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Northwest Atlantic mackerel

2023 Management Track Assessment Report

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National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts

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This assessment of the northwest Atlantic mackerel (Scomber scombrus) stock was completed as a level 2 management track assessment of the existing 2021 management track assessment (NEFSC 2022). Based on the 2021 assessment, the stock was overfished and overfishing was occurring. This assessment updates commercial and recreational fishery catch data, research survey indices of abundance, the analytical ASAP assessment model and reference points through 2022. Additionally, stock projections have been updated through 2032.

State of Stock: Based on this management track assessment, the northwest Atlantic mackerel (*Scomber scombrus*) stock is overfished and overfishing is not occurring (Figures 1-2). Retrospective patterns were minor, though consistent in direction, and retrospective adjustments for terminal year estimates were not needed. Spawning stock biomass (SSB) in 2022 was estimated to be 19,017 (mt), corresponding to 12% of the biomass target (SSB_{MSY} *proxy* = 154,107; Figure 1). The 2022 fully selected fishing mortality was estimated to be 0.18, corresponding to 86% of the overfishing threshold proxy (F_{MSY} *proxy* = 0.21; Figure 2).

Table 1: Catch and status table for northwest Atlantic mackerel. All weights are in (mt), recruitment is in (000s), and F represents the fishing mortality on fully selected ages (ages 6+). Model results are from the current ASAP assessment updated through 2022.

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
					Data					
US commercial landings	4,372	5,905	5,616	5,687	6,974	8,717	5,379	8,150	5,681	2,027
US recreational catch	2,405	2,295	4,274	4,568	4,161	2,393	2,116	2,016	2,222	1,439
US commercial discards	19	51	13	17	82	177	199	48	61	113
Canada	8,673	6,678	4,272	8,045	9,752	10,907	8,749	7,947	4,505	56
Other countries	0	0	0	0	0	0	0	0	0	0
Total catch	15,471	14,930	14,176	18,319	20,971	22,195	16,445	18,163	12,470	3,636
					Model Results					
Spawning Stock Biomass	18,146	15,330	16,774	24,477	31,505	30,388	23,505	17,048	12,321	19,017
F	1.14	1.06	1	0.77	0.73	0.74	0.72	1.07	1.06	0.18
Recruits (age1)	41,564	83,800	131,514	316,570	23,392	104,960	51,031	64,856	67,745	252,424

Table 2: Comparison of reference points estimated in the previous assessment (2021) and from the current management track assessment. An $F_{40\%}$ proxy was used for the overfishing threshold and was based on long-term stochastic projections.

	2021	2023
$F_{40\%}$	0.22	0.21
SSB_{MSY} *proxy* (mt)	181090	154107 (86490 - 332677)
MSY proxy (mt)	34103	30460 (17321 - 63448)
Median recruits (age 1) (000s)	178,743	177,711
Overfishing	Yes	No
Overfished	Yes	Yes

Projections: Following the established Rebuilding 2.0 Amendment (MAFMC 2023), short-term projections were derived assuming two recruitment stanzas. When projected SSB for a given iteration was less than $\frac{1}{2}$ of SSB_{MSY} *proxy*, recruitment was derived by sampling from a cumulative distribution function of recruitment estimates from 2009 onward from the final ASAP model; when projected SSB for a given iteration was greater than or equal to $\frac{1}{2}$ of SSB_{MSY} *proxy*, recruitment was dervied by sampling from a cumulative distribution function of recruitment

estimates from 1975 onward. The annual fishery selectivity, maturity ogive, and mean weights-at-age used in the projections represent the most recent 5-year averages. Following the Rebuilding 2.0 amendment, $F_{Rebuild}$ is defined as the fishing mortality that results in a 61% probability of the stock being rebuilt by 2032. Using the results of this Management Track assessment, $F_{Rebuild}$ was updated from 0.12 to 0.11.

Table 3: Short-term projections of total fishery catch and spawning stock biomass for northwest Atlantic mackerel based on a harvest scenario of fishing at $F_{Rebuild}$ between 2024 and 2032. F=0.11 was chosen as the updated $F_{Rebuild}$ because it had a 61.5% probability of rebuilding by 2032. Given a continued closure of the Canadian commercial and bait fisheries in 2023, Canadian catch in 2023 was assumed to be the same as that observed in 2022 (56 (mt)). 2023 U.S. catch was assumed to be equivalent to the U.S. Annual Catch Limit of 5,897 (mt), resulting in an assumed total stock-wide catch of 5,953 (mt) for 2023.

Year	Catch (mt)	SSB (mt)	F
2023	5953	43721 (17764 - 100647)	0.153

Year	Catch (mt)	SSB (mt)	F
2024	6864	69870 (33366 - 148466)	0.11
2025	8571	85584 (47611 - 175240)	0.11
2026	9830	96586 (56066 - 207270)	0.11
2027	11417	109397 (62547 - 258135)	0.11
2028	12710	121447 (66892 - 297009)	0.11
2029	14129	135534 (70376 - 333230)	0.11
2030	15764	151543 (75546 - 363230)	0.11
2031	17020	163892 (80678 - 382406)	0.11
2032	18197	175493 (86602 - 397140)	0.11

Special Comments:

- Sources of uncertainty:

  Following the 2021 Management Track (MT) assessment, natural mortality (M) was assumed to be constant over both time and age. To consider evidence of different natural mortality rates, a likelihood profile for natural mortality was completed and is included in the supplementary material. In collaboration with Canada's Department of Fisheries and Oceans (DFO) and through the ICES Working Group of Northwest Atlantic Mackerel (WGNAM), work is currently underway to estimate temporal trends in predation of mackerel by both finfish and marine mammals. In particular, current work is focused on developing empirical estimates of natural mortality based on life history parameters to estimate the overall magnitude of M, and developing a Predation Pressure Index (Richards and Jacobson 2016) for finfish, pinnipeds and gannets that could be used to scale M and permit time-varying estimates that reflect changes in predator biomass over time.

  Canadian catch estimates represent a subset of total Canadian catch because bait fishery, recreational fishery and commercial discard estimates are not available. Additionally, during their most recent assessment (DFO 2023), Canada applied a bias correction to 2022 catch-at-age (CAA) due to the atypical sampling that resulted from the fishery closure. More specifically, the average stratum-specific landings of 2017-2021 were used to determine CAA, rather than the observed composition of the landings, and the resulting CAA was rescaled to the 2022 total aggregate landings. These bias-corrected estimates were incorporated into total stock-wide estimates of CAA for this MT assessment.

  To create a range-wide egg index, SSB estimates from Canada's dedicated egg survey and the U.S.'s ecosystem surveys are used. However, GSI estimates are not available for the southern contingent because the primary U.S. fishery does not overlap with the spawning season and the seasonal bottom trawl surveys occur before or after the spawning season. Consequently, an average spawning seasonality function was used to

calculate annual egg production. Similarly, due to a lack of fecundity estimates for the southern contingent, annual fecundity estimates from the Gulf of St. Lawrence were used to calculate spawning stock biomass from annual egg production. Efforts are currently underway to collect spawning mackerel from the southern contingent to provide updated fecundity estimates.

- Retrospective analysis (a major retrospective pattern occurs when the adjusted SSB or F_{Full} lies outside of the approximate joint confidence region for SSB and F_{Full}):

  The 5-year Mohn's ρ, relative to SSB, was 0.326 in the 2021 assessment (terminal year of 2019) and 0.485 in this assessment (terminal year of 2022). The 5-year Mohn's ρ, relative to F, was -0.093 in the 2021 assessment (terminal year of 2019) and -0.306 in this assessment (terminal year of 2022). The retrospective pattern for this assessment was considered to be minor because the ρ-adjusted estimates of 2022 SSB (SSB_ρ=12810) and 2022 F (F_ρ=0.256) were within the approximate 90% confidence intervals around SSB (9,251 - 39,094) and F (0.083 - 0.391). Consequently, a retrospective adjustment of spawning stock biomass or fishing mortality in 2022 was not required.

  Even though the observed retrospective pattern did not trigger an adjustment to terminal year estimates, the retrospective analysis indicated a consistent underestimation of fishing mortality and overestimation of spawning stock biomass (see supplementary material).

- Population projections

  The stochastic short-term projections completed for this management track assessment followed the methodology established by the Atlantic Mackerel Rebuilding 2.0 Amendment (MAFMC 2023) where recruitment is derived by sampling from two stanzas based on SSB (one based on recruitment estimates from 2009 onward and one based on recruitment estimates from 1975 onward).

  After the 2021 MT assessment, a target fishing mortality of 0.12 was selected as the F that would have a 61% probability of rebuilding the stock within ten years (by 2032). Similar to the 2021 MT, this updated model indicates that the increase in SSB projected during the last assessment was not realized (see supplementary material), demonstrating the high uncertainty in short-term projections for this stock. Rebuilding projections resulting from the 2017 benchmark assessment (NEFSC 2018) projected a spawning stock biomass of approximately 162,796 mt in 2019; however, the 2021 MT assessment estimated a terminal year SSB of 42,862 mt for 2019, which was then updated to 23,505 mt during this MT. Likewise, the 2021 MT assessment projected a spawning stock biomass of approximately 70,768 mt in 2022; however, this assessment estimated a terminal year SSB of 19,017 mt for 2022. As in the 2017 benchmark assessment, the short-term projections completed for this MT are driven by a strong incoming year class (2015 year class for the 2017 benchmark and 2021 year class for the 2023 MT). While the 2023 MT indicates that the 2015 year class is still larger than the time-series median, the estimated size of this year class is 30% lower than that originally estimated during the 2017 assessment. Furthermore, DFO Canada's recent assessment of the northern spawning contingent (see additional issues) estimated the 2021 year class (2022 recruitment) as the third lowest of the time series (DFO 2023). Given the poor performance of short-term projections to-date and per the request of MAFMC staff, additional short-term projections were completed that assumed 2022 recruitment (in thousands of fish) was equal to the median from 2009 onward (87,637) instead of the estimated value from the final ASAP model (252,424) (see supplementary material).

- Changes made to the current assessment, beyond incorporating additional years of data:

  Canada's DFO revised the full suite of input data for their 2023 assessment of the northern contingent (DFO 2023), including catch-at-age, egg survey, maturity-at-age, weight-at-age and fecundity-at-age estimates. Sequential bridge runs were completed to demonstrate the impact of each updated dataset and are provided in the supplementary material. While the revised Canadian data impacted spawning stock biomass, fishing mortality and recruitment estimates in some years, they did not impact the general temporal trend or resulting stock status. The only update to the U.S. data was the incorporation of tow-specific estimates of area swept in the development of bottom trawl survey indices. This update had a negligible impact on resulting model estimates. Due to minor diagnostic issues, the annual CVs for the egg survey index were increased by 0.3 to reduce the retrospective pattern and to reduce the root mean square error to within the confidence bounds associated with a N(0,1) distribution for the index sample size. This change had a minor impact on fishing mortality estimates.

- Changes in stock status:

  The stock status of northwest Atlantic mackerel has changed since the previous assessment (NEFSC 2021). While the stock continues to be overfished, overfishing is not occurring in 2022, for the first time in 35 years. This change in overfishing status is likely due to the closure of the Canadian directed commercial and bait fisheries and low U.S. removals in 2022.

- Qualitative description of stock condition:

  Fishery composition data show a truncation in age structure, though age-9 fish were observed in 2019-2021 catches for the first time since 2012. After reaching a time-series minimum in 2010, range-wide SSB estimates developed from the egg surveys generally increased until 2018 but declined to within 10% of the 2010 estimate by 2022 and have been below the time-series median since 2009. However, egg production estimates for the southern contingent have been approximately an order of magnitude greater since 2018 compared to the previous ten years, and since 2018, the southern contingent has represented between 11-50% of the range-wide spawning stock biomass. With the exception of the 2015 and 2021 year classes (2016 and 2022 recruitment), recruitment estimates have been below the corresponding time-series median since 2009 and the 2016 year class was the smallest of the time series.

- Research recommendations:

  As mentioned in the above section on sources of uncertainty, fecundity estimates for the southern contingent are needed to improve spawning stock biomass estimates developed from the egg surveys. Additionally, further work is needed to explore both the magnitude and temporal variation in natural mortality as an incorrect characterization of natural mortality could contribute to the observed retrospective pattern and poor performance of short-term projections.

  Further work on stock structure and the extent of contingent mixing is also needed. Arai et al. (2021) demonstrated a shift in baseline otolith natal isotopic composition values of the two spawning contingents during the past two decades. Redding et al. (2020) found that for the 1998-2000 year classes, the majority of age-3+ fish collected from US waters in March represented the northern contingent. However, Arai et al. (2021) found that the southern contingent was dominant in age-3 and age-4 fish collected during the U.S. winter fishery in more recent years (2011-2016 year classes), and that contingent mixing levels varied among year classes. Consequently, in order to develop spatially-explicit assessment models that consider the dynamics of each spawning contingent separately, year-class-specific baselines and annual estimates of contingent composition in fishery catches would be needed. Recent genetic work (Bourret et al 2023) has indicated small, but potentially significant genetic differentiation between the two spawning contingents; however, improvements in the reference samples used for the southern contingent are needed to minimize potential bias in contingent assignments and further investigate whether the southern continent is present in Canadian waters during late spring to autumn.

- Additional issues:

  DFO Canada's 2023 assessment of the northern spawning contingent of northwest Atlantic mackerel (DFO 2023) indicated that the northern contingent has been in or near the Critical Zone, as defined by DFO's precautionary approach framework, since 2011. Estimated spawning stock biomass reached a time-series minimum in 2021 (16,800 mt at the time of spawning) and increased slightly in 2022, but still remained at only 42% of the limit reference point. Estimated fishing mortality for fully selected fish (age-5+) fell below $F_{40\%}$ in 2022 for the first time since 1997. Estimated recruitment has been below the time-series median since 2009 and 2022 recruitment represented the third lowest estimate of the time series, in contrast to the 2022 recruitment value estimated in this Management Track assessment.

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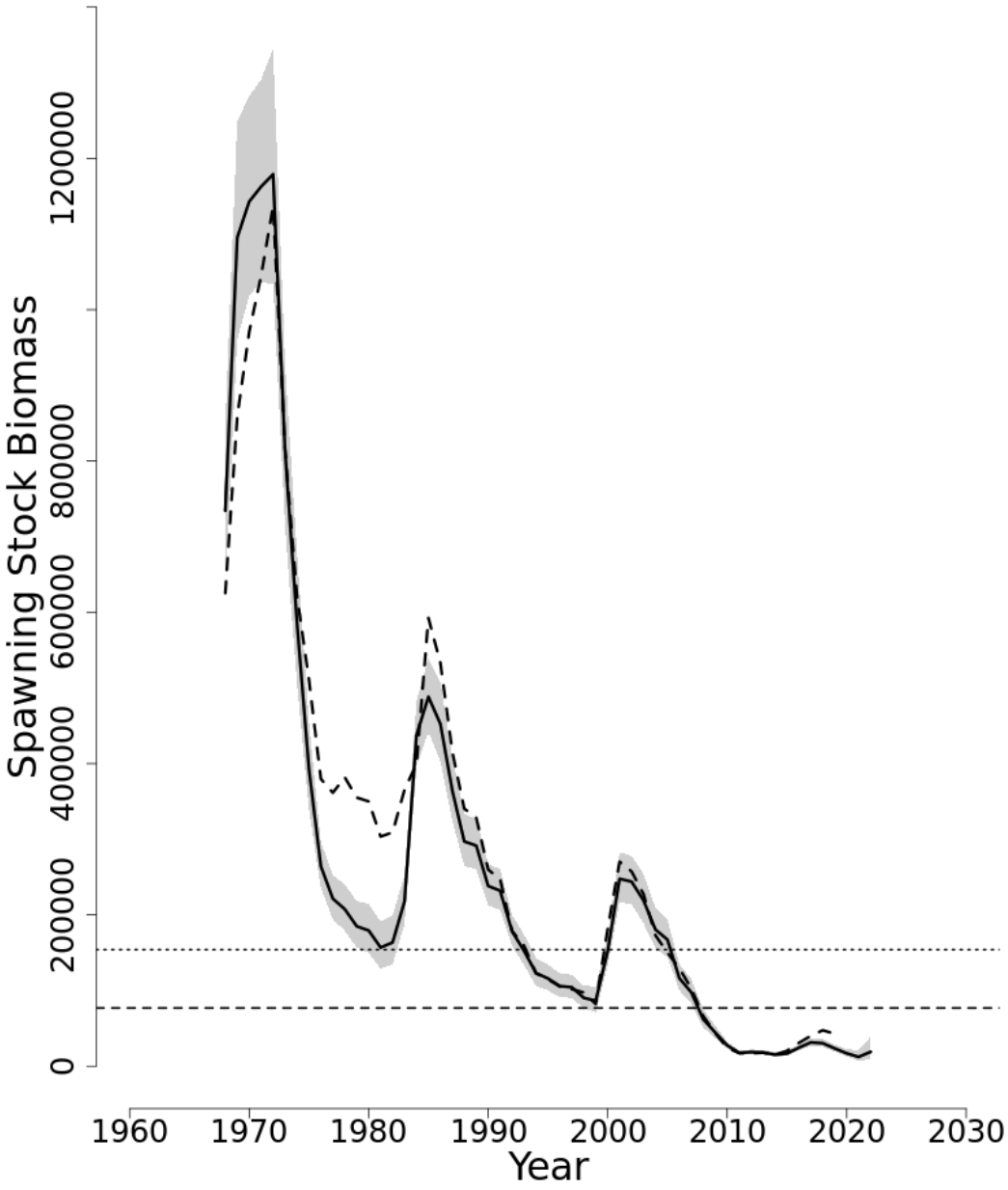

Figure 1: Trends in spawning stock biomass (mt) of northwest Atlantic mackerel between 1968 and 2022 from the current (solid line) and previous (dashed line) assessment and the corresponding $SSB_{Threshold}$ ($\frac{1}{2}$ SSB_{MSY} *proxy*; horizontal dashed line) as well as SSB_{Target} (SSB_{MSY} *proxy*; horizontal dotted line) based on the 2023 assessment. The approximate 90% lognormal confidence intervals are shown.

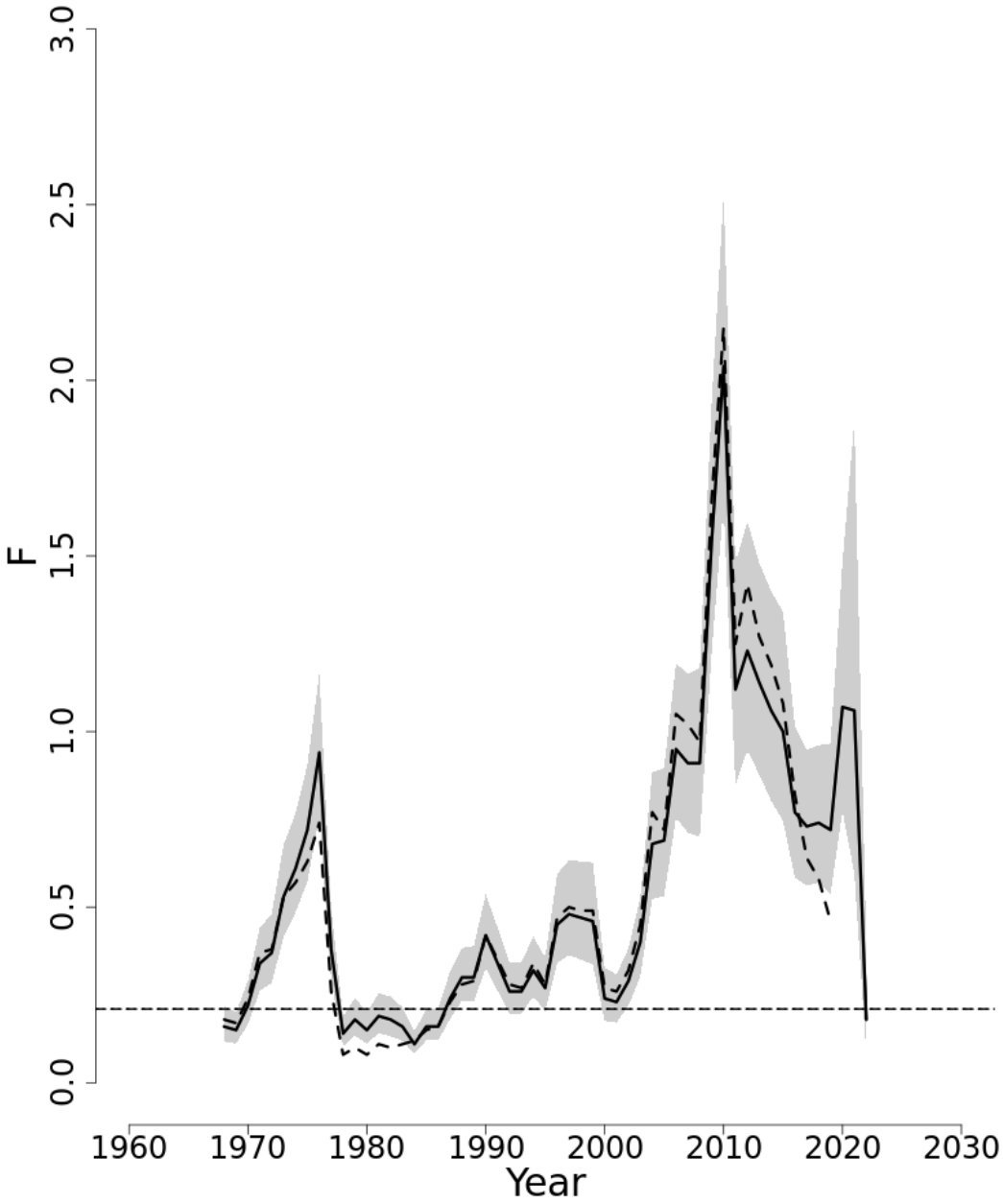

Figure 2: Trends in the fully selected fishing mortality (F) of northwest Atlantic mackerel between 1968 and 2022 from the current (solid line) and previous (dashed line) assessment and the corresponding $F_{Threshold}$ (F_{MSY} *proxy*=0.21; horizontal dashed line). The approximate 90% lognormal confidence intervals are shown.

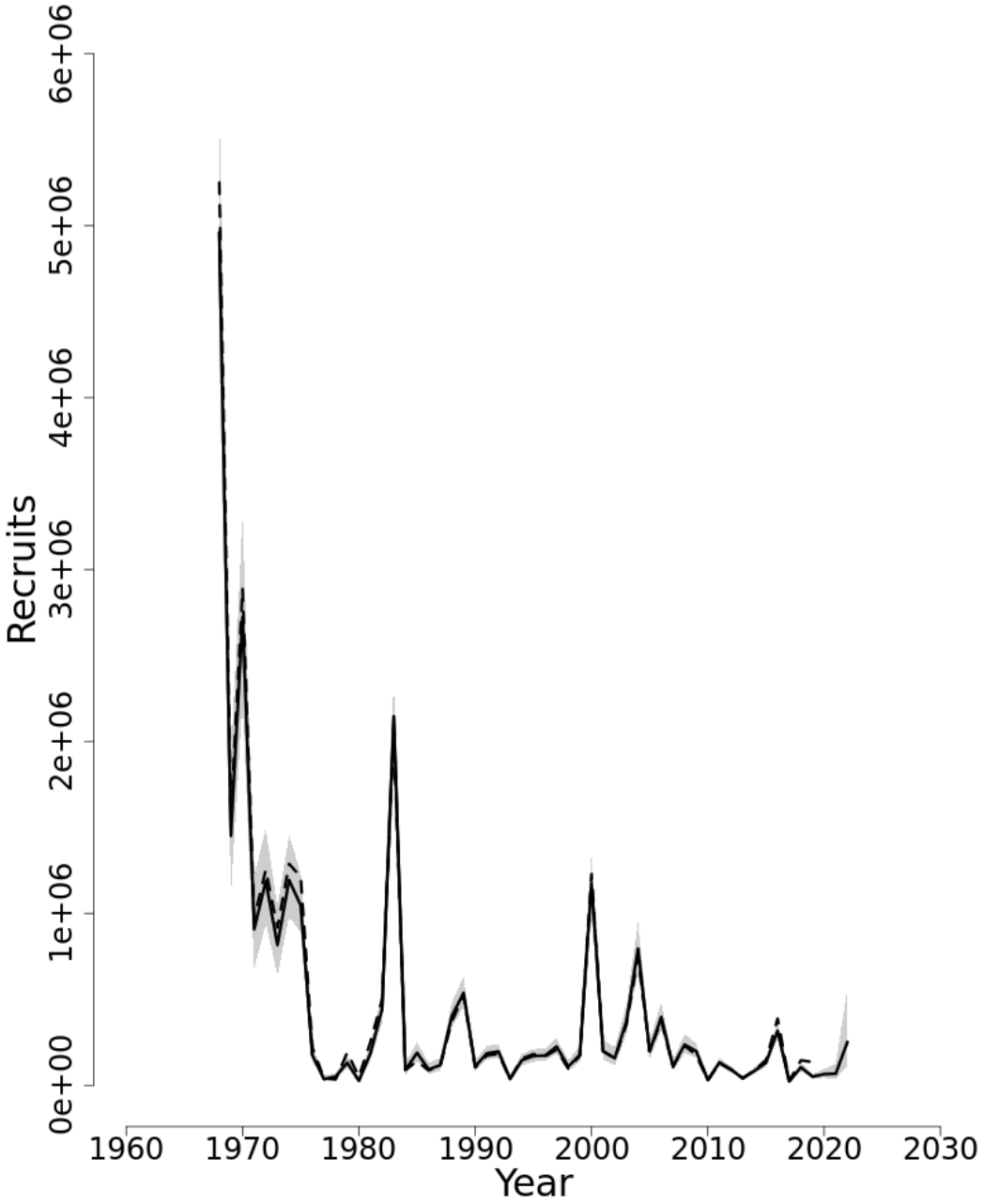

Figure 3: Trends in Recruits (age-1) (000s) of northwest Atlantic mackerel between 1968 and 2022 from the current (solid line) and previous (dashed line) assessment. The approximate 90% lognormal confidence intervals are shown.

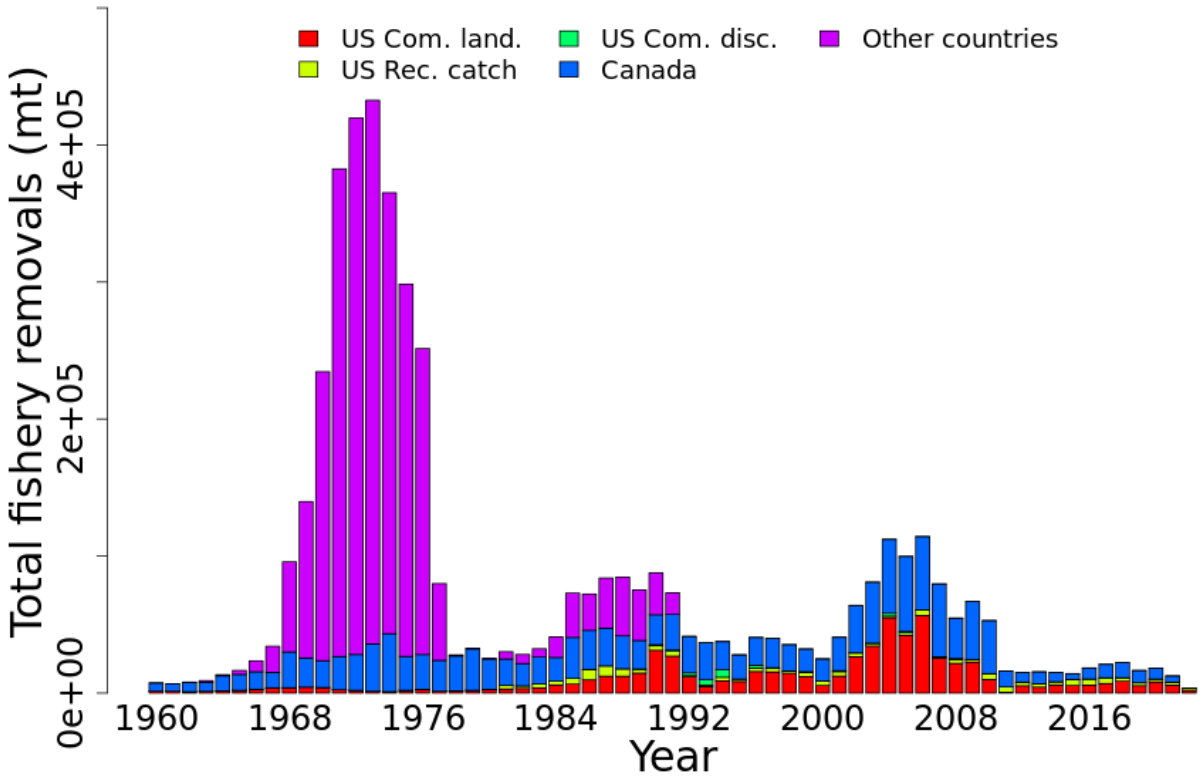

Figure 4: Total catch of northwest Atlantic mackerel between 1968 and 2022 by all sources. U.S. recreational catch represents recreational landings plus discards, Canada represents Canadian landings (discards are not available), and other countries represents landings by all other countries.

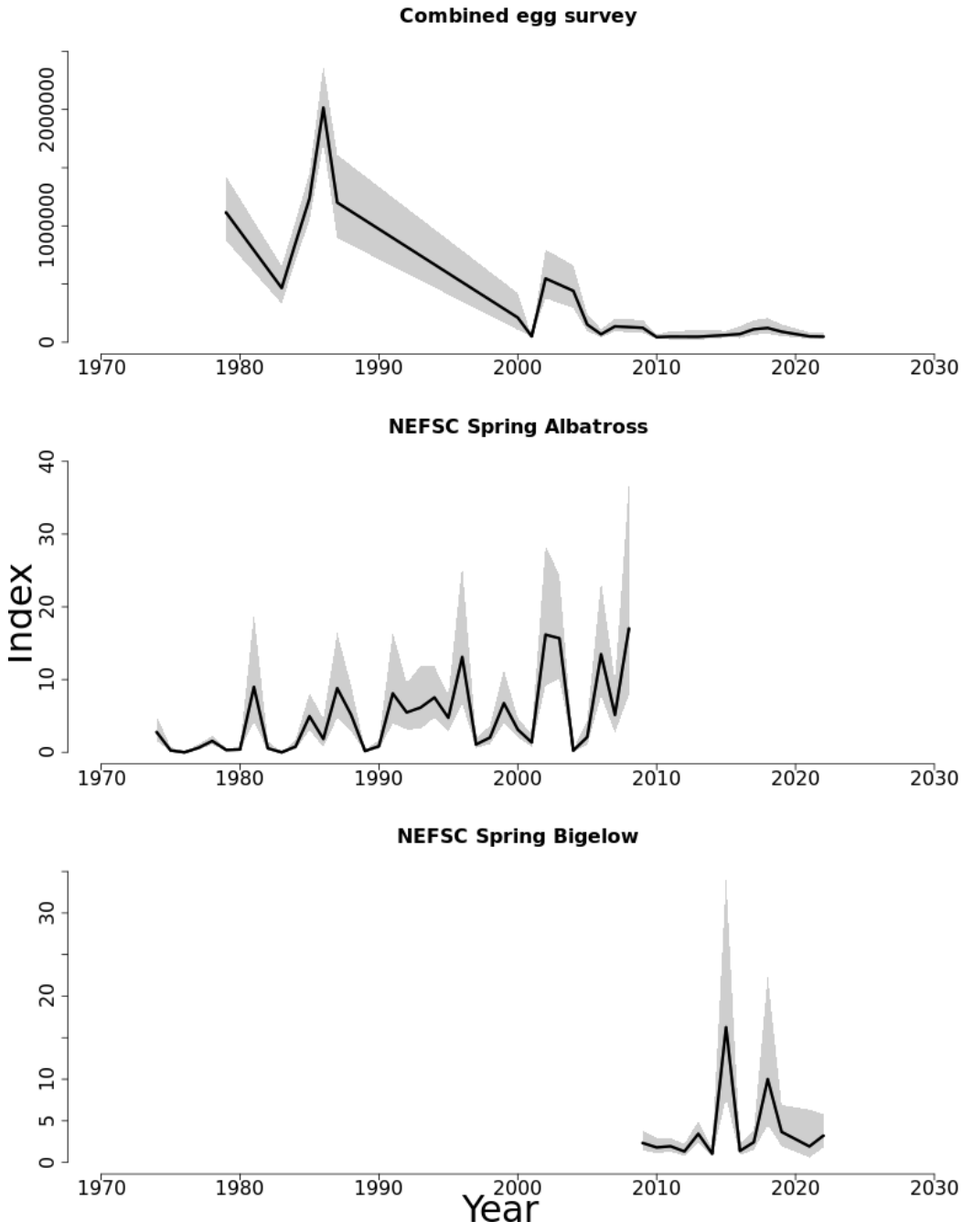

Figure 5: Indices of spawning stock biomass (mt) from the combined egg surveys and age-3+ fish/tow from the NEFSC spring bottom trawl survey for northwest Atlantic mackerel between 1974 and 2022.