fishing mortality for ages 7-8 (fully selected ages for the mobile fleet) was estimated to be 0.263 which is 58% of the overfishing threshold proxy (F_{MSY} *proxy* = 0.45; 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.

	2016	2017	2018	2019	2020	2021	2022	2023
				Data				
US Catch	62,597	48,796	45,527	12,792	8,076	5,202	3,929	9,505
Canadian Catch	4,132	2,133	13,036	5,821	6,041	2,663	3,937	936
Total Catch	66,729	50,929	58,563	18,613	14,117	7,865	7,866	10,441
				Model Results				
Spawning Stock Biomass	139,300	96,996	55,824	46,825	47,303	48,350	87,760	74,977
$\bar{F}_{7-8}$	0.492	0.546	0.793	0.377	0.218	0.137	0.078	0.194
recruits (age1)	314,330	942,400	730,670	1,229,200	756,860	364,770	567,500	1,757,800

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.

	2022	2024
F_{MSY} *proxy*	0.5	0.45
SSB_{MSY} (mt)	185,750 (91,100 - 355,800)	186,367 (95,900 - 340,000)
MSY mt	68,980 (37,390 - 120,154)	78,710 (45,000 - 128,800)
Median recruits (age 1)	2,820,600 (578,900 - 10,441,500)	2,493,500 (485,400 - 9,107,300)
Overfishing	No	No
Overfished	Yes	Yes

Projections: 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 4,047 mt. This fixed gear catch equals the sum of the ten year (2014-2023) averages of the Canadian (4,031 mt) and US (16 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. Projected recruitment followed an autoregressive process (AR(1)), and projections were initialized at the 2023 estimated recruitment adjusted for the retrospective pattern (i.e., adjusted value = 1,124,659).

Table 3: Projection results.

Year	Catch mt	SSB (mt)	$\bar{F}_{7-8}$
2024	23,409	34,451	0.593

Year	Catch mt	SSB (mt)	$\bar{F}_{7-8}$
2025	6,741	51,904	0.076
2026	10,885	56,718	0.161
2027	15,435	86,607	0.184

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.Without other information about recruitment, the likelihood penalty has the effect of pulling the more recent recruitment estimates (i.e., 2022 and 2023) 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 <1% 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.

  None.

- 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. Modeling the effect of haddock predation on herring eggs is being considered in the Research Track, however. An index of age-1 recruitment based on seabird diet data is being considered in the ongoing Research Track Assessment. This index could be especially informative because the fishery and indices based on bottom trawls do not consistently capture age-1 herring, 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). 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.

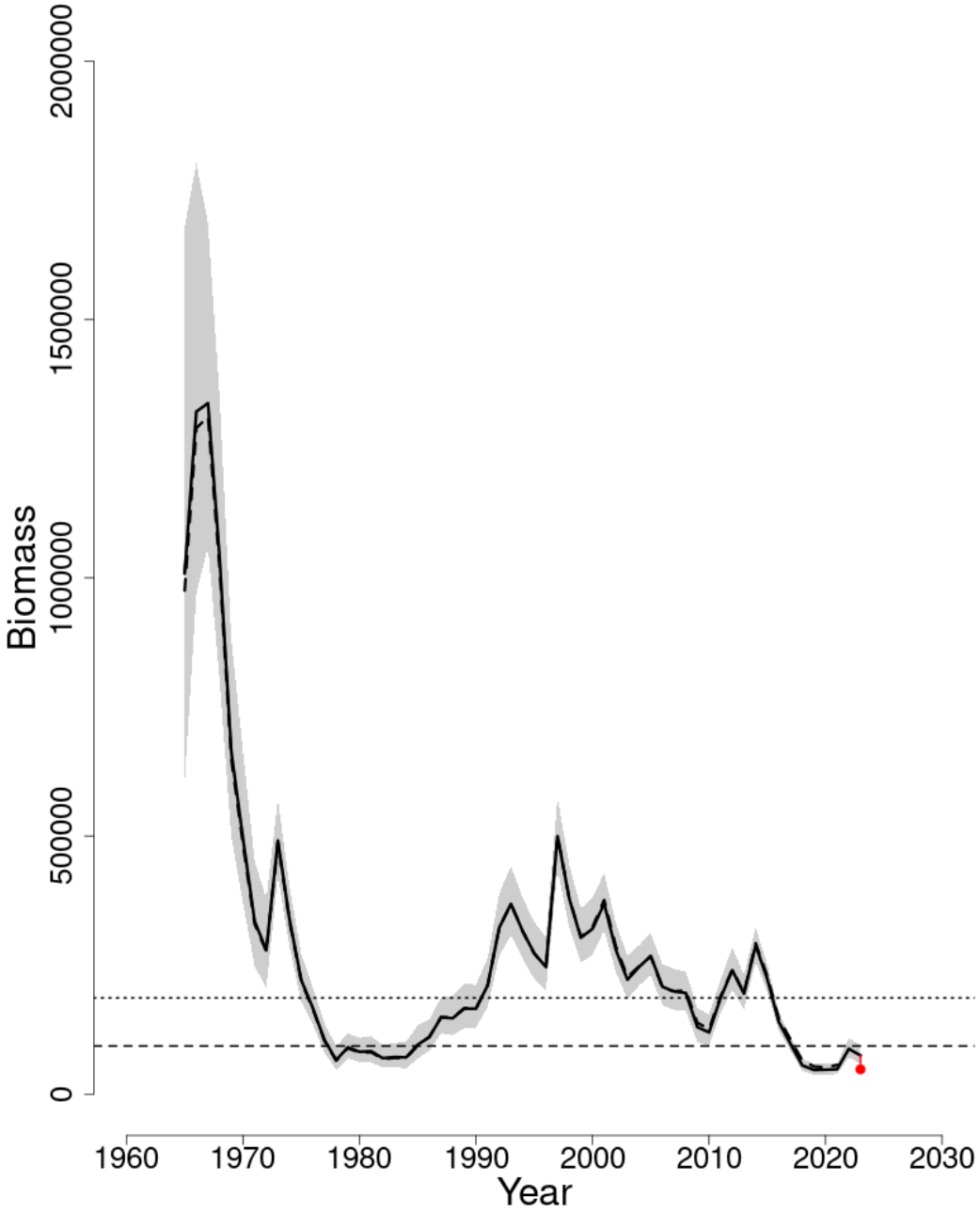

Figure 1: Trends in spawning stock biomass of Atlantic Herring between 1965 and 2023 from the current (solid line) and previous (dashed line) assessment and the corresponding $SSB_{Threshold}$ ($\frac{1}{2}$ SSB_{MSY} *proxy*; horizontal dashed line) as well as SSB_{Target} (SSB_{MSY} *proxy*; horizontal dotted line) based on the 2024 assessment. The approximate 90% confidence intervals are shown. The red line and dot show the value from the 2024 assessment adjusted for the retrospective pattern.

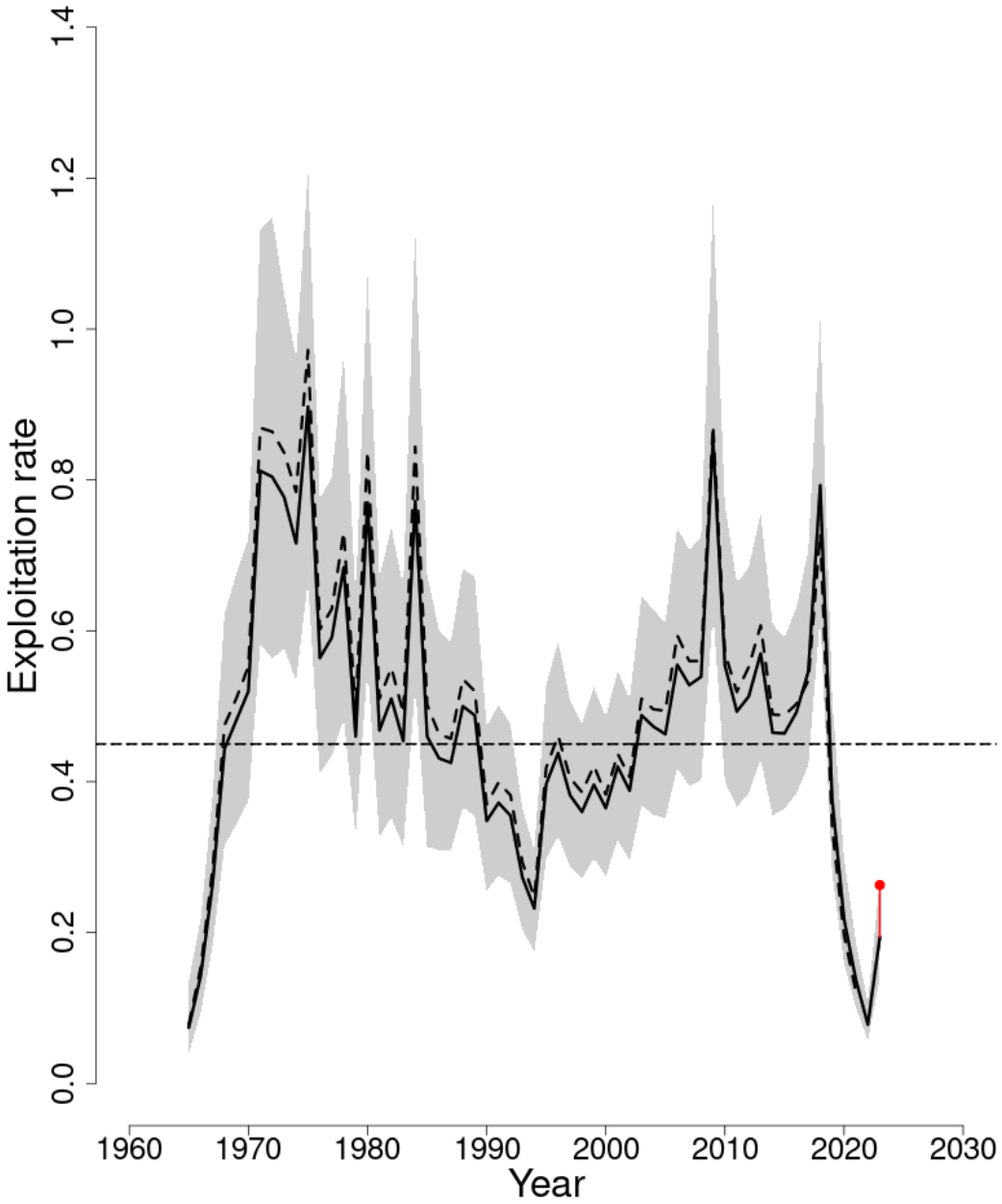

Figure 2: Trends in the average fishing mortality rate for ages 7-8, which are fully selected by the mobile fleet ($\bar{F}_{7-8}$), between 1965 and 2023 from the current (solid line) and previous (dashed line) assessment and the corresponding $F_{Threshold}$ (F_{MSY} *proxy*=0.45; horizontal dashed line). The approximate 90% confidence intervals are shown. The red line and dot show the value from the 2024 assessment adjusted for the retrospective pattern.

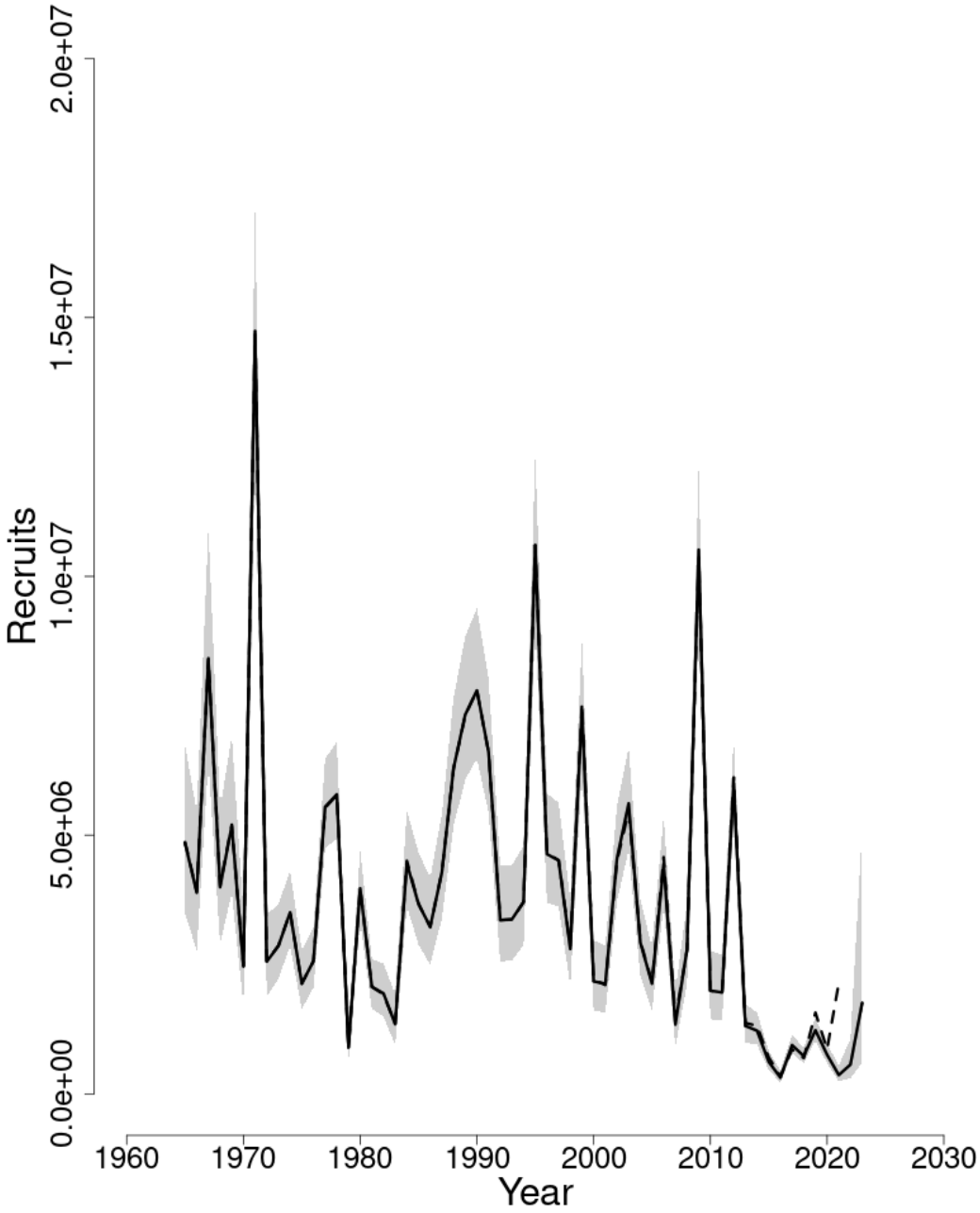

Figure 3: Trends in recruits (age-1)(000s) of Atlantic Herring between 1965 and 2023 from the current (solid line) and previous (dashed line) assessment. The approximate 90% confidence intervals are shown.

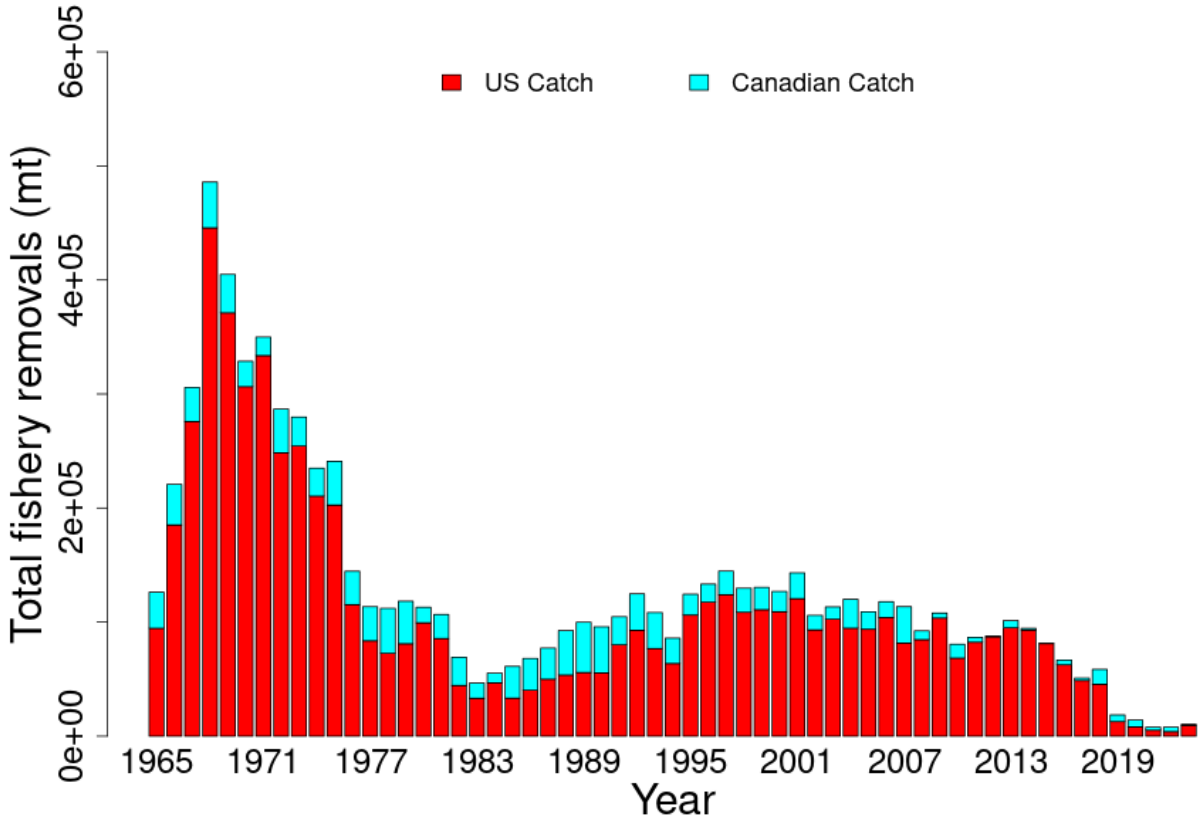

Figure 4: Total catch of Atlantic Herring between 1965 and 2023 by US and Canadian fleets.

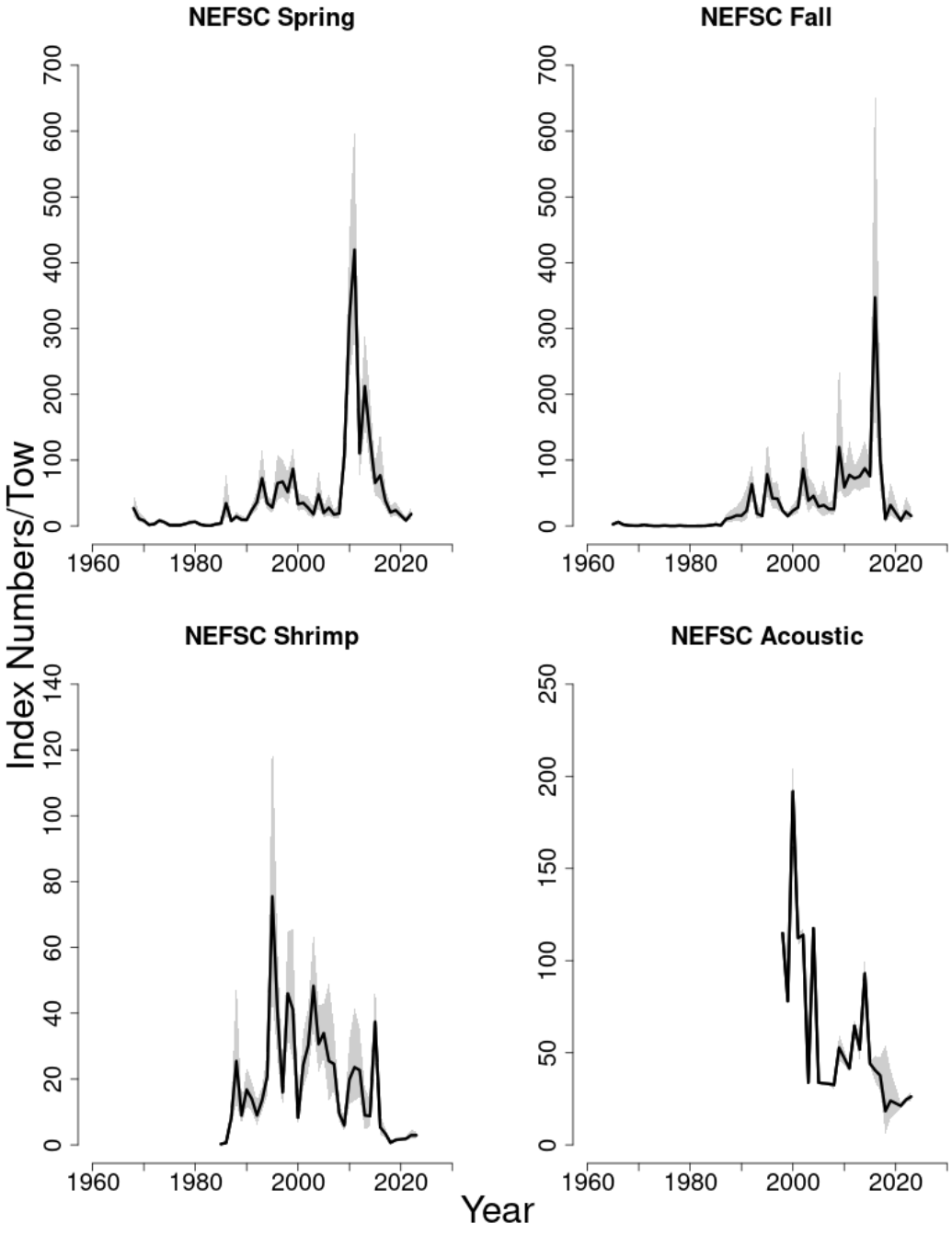

Figure 5: Indices of abundance for Atlantic Herring between 1965 and 2023 for the Northeast Fisheries Science Center (NEFSC) spring, fall, and shrimp bottom trawl surveys. The NEFSC acoustic index is collected during the fall bottom trawl survey and is in units of acoustic backscatter, not absolute numbers. The approximate 90% confidence intervals are shown.