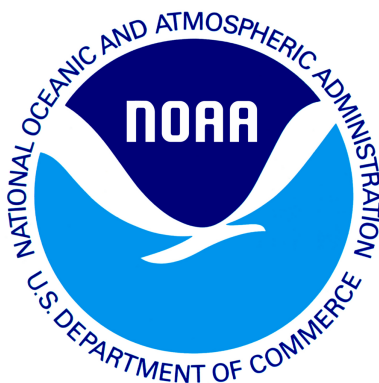


draft working paper for peer review only



Northwest Atlantic mackerel

2021 Management Track Assessment Report

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

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This assessment of the northwest Atlantic mackerel (*Scomber scombrus*) stock is a level 2 management track assessment of the existing 2017 benchmark assessment (NEFSC 2018). Based on the previous 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 2019. Additionally, stock projections have been updated through 2023.

State of Stock: Based on this management track assessment, the northwest Atlantic mackerel (*Scomber scombrus*) stock is overfished and overfishing is occurring (Figures 1-2). Retrospective patterns were minor and retrospective adjustments for terminal year estimates were not needed. Spawning stock biomass (SSB) in 2019 was estimated to be 42,862 (mt), corresponding to 24% of the biomass target ($SSB_{MSY} proxy = 181,090$; Figure 1). The 2019 fully selected fishing mortality was estimated to be 0.458, corresponding to 208% of the overfishing threshold proxy ($F_{MSY} proxy = 0.22$; 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 2019.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	<i>Data</i>									
US commercial landings	9,877	533	5,333	4,372	5,905	5,616	5,687	6,975	8,717	5,379
US recreational catch	4,288	4,040	2,670	2,406	2,296	4,274	4,569	4,161	2,394	2,117
US commercial discards	97	38	33	20	51	13	18	83	177	200
Canada	38,701	11,508	6,849	8,675	6,680	4,281	8,057	9,786	10,964	8,626
Other countries	0	0	0	0	0	0	0	0	0	0
Total catch	52,962	16,118	14,885	15,473	14,932	14,185	18,331	21,005	22,252	16,322
	<i>Model Results</i>									
Spawning Stock Biomass	24,412	17,317	17,018	17,877	15,319	20,266	30,870	40,190	47,554	42,862
F	2.151	1.248	1.424	1.27	1.194	1.081	0.82	0.638	0.576	0.458
Recruits (age1)	27,537	128,850	90,792	40,653	87,113	147,315	387,668	25,474	145,584	135,882

Table 2: Comparison of reference points estimated in the previous assessment (2017) 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.

	2017	2021
$F_{40\%}$	0.26	0.22
$SSB_{MSY} proxy$ (mt)	196894	181090 (102292 - 386653)
MSY proxy (mt)	41334	34103 (19404 - 70927)
Median recruits (age 1) (000s)	180,572	178,743
<i>Overfishing</i>	Yes	Yes
<i>Overfished</i>	Yes	Yes

Projections: Short-term projections were derived by sampling from a cumulative distribution function of recruitment estimates from 1975 onward from the final ASAP model. Additional short-term projections were completed using recruitment estimates from 1999 and 2009 onward, and are presented in the supplementary material as sensitivity analyses. The annual fishery selectivity, maturity ogive, and mean weights-at-age used in the projections represent the most recent 5-year averages.

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_{MSY} proxy between 2022 and 2023. The primary U.S. commercial mackerel fishery in 2020 occurred before the COVID pandemic began and discards represent a small proportion of total catch; therefore, the preliminary 2020 total catch estimate of 18,038 (mt) was used in projections.. Catch in 2021 is assumed as the sum of the U.S. ABC and the Candian quota (23,184 (mt)).

Year	Catch (mt)	SSB (mt)	F
2020	18038	62039 (27791 - 120790)	0.366
Year	Catch (mt)	SSB (mt)	F
2021	23184	70137 (29523 - 140000)	0.412
2022	14881	84382 (38079 - 188330)	0.22
2023	18596	103970 (52807 - 261522)	0.22

Special Comments:

- Sources of uncertainty:

Natural mortality was assumed to be constant over both time and age. During the 2017 benchmark, the working group acknowledged that natural mortality likely varied over time, but concluded that the percent occurrence of mackerel in the diets of those predators well sampled by the NEFSC bottom trawl surveys was not sufficient to inform time-varying natural mortality rates. In addition, estimates of predation mortality were not available for the months the northern contingent was outside of the NEFSC trawl survey area. The working group also discussed the possibility of modeling natural mortality as age-varying, though time-invariant. However, recent work on the performance of assessment models across varying assumed natural mortality rates indicated that an assumed age-invariant natural mortality that approximates the average natural mortality across ages performed similarly to age-varying natural mortality values (Deroba and Schueller 2013). Accordingly, the working group moved forward with the assumption that natural mortality was constant across all ages and years. To consider evidence of different natural mortality rates, a likelihood profile for natural mortality was completed and is included in the supplementary material.

Canadian catch estimates represent a subset of total Canadian catch because bait fishery, recreational fishery and commercial discard estimates are not available.

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 both contingents 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 0.162 in the 2017 assessment and 0.326 in 2019. The 5-year Mohn’s ρ , relative to F, was 0.112 in the 2017 assessment and -0.093 in 2019. The retrospective pattern for this assessment was considered to be minor because the ρ -adjusted estimates of 2019 SSB ($SSB_{\rho}=32323$) and 2019 F ($F_{\rho}=0.505$) were within the approximate 90% confidence intervals around SSB (24,782 - 74,133) and F (0.25 - 0.84). Consequently, a retrospective adjustment of spawning stock biomass or fishing mortality in 2019 was not required.

- Population projections

The stochastic short-term projections completed for this management track assessment followed the

methodology accepted during the 2017 benchmark (NEFSC 2018) where recruitment is modeled by sampling from an empirical cumulative density function derived using recruitment estimates from 1975 onward. Due to recent low recruitment, additional short-term projections were completed using recruitment estimates from 1999 onward and 2009 onward. These projections are presented in the supplementary material as sensitivity analyses.

Northwest Atlantic mackerel is currently in a rebuilding plan and after the 2017 benchmark assessment, a target fishing mortality of 0.237 was selected as the F that would rebuild the stock in five years (by 2023). The short-term projections completed for the rebuilding plan were largely driven by a strong incoming (2015) year class. While this management track assessment indicates that 2016 recruitment is only 15% lower than that estimated during the 2017 assessment (and the only recruitment estimate since 2008 above the time-series median), the subsequent projected increase in SSB was not realized. As a result, even in the absence of fishing, the stock is not projected to be rebuilt by 2023. The absence of an increase in SSB is likely due to a combination of factors, including the increase in total removals in recent years due to the recalibrated MRIP estimates, a time-series low recruitment estimate for 2017, a minor retrospective pattern that resulted in an overestimation of spawning stock biomass, and a recent (2017-2019) decline in age-2 and age-3 maturity. Temporal trends in the proportion mature-at-age are included in the supplementary material.

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

U.S. catch was updated to include the recalibrated MRIP estimates. Updating the MRIP estimates did not impact the general temporal trend in recreational catch; however, from 2008-2016 the recalibrated catch estimates were approximately 213% higher than the original estimates used in the 2017 benchmark assessment (NEFSC 2018). A comparison of the original and realibrated MRIP estimates is included in the supplementary material. Additionally, updates to Canadian catch, catch-at-age and weight-at-age (WAA) were provided by Canada's Department of Fisheries and Oceans (DFO). The updated total catch and WAA estimates resulted in only minor changes to SSB and did not impact the temporal trend in fishing mortality, but the magnitude of F increased from 2010 onward by up to 20%. Minor updates were also provided for the U.S. egg index; these updates had a negligible impact on resulting model estimates. A comparison of the results from these bridge runs is provided in the supplementary material.

- Changes in stock status:

The stock status of northwest Atlantic mackerel has not changed since the previous assessment (NEFSC 2018).

- Qualitative description of stock condition:

Fishery composition data show a truncation in age structure, though age-9 fish were observed in the 2019 catch 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 2017 but declined in 2018 and 2019. With the exception of 2017, these range-wide SSB estimates have been below the time-series median since 2005. However, egg production estimates for the southern contingent were approximately an order of magnitude greater in 2018 and 2019 compared to the previous ten years, and in 2018 and 2019 the southern contingent represented 54% and 18%, respectively, of the range-wide spawning stock biomass. With the exception of the 2015 year class (2016 recruitment), recruitment estimates have been below the corresponding time-series median since 2008 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 on stock structure and the extent of contingent mixing is 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. Genetic work is also needed to distinguish the two spawning contingents and samples are currently being collected for a genetics study recently initiated by Canada's DFO.

- Additional issues:

DFO Canada is currently finalizing an assessment of the northern spawning contingent of northwest Atlantic mackerel, which indicates that the northern contingent has been in the Critical Zone, as defined by DFOs precautionary approach framework, since 2009. Estimated spawning stock biomass in 2020 was 29,109 mt and represented the second lowest estimate of the time series. Estimated 2020 fishing mortality for fully selected fish (age-5+) was 1.30 and above $F_{40\%}$. The 2015 year class was the only year class estimated to be greater than the time-series median since 2009, with this cohort now representing less than 8% of the harvested catch in 2020.

References:

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- Redding, S. G., L. W. Cooper, M. Castonguay, C. Wiernicki, and D. H. Secor. 2021. Northwest Atlantic mackerel population structure evaluated using otolith d18O composition. *ICES Journal of Marine Science*. doi:10.1093/icesjms/fsaa117.

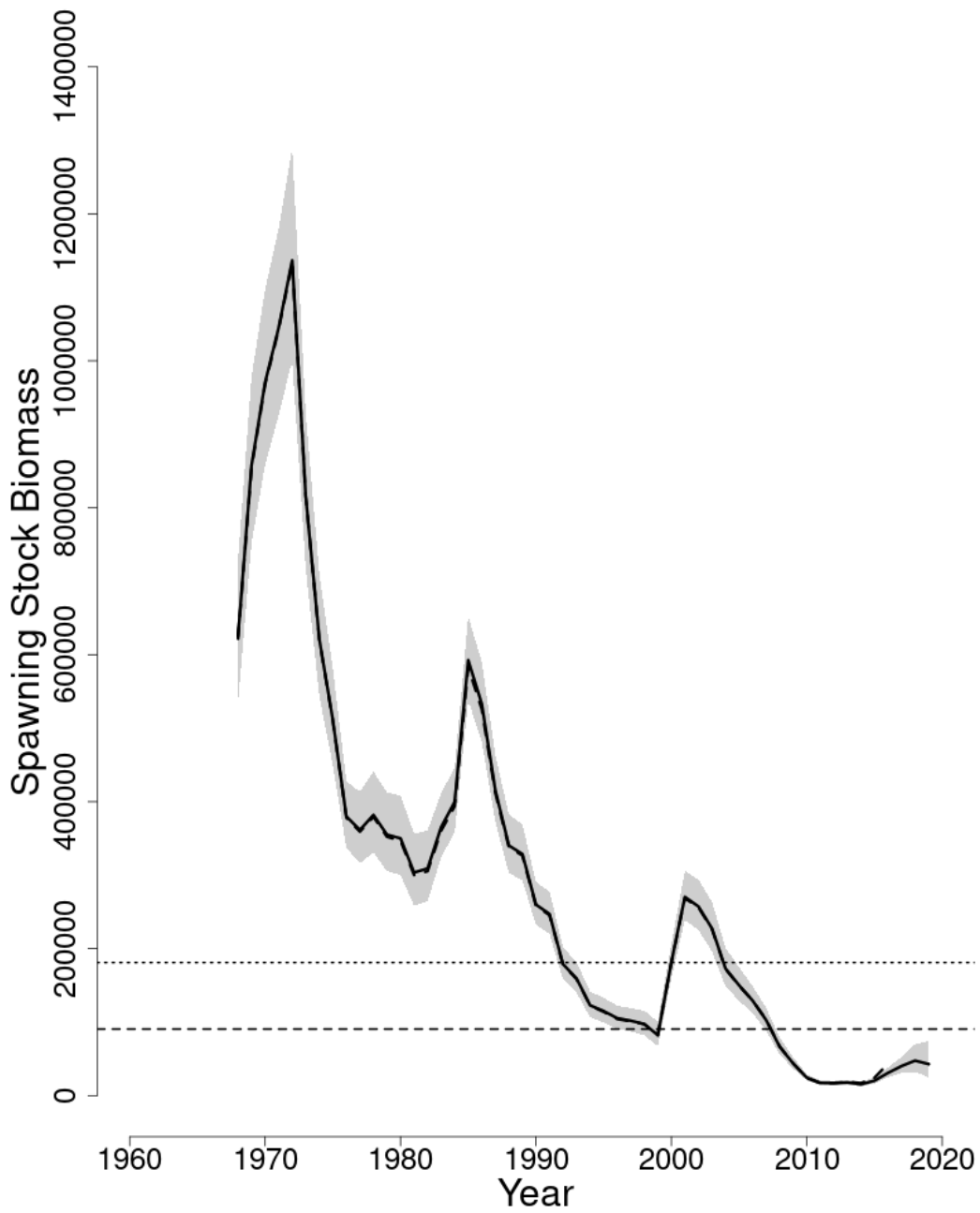


Figure 1: Trends in spawning stock biomass (mt) of northwest Atlantic mackerel between 1968 and 2019 from the current (solid line) and previous (dashed line) assessment and the corresponding $SSB_{Threshold}$ ($\frac{1}{2} SSB_{MSY}$ proxy; horizontal dashed line) as well as SSB_{Target} (SSB_{MSY} proxy; horizontal dotted line) based on the 2021 assessment. The approximate 90% lognormal confidence intervals are shown.

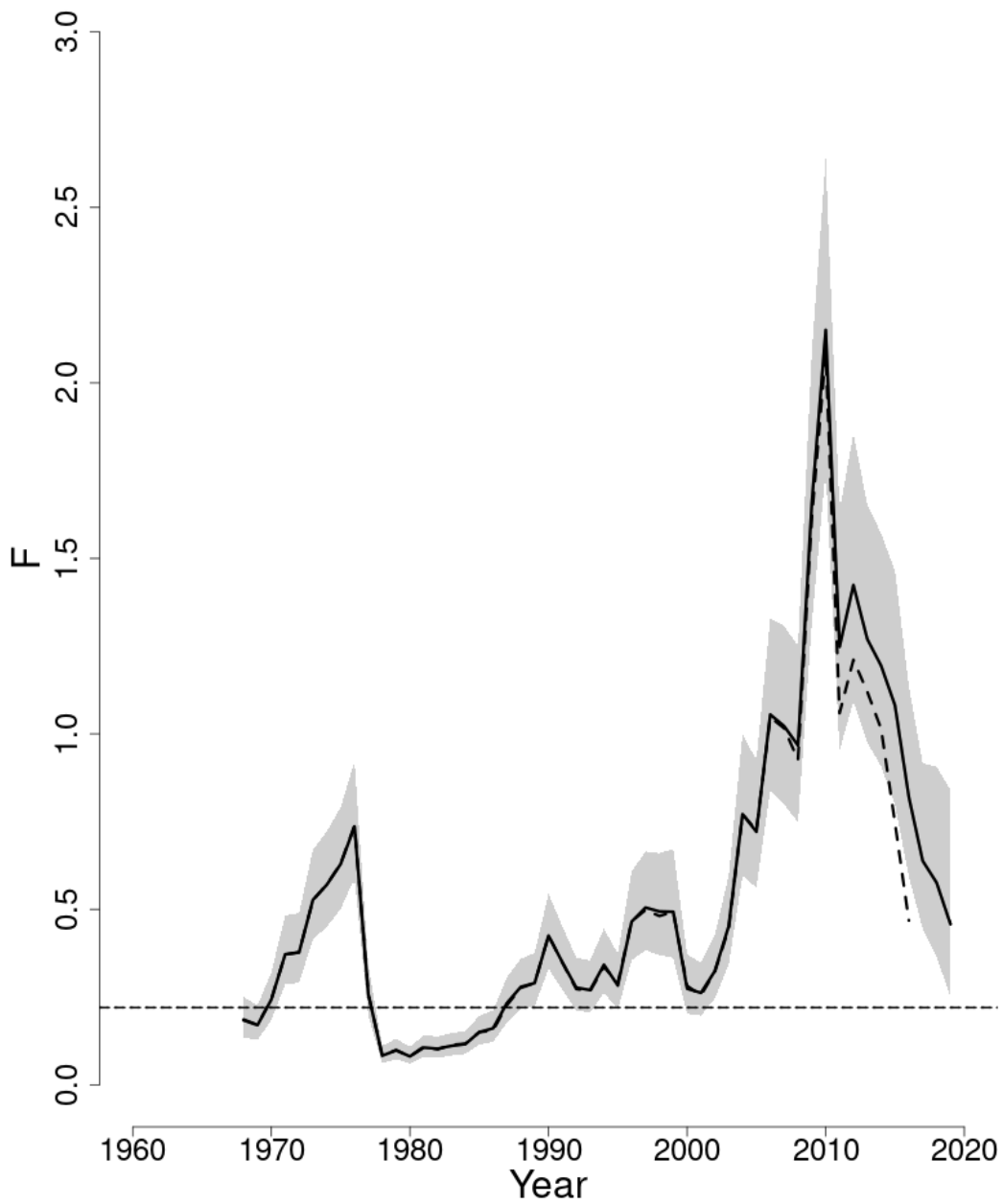


Figure 2: Trends in the fully selected fishing mortality (F) of northwest Atlantic mackerel between 1968 and 2019 from the current (solid line) and previous (dashed line) assessment and the corresponding $F_{Threshold}$ ($F_{MSY proxy}=0.22$; horizontal dashed line). The approximate 90% lognormal confidence intervals are shown.

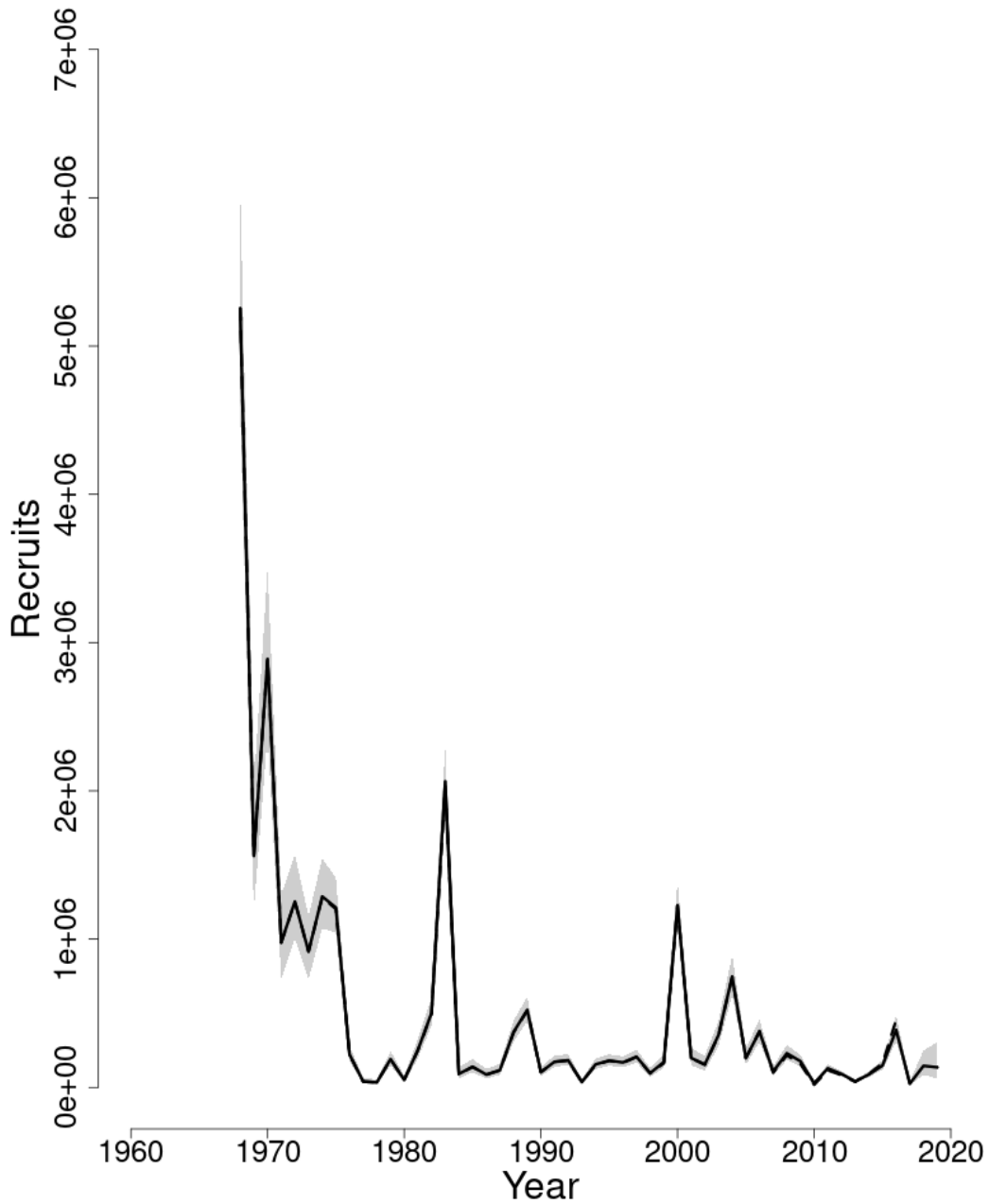


Figure 3: Trends in Recruits (age-1) (000s) of northwest Atlantic mackerel between 1968 and 2019 from the current (solid line) and previous (dashed line) assessment. The approximate 90% lognormal confidence intervals are shown.

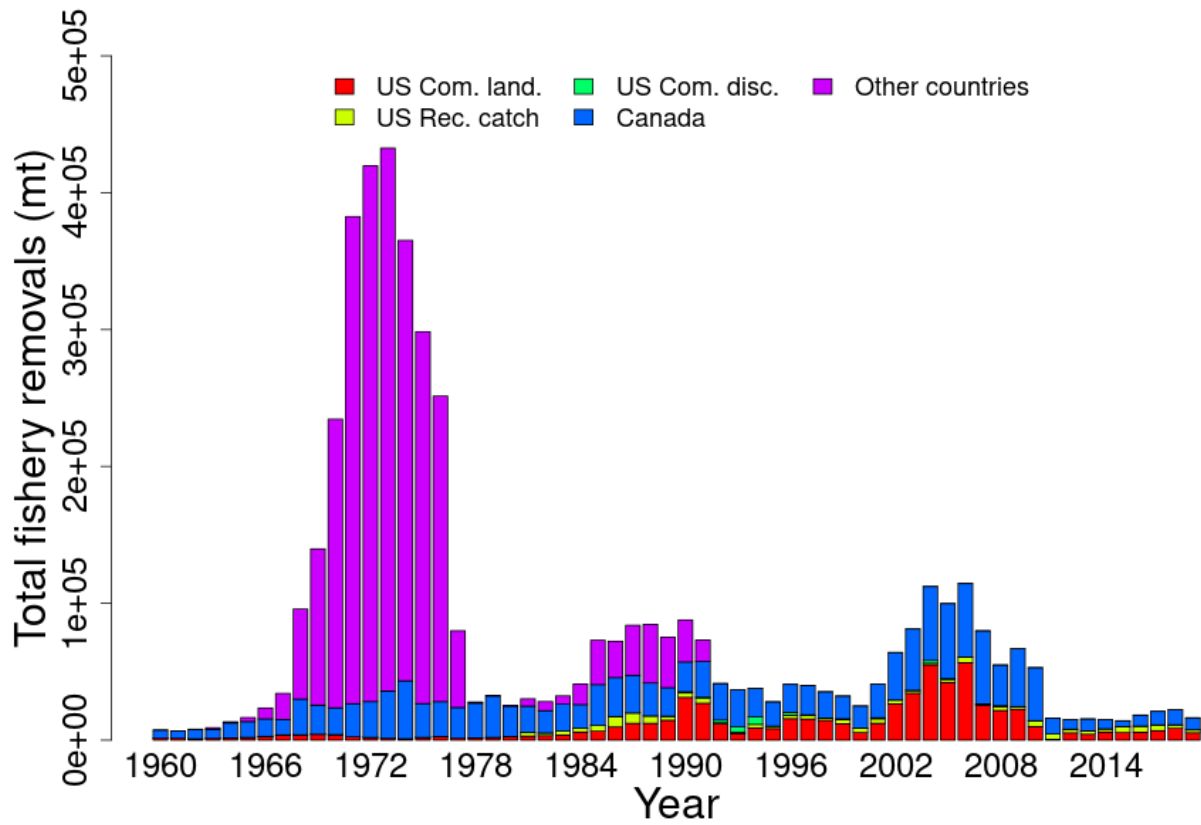


Figure 4: Total catch of northwest Atlantic mackerel between 1968 and 2019 by all sources. U.S. recreational catch represents recreational landings plus discards, Canada represents Canadian landings (discards are not available), and other countries represents landings by all other countries.

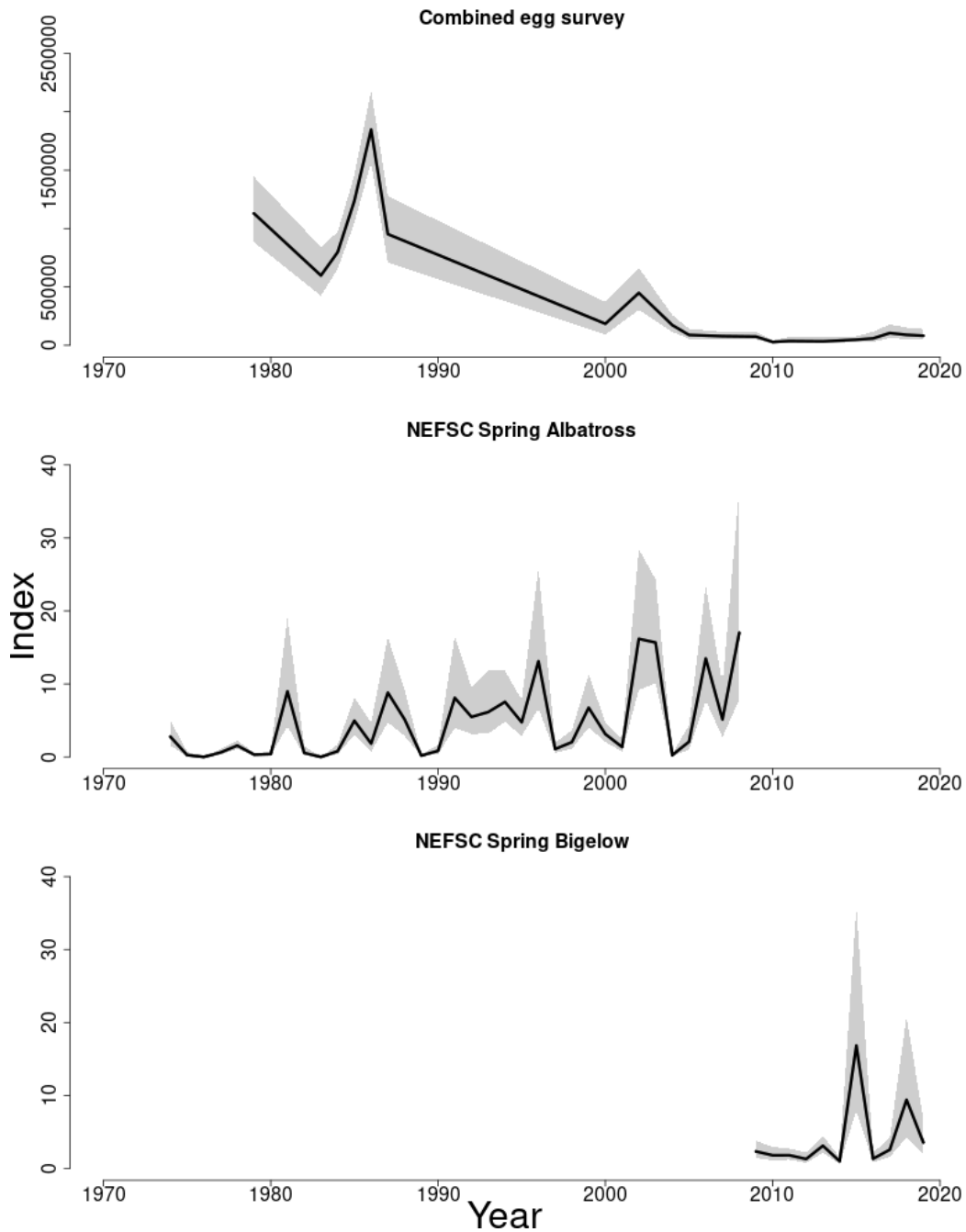


Figure 5: Indices of spawning stock biomass (mt) from the combined egg surveys and age-3+ fish/tow from the NEFSC spring bottom trawl survey for northwest Atlantic mackerel between 1974 and 2019.