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Gulf of Maine Atlantic cod

2021 Update 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 Gulf of Maine Atlantic cod (Gadus morhua) stock is an operational assessment of the existing benchmark assessment (NEFSC 2013). This stock was most recently assessed in 2019. This assessment updates commercial and recreational fishery catch data, research survey indices of abundance, and the analytical ASAP assessment models through 2019. Additionally, stock projections have been updated through 2024. In what follows, there are two population assessment models brought forward from the most recent benchmark assessment (NEFSC 2013): the M=0.2 (natural mortality = 0.2) and the M-ramp (M ramps from 0.2 to 0.4) assessment models (see NEFSC 2013 for a full description of the model formulations).

State of Stock: Based on this updated assessment, the stock status for the Gulf of Maine Atlantic cod (*Gadus morhua*) stock is overfished and overfishing is occurring for the M=0.2 model, and overfished and overfishing is not occurring for the M-ramp model (Figures 1-2). Retrospective adjustments were made to the M=0.2 model results because the retrospective pattern was major (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}). Retrospective adjustments were not made to the M-ramp model because the retrospective pattern was minor. Spawning stock biomass (SSB) in 2019 was estimated to be 1969 (mt) under the retro-adjusted M=0.2 model and 3223 (mt) under the M-ramp model scenario (Table 1) which is 5% and 5% (respectively) of the biomass target, SSB_{MSY} *proxy* (39,912 (mt) and 60,010 (mt); Figure 1). The 2019 fully selected fishing mortality was estimated to be 0.249 under the retro-adjusted M=0.2 model and 0.172 under the M-ramp model, which is 144% and 98% of the F_{MSY} *proxy*($F_{40\%}$; 0.173 and 0.175; Figure 2).

Table 1: Catch and status table for Gulf of Maine Atlantic cod. All weights are in (mt), recruitment is in (000s), and F_{Full} is the fishing mortality on fully selected ages. Note terminal year SSB and F_{Full} is not retro-adjusted in this table.

	2012	2013	2014	2015	2016	2017	2018	2019
Data								
Recreational discards	103	195	151	168	334	617	340	111
Recreational landings	1,245	1,524	796	11	187	169	11	43
Commercial discards	97	54	27	14	8	16	17	7
Commercial landings	2,759	951	832	227	320	376	398	335
Catch for Assessment	4,204	2,723	1,806	420	850	1,177	766	497
Model Results (M=0.2)								
Spawning Stock Biomass	3494	1826	1145	1184	1736	2126	2314	3083
F_{Full}	1.66	2.16	2.37	0.43	0.59	0.61	0.32	0.16
Recruits $age1$	1606	667	2119	804	530	966	3141	1298
Model Results (M-ramp)								
Spawning Stock Biomass	4174	2288	1655	1859	2485	2776	2726	3223
F_{Full}	1.46	1.85	1.74	0.3	0.44	0.49	0.28	0.17
Recruits $age1$	3285	1484	4739	1699	1024	1717	5160	1981

Table 2: Comparison of reference points estimated in an earlier assessment and from the current assessment update. The overfishing threshold is the F_{MSY} *proxy* ($F_{40\%}$). The biomass target, (SSB_{MSY} *proxy*) was based on long-term stochastic projections of fishing at the F_{MSY} *proxy*. Median recruitment reflects the median estimated age-1 recruitment from 1982 - 2017. Intervals shown reflect the 5^{th} and 95^{th} percentiles.

	2019 M=0.2	2019 M-ramp	M=0.2	M-ramp
F_{MSY}	0.173	0.175	0.173	0.175
SSB_{MSY} (mt)	42,692 (27,916 - 62,785)	63,867 (46,144 - 84,098)	39,912 (25,472 - 59,589)	60,010 (41,916 - 80,517)
MSY (mt)	7,580 (4,853 - 11,366)	11,420 (8,149 - 15,268)	7,171 (4,462 - 11,023)	10,873 (7,439 - 14,841)
Median recruits age-1) (000s)	4,377 (1,161 - 14,434)	8,464 (2,353 - 15,934)	4,677 (1,064 - 16,392)	9,249 (2,129 - 18,031)
Overfishing	Yes	Yes	Yes	No
Overfished	Yes	Yes	Yes	Yes

Projections: Short term projections of median total fishery yield and spawning stock biomass for Gulf of Maine Atlantic cod were conducted based on a harvest scenario of fishing at the FMSY proxy between 2022 and 2024. Catch in 2020 and 2021 was estimated at 409 and 523 mt, respectively. Recruitment was sampled from a cumulative distribution function derived from ASAP estimated age-1 recruitment between 1982 and 2017. The projection recruitment model declines linearly to zero when SSB is below 6.3 kmt under the M=0.2 model and 7.9 kmt under the M-ramp model. The 2020 age-1 recruitment was estimated from the geometric mean of the 2015-2019 ASAP recruitment estimates. A retrospective adjustment was applied to the M=0.2 model. Assumed weights are based on an average of the most recent three years. For the M-ramp model, projections are shown under the assumption of M=0.4 short-term natural mortality.

Table 3: Short term projections of total fishery catch and spawning stock biomass for Gulf of Maine Atlantic cod based on a harvest scenario of fishing at the F_{MSY} *proxy* ($F_{40\%}$) between 2022 and 2024. Catch in 2020 and 2021 has been estimated at 409 (mt) and 523 (mt), respectively. For the M=0.2 model, a retrospective adjustment has been appiled. For the M-ramp model, projections are shown under the assumption of M=0.4 short-term natural mortality.

Year	Catch (mt)	SSB (mt)	F_{Full}	Catch (mt)	SSB (mt)	F_{Full}
		M=0.2			*M-ramp*	
2020	409	2,635	0.162	409	3,925	0.119

Year	Catch (mt)	SSB (mt)	F_{Full}	Catch (mt)	SSB (mt)	F_{Full}
		M=0.2			*M-ramp*	
2021	523	3,599	0.137	523	4,759	0.113
2022	821	4,508	0.173	892	5,254	0.175
2023	959	5,488	0.173	919	5,707	0.175
2024	1,244	7,279	0.173	1,017	6,802	0.175

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).

  The existence of two models with differing assumptions of natural mortality is an important source of

uncertainty. Past investigations into changes in natural mortality over time have been inconclusive (NEFSC 2013), however the M-ramp model exhibited lower retrospective error in the last benchmark (NEFSC 2013), although the difference in retrospective error has been reduced in recent updates. Ultimately, both the M=0.2 and M-ramp model were accepted as final models in the SARC55 review (NEFSC 2013). The different assumptions about natural mortality affect the scale of the biomass, recruitment, fishing mortality estimates, and the overfishing status, though terminal estimates (2019) of biomass, fishing mortality and recruitment are similar under both models. Other areas of uncertainty include the increasing amount of retrospective error in both models, stock structure, ecosystem effects, and the veracity of fishery catch data.

- 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 F_{Full} lies outside of the approximate joint confidence region for SSB and F_{Full}).

  The M=0.2 model has a major retrospective pattern (7-year Mohn's rho SSB=0.73, F=-0.35), while the M-ramp model has a minor retrospective pattern (7-year Mohn's rho SSB=0.42, F=-0.21). The 7-year Mohn's rho values from the current assessment have increased from the 2019 assessment for both models (M=0.2: SSB=0.52, F=-0.29; M-ramp: SSB=0.29, F=-0.16). The terminal year M=0.2 model estimates have been retro-adjusted due to the major retrospective pattern.

- 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?

  Population projections for Gulf of Maine Atlantic cod are reasonably well determined, though the projected biomasses for the M=0.2 model from the last assessment did not fall within the confidence bounds of the biomass estimated in the current assessment. The SSB projections for this stock have been biased high in recent years for both models. Multiple factors likely contribute to this, including overestimation of the initial stock size, underestimation of F in the projection bridge year, and reduced recruitment in recent years. Underestimation of F and overestimation of SSB is likely to have a larger impact on short-term projections than reduced recruitment because short-term projections are more strongly driven by existing biomass than future recruitment. However, an additional set of projections were performed for each model using recruitment observations from the most recent 15-year time period (2004 - 2018 year classes) which projected reduced SSB and catch estimates compared to the projections using the full recruitment time series. This stock is not on target to rebuild by 2024.

- 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.

  Recreational catch estimates for 2017 and 2018 were updated due to a change in the MRIP code and database. This resulted in a small (<3%) change to the recreational catch estimates in those years. No other changes were made beyond incorporating an additional year of data (2019).

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

  Overfished status has not changed. Overfishing is still occuring according to the retro-adjusted M=0.2 model, however it is no longer occurring according to the M-ramp model.

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

  The Gulf of Maine Atlantic cod shows a truncated size and age structure, consistent with a population experiencing high mortality. There are only limited signs of incoming recruitment, continued low survey indices, and the current spatial distribution of the stock is considerably less than its historical range within the Gulf of Maine.

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

  The Gulf of Maine Atlantic cod assessment could be improved with additional studies on natural mortality, a characterization of the overall uncertainty and possible biases in the fishery catch estimates, and research into potential causes of low stock productivity (i.e., low recruitment).

- Are there other important issues?

  When setting catch advice, careful attention should be given to the retrospective error present in both models, particularly given the over-predictions of SSB in previous projections. Also of note is that the 2021 Spring NMFS Bottom Trawl Survey and the 2021 Spring MADMF Bottom Trawl Survey both show declining biomass and abundance, which is not able to be incorporated into this year's assessment or Figure 5.

References:

Northeast Fisheries Science Center. 2013. 55^{th} Northeast Regional Stock Assessment Workshop (55^{th} SAW). US Dept Commer, Northeast Fish Sci Cent Ref Doc. 13-11; 849 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026. CRD13-11

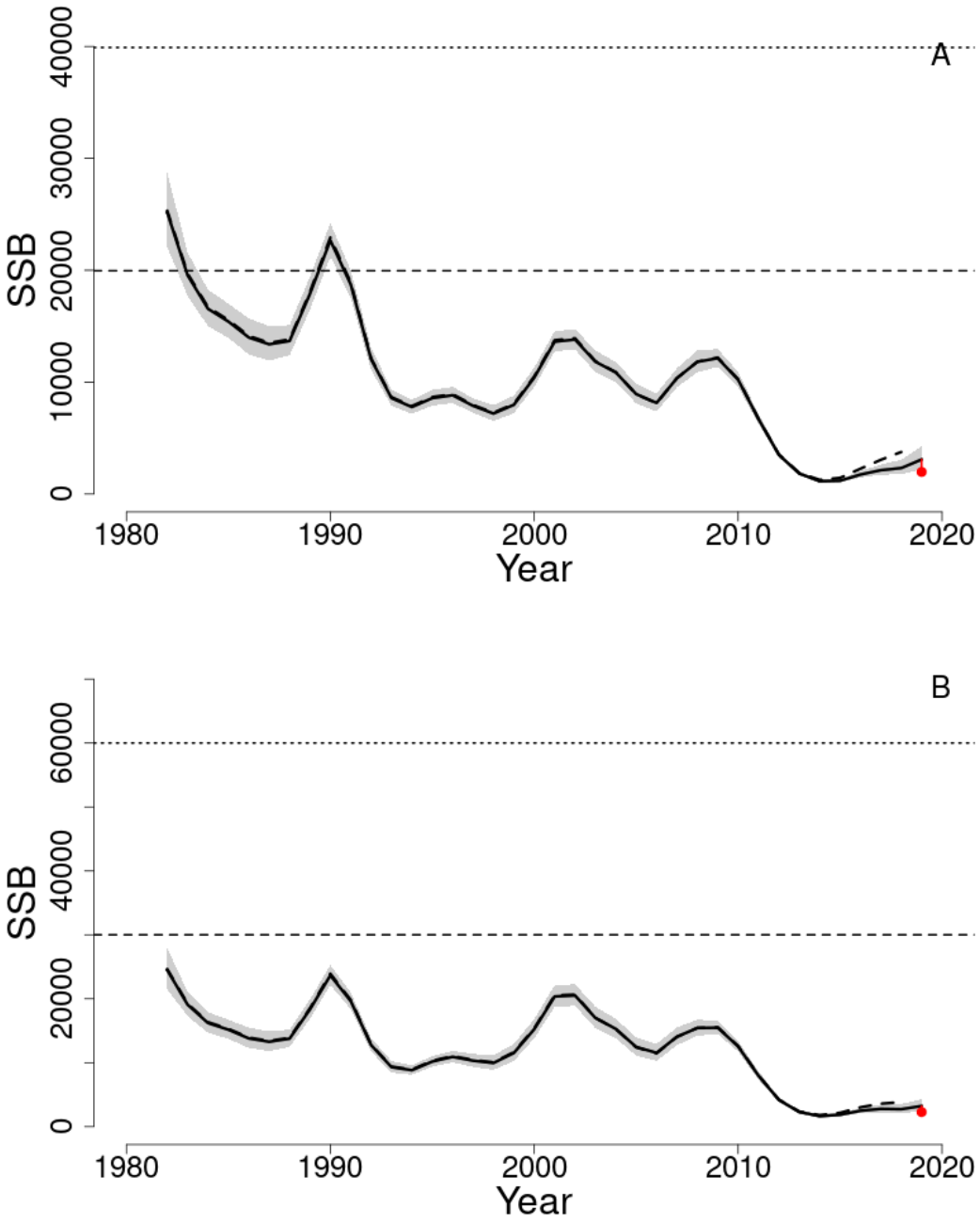

Figure 1: Estimated trends in the spawning stock biomass (SSB) of Gulf of Maine Atlantic cod between 1982 and 2019 from the current (solid line) and previous (dashed line) assessment and the corresponding $SSB_{Threshold}$ ($\frac{1}{2}$ SSB_{MSY}; horizontal dashed line) as well as SSB_{Target} SSB_{MSY}; horizontal dotted line) based on the 2020 M=0.2 (A) and M-ramp (B) assessment models. The 90% lognormal confidence intervals are shown. The red dot indicates the rho-adjusted SSB value that resulted for the M=0.2 model, and would have resulted had a retrospective adjusment been made to the M-ramp model.

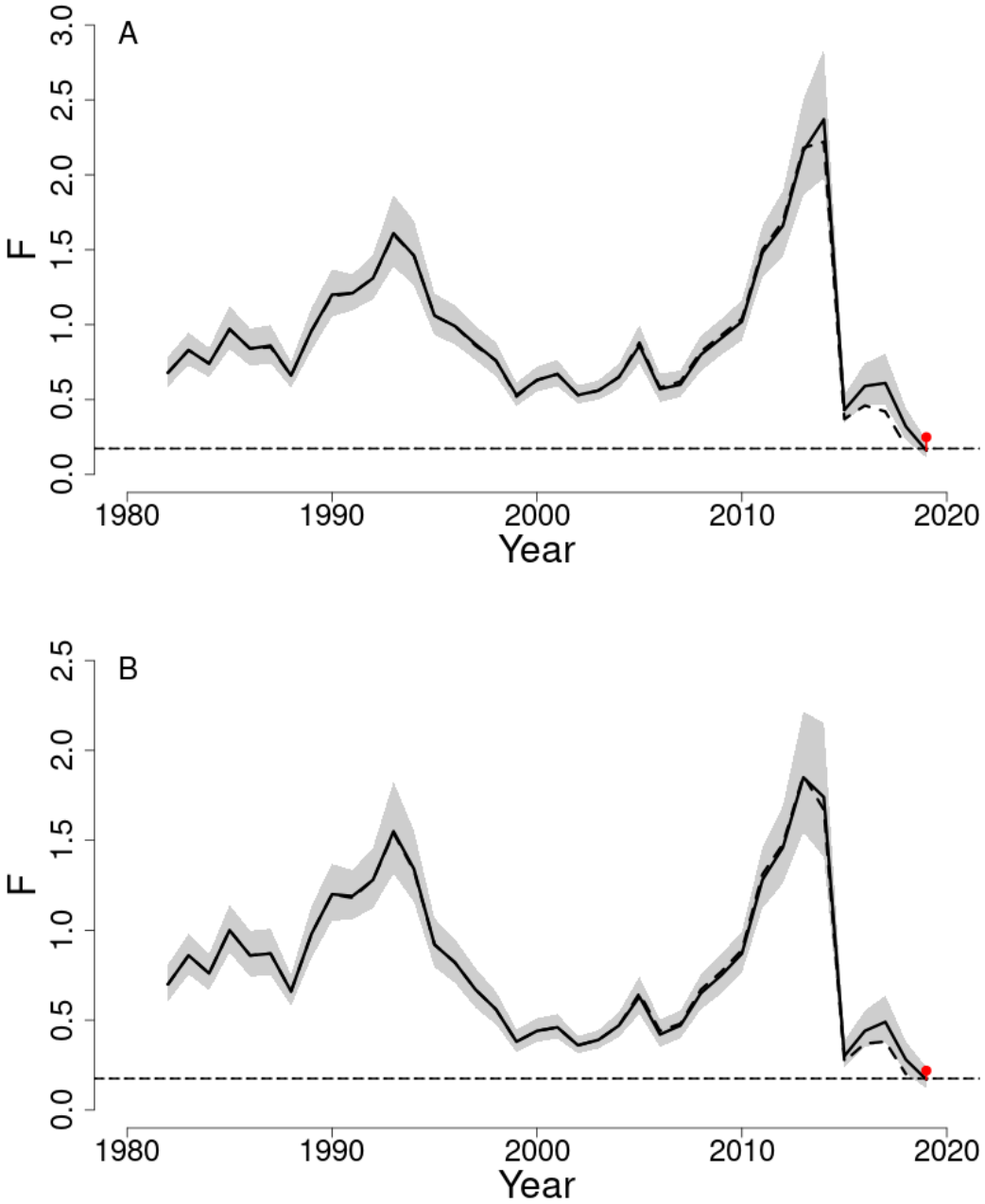

Figure 2: Estimated trends in the fully selected fishing mortality (F) of Gulf of Maine Atlantic cod between 1982 and 2019 from the current (solid line) and previous (dashed line) assessment and the corresponding $F_{Threshold}$ (0.173 (M=0.2), 0.175 (M-ramp); dashed line) based on the 2020 M=0.2 (A) and M-ramp (B) assessment models. The 90% lognormal confidence intervals are shown. The red dot indicates the rho-adjusted F value that resulted for the M=0.2 model, and would have resulted had a retrospective adjusment been made to the M-ramp model.

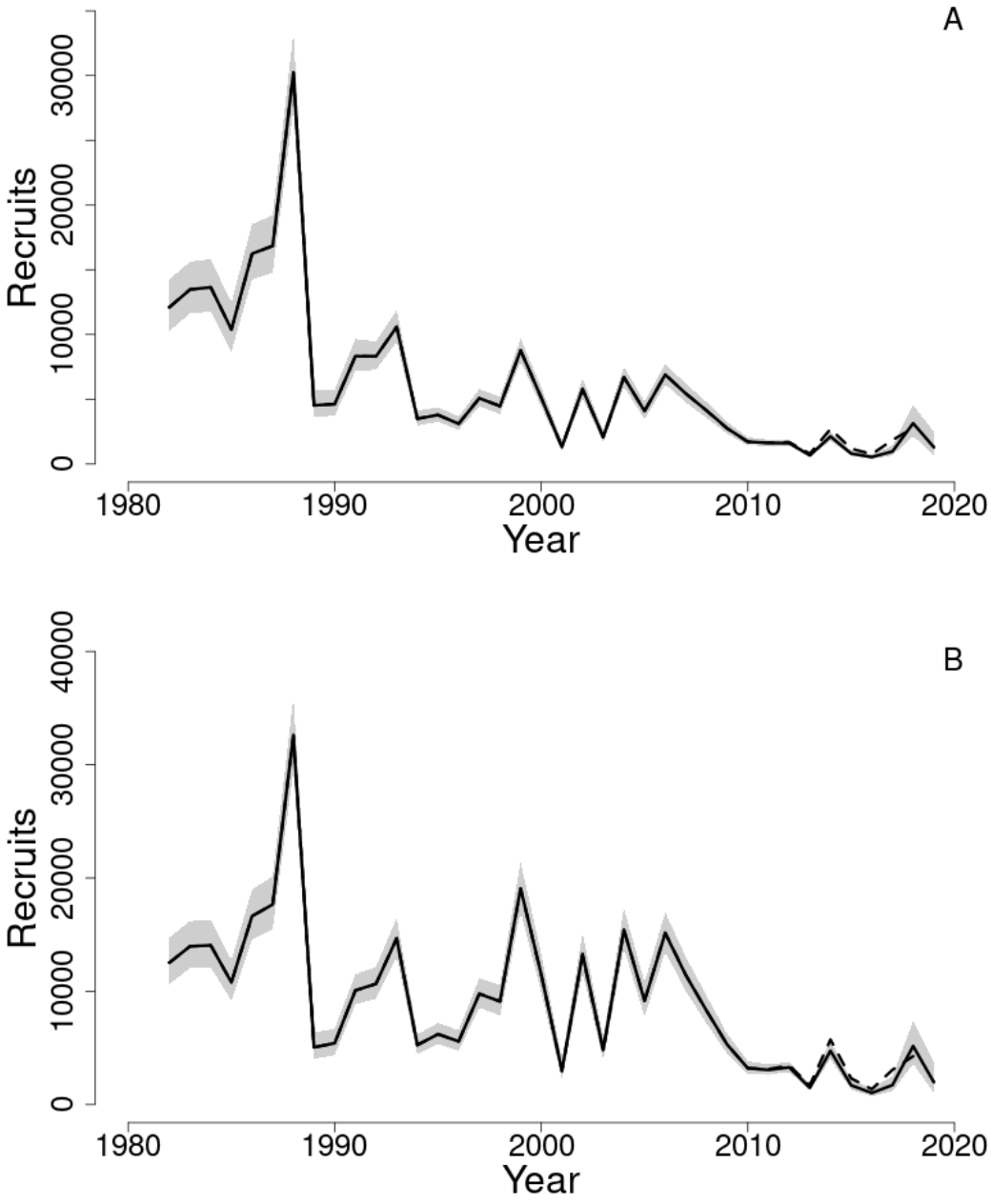

Figure 3: Estimated trends in age-1 recruitment (000s) of Gulf of Maine Atlantic cod between 1982 and 2019 from the current (solid line) and previous (dashed line) M=0.2 (A) and M-ramp (B) assessment models. The 90% lognormal confidence intervals are shown.

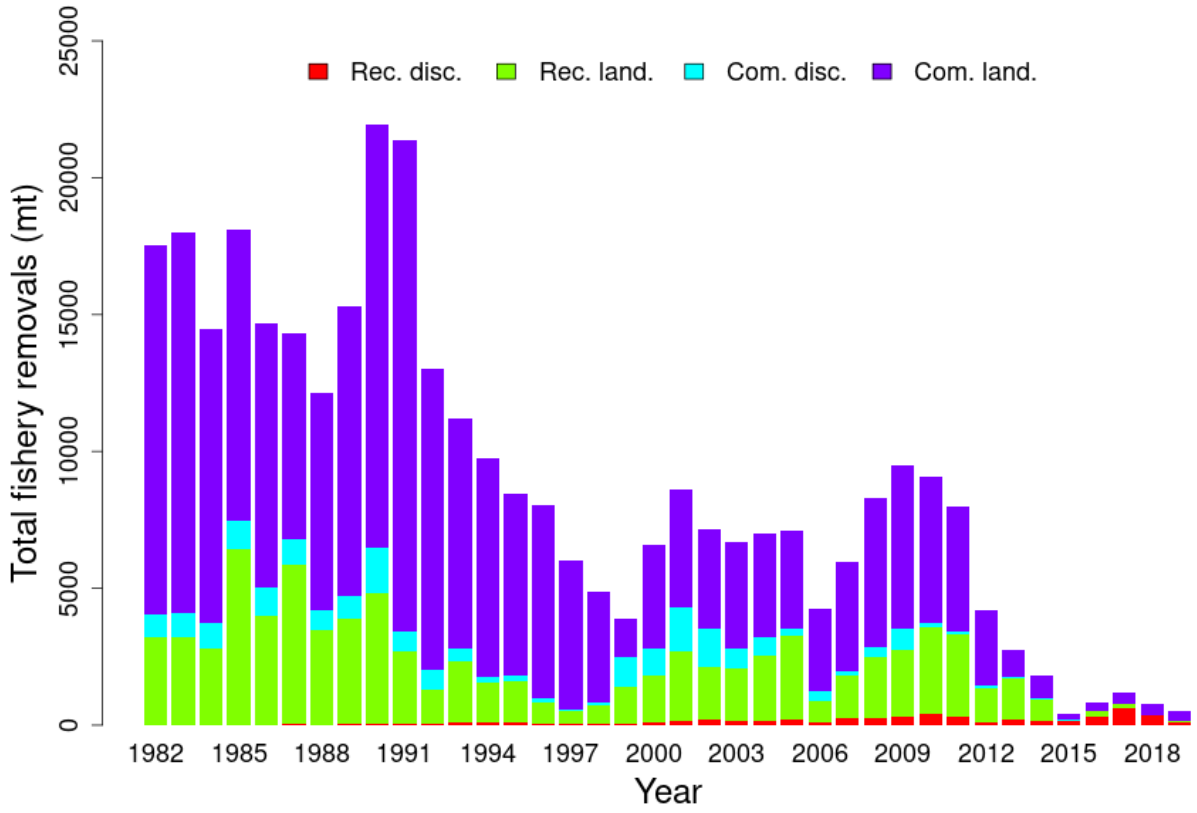

Figure 4: Total catch of Gulf of Maine Atlantic cod between 1982 and 2019 by fleet (commercial and recreational) and disposition (landings and discards).

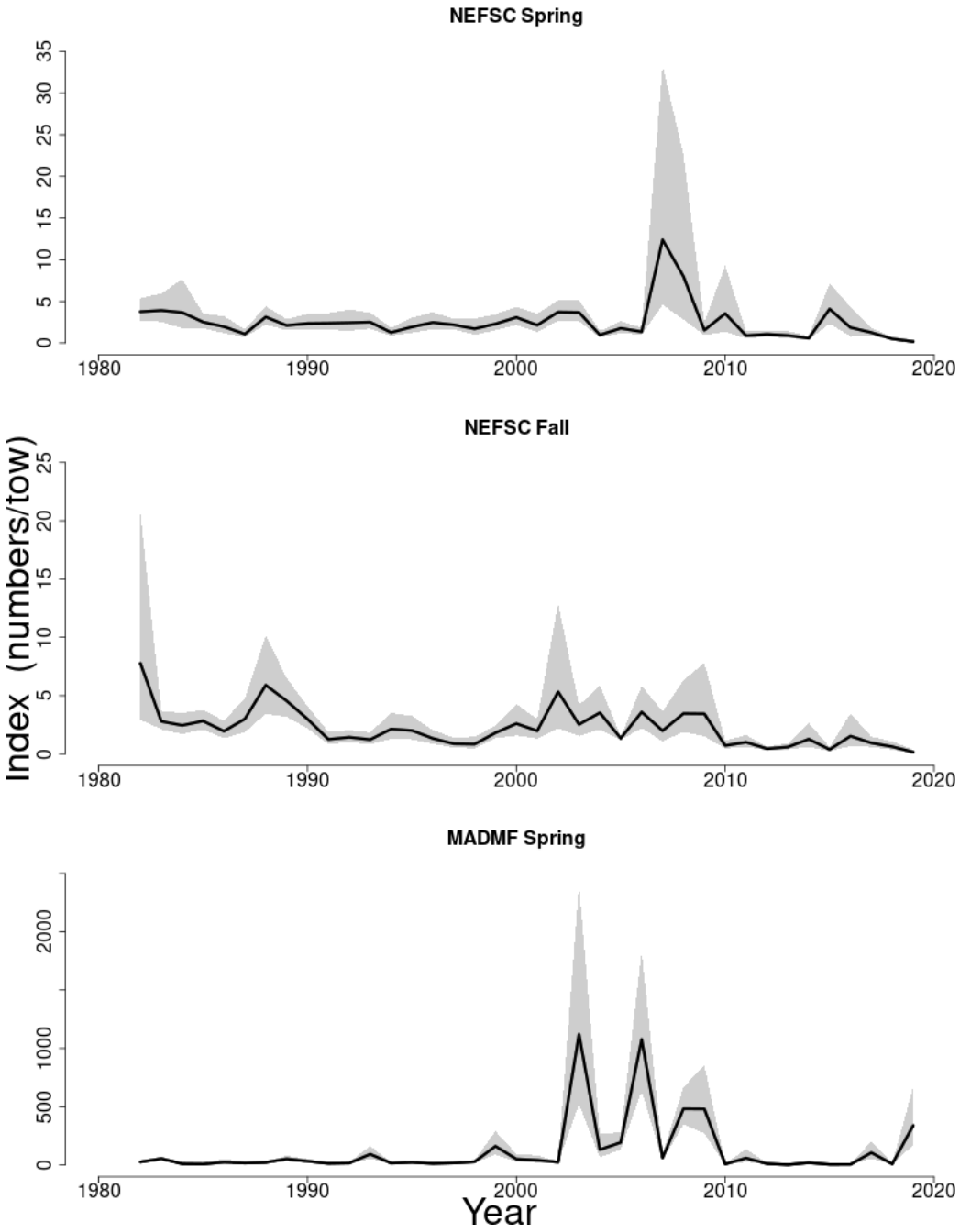

Figure 5: Indices of biomass for the Gulf of Maine Atlantic cod between 1982 and 2019 for the Northeast Fisheries Science Center (NEFSC) spring and fall bottom trawl surveys and Massachusetts Division of Marine Fisheries (MADMF) spring bottom trawl survey. The 90% lognormal confidence intervals are shown.