draft working paper for peer review only

Georges Bank haddock

2019 Assessment Update 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 Georges Bank haddock (Melanogrammus aeglefinus) stock is a Level-2 operational update of the existing 2017 update VPA assessment (NEFSC, 2017). The last benchmark for this stock was in 2008 (Brooks et al., 2008). Based on the previous assessment in 2017, the stock was not overfished, and overfishing was not ocurring. This assessment updates commercial fishery catch data, research survey indices of abundance, weights and maturity at age, and the analytical VPA assessment model and reference points through 2018. Stock projections have been updated through 2022. This report reflects decisions made during the Peer Review September 9-12, 2019.

State of Stock: Based on this updated assessment, the Georges Bank haddock (*Melanogrammus aeglefinus*) stock is not overfished, and overfishing is not occurring (Figures 1-2). Retrospective adjustments were made to the model results. Spawning stock biomass (SSB) in 2018 was estimated to be 507,130 (mt) which is 365% of the biomass target (SSB_{MSY} *proxy* = 138,924; Figure 1). The 2018 average fishing mortality on ages 5-7 was estimated to be 0.061 which is 18% of the overfishing threshold proxy (F_{MSY} *proxy* = 0.33; Figure 2). The F_{MSY} *proxy* is expressed as the average F on ages 5-7 for compariability with the VPA estimated F.

Table 1: Catch and status table for Georges Bank haddock. All weights are in (mt), recruitment is in (000s), and $\bar{F}_{5-7}$ is the average fishing mortality on ages 5 to 7. Model results are from the current updated VPA assessment. A rho adjustment was not applied to values in this Table.

	2011	2012	2013	2014	2015	2016	2017	2018
				Data				
US Commercial discards	212	321	538	1,409	1,552	1,880	786	408
US Commercial landings	5,210	1,550	1,659	4,240	4,762	3,682	3,217	4,017
Canadian Catch	11,248	5,064	4,631	12,953	14,374	11,713	13,384	12,222
Catch for Assessment	16,670	6,935	6,828	18,601	20,687	17,274	17,387	16,647
				Model Results				
Spawning Stock Biomass	45,624	35,501	83,187	118,415	202,052	574,481	793,125	859,587
$\bar{F}_{5-7}$	0.425	0.522	0.45	0.447	0.332	0.23	0.068	0.034
Recruits (age 1)	207,156	38,754	29,515	2,267,641	55,083	154,684	546,138	79,974

Table 2: Comparison of reference points estimated in an earlier assessment and from the current assessment update. An $F_{40\%}$ proxy was used for the overfishing threshold (simple average for the current assessment, numbers weighted average for the previous assessment). The medians and 90% probability intervals are reported for MSY, SSBMSY, and RMSY, based on long-term stochastic projections with fishing mortality fixed at $F_{40\%}$.

	2017	2019
F_{MSY} *proxy*	0.41	0.33
SSB_{MSY} (mt)	104,312	138,924 (67,347 - 511,852)
MSY (mt)	24,400	30,489 (14,894 - 111,258)
Median recruits (age 1) (000s)	52,249	59,143 (2,780 - 394,017)
Overfishing	No	No
Overfished	No	No

Projections: Short term projections of biomass were derived by sampling from a cumulative distribution function (cdf) of recruitment estimates from ADAPT VPA (corresponding to SSB>75,000 mt and dropping the two most recent year class estimates for 2017 and 2018). The extremely large 1963, 2003, 2010, 2013, and 2016 year classes were included in the cdf. The annual fishery selectivity was a recent 5 year average except for the 2013 year class, which was assigned the same selectivity at age as the 2010 year class. Thes 2010 and 2013 year classes have demonstrated the slowest growth of any observed year classes in the time series. The maturity ogive was a recent 5 year average. Mean weights at age were a recent 2 year average, except for the 2010 and 2013 year classes, where recent trends in growth were assumed to continue. Retrospective adjustments were applied to the starting numbers at ages (2019) in the projections (each age was multiplied by 0.59).

Table 3: Short term projections of total fishery catch and spawning stock biomass for Georges Bank haddock based on a harvest scenario of fishing at F_{MSY} *proxy* between 2020 and 2022. Catch in 2019 was assumed to be 19,445 mt (estimate provided by the Groundfish Plan Development Team).

Year	Catch (mt)	SSB (mt)	$\bar{F}_{5-7}$
2019	19,445	605,990 (443,224 - 853,0145)	0.052 (0.036 - 0.072)

Year	Catch (mt)	SSB (mt)	F_{5-7}
2020	184,822 (131,096 - 271,319)	581,672 (429,415 - 810,119)	0.332
2021	106,805 (79,085 - 148,763)	503,812 (363,623 - 755,210)	0.332
2022	100,009 (73,029 - 145,801)	412,276 (289,733 - 718,407)	0.332

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).

Sources of uncertainty include the retrospective bias, and future assumptions about weights and selectivity at age. The 2013 year class accounts for a substantial portion of catch and SSB in projections (approximately 80% of catch and 60% of SSB in 2019 and 2020). The ρ-adjusted projections reduce all starting numbers at age to 59% of unadjusted values (i.e., all 2019 numbers at age are multiplied by 1/(1 + ρ[SSB]) = 0.59). The assumed values for selectivity and weights at age in the 2017 update were fairly accurate when compared to the observed weights and estimated selectivity for 2017 and 2018, and may indicate less uncertainty for these parameters compared to previous projections. This update has retained the assumptions used to derive those values in the current projections, but it is unknown if growth and selectivity patterns will change if abundance increases further. The magnitude of the 2016 year class is another source of uncertainty. It is currently estimated to be more than twice the size of the current estimate of the 2010 year class, and accounts for about 20% of projected SSB and 10-30% of projected catch in 2020-2022. The 2018 year class is also estimated to be large (1.66 times the current estimate of the 2010 year class) and highly uncertain (CV=138%), however, its contribution to projections is negligible until 2021 for SSB (18%) and 2022 for catch (11%).

- 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 $\bar{F}_{5-7}$ lies outside of the approximate joint confidence region for SSB and $\bar{F}_{5-7}$).

  The 7-year Mohn's ρ, relative to SSB, was 0.89 in the 2017 assessment and was 0.70 in 2018. The 7-year Mohn's ρ, relative to F, was -0.55 in the 2017 assessment and was -0.44 in 2018. There was a major retrospective pattern for this assessment because the ρ adjusted estimates of 2018 SSB (SSB_ρ=507,130) and 2018 F (F_ρ=0.061) were outside the approximate 90% confidence regions around SSB (614,031 - 1,253,991) and F (0.026 - 0.046). A retrospective adjustment was made for both the determination of stock status and for projections of catch in 2020. The retrospective adjustment changed the 2018 SSB from 859,587 to 507,130 and the 2018 $\bar{F}_{5-7}$ from 0.034 to 0.061.

- 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?

  As noted in (1) above, population projections for Georges Bank haddock are uncertain due to the retrospective bias, assumed future values of selectivity and weights at age, and magnitude of incoming 2016 and 2018 year classes. This stock is not in a rebuilding plan.

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

  No changes, other than the incorporation of new data, were made to the Georges Bank haddock assessment for this update. However, recent years where the DFO survey did not sample the full Georges Bank strata (2012, 2013, 2015, 2017, 2018) were dropped from the VPA analysis.

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

  The stock status of Georges Bank haddock has not changed.

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

The Georges Bank haddock shows a broad age structure, and broad spatial distribution. This stock has produced several exceptionally strong year classes in the last 15 years, leading to record high SSB in recent years. Catches in recent years have been well below the total quota (US+Canada). All survey indices of abundance support the finding that this stock is at an all-time high. Weights at age have been declining since the large 2003 year class, and show further declines with the most recent data.

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

  Projection advice and reference points for Georges Bank haddock are strongly dependent on recruitment. A decade ago, extremely large year classes were considered anomalies (e.g., 1963 and 2003). However, since 2003, there have been four more extremely large year classes (2010, 2013, 2016, and 2018). Future work could focus on recruitment forecasting and providing robust catch advice. Assumptions about weights at age and selectivity are very influential in short term projections. As multiple large year classes move through the population, it is difficult to predict how strong the density dependent response will be, but future work could continue examining performance of projected values with realized values. For this assessment, reference points are estimated with a recent 5 year average for selectivity, maturity, and weights at age, whereas short-term projections use year-specific decisions to deal with the current large year classes. Considering that estimated population abundance at MSY is much less than the current population abundance, recent average biological and fishery parameters may not reflect MSY conditions. Calculating per recruit statistics on an annual basis demonstrates the dynamic range of reference points in response to density dependent changes in growth (see Model Results pdf).

- Are there other important issues?

  The Georges Bank haddock assessment has developed a major retrospective pattern in recent years. This stock assessment has historically performed very consistently. This should continue to be monitored. Density-dependent responses in growth should also continue to be monitored. On an annual basis, known research removals account for 0-0.7% of annual catch removals by weight, and 0-4.6% of annual catch removals by number; this level is insufficient to cause the observed retrospective pattern.

References:

Brooks, E.N, M.L. Traver, S.J. Sutherland, L. Van Eeckhaute, and L. Col. 2008. In. Northeast Fisheries Science Center. 2008. Assessment of 19 Northeast Groundfish Stocks through 2007: Report of the 3^{rd} Groundfish Assessment Review Meeting (GARM III), Northeast Fisheries Science Center, Woods Hole, Massachusetts, August 4-8, 2008. US Dep Commer, NOAA Fisheries, Northeast Fish Sci Cent Ref Doc. 08-15; 884 p + xvii. http://www.nefsc.noaa.gov/publications/crd/crd0815/

Northeast Fisheries Science Center. 2017. Operational Assessment of 19 Northeast Groundfish Stocks, Updated Through 2016. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 17-17; 259 p. doi: 10.7289/V5/RD-NEFSC-17-17

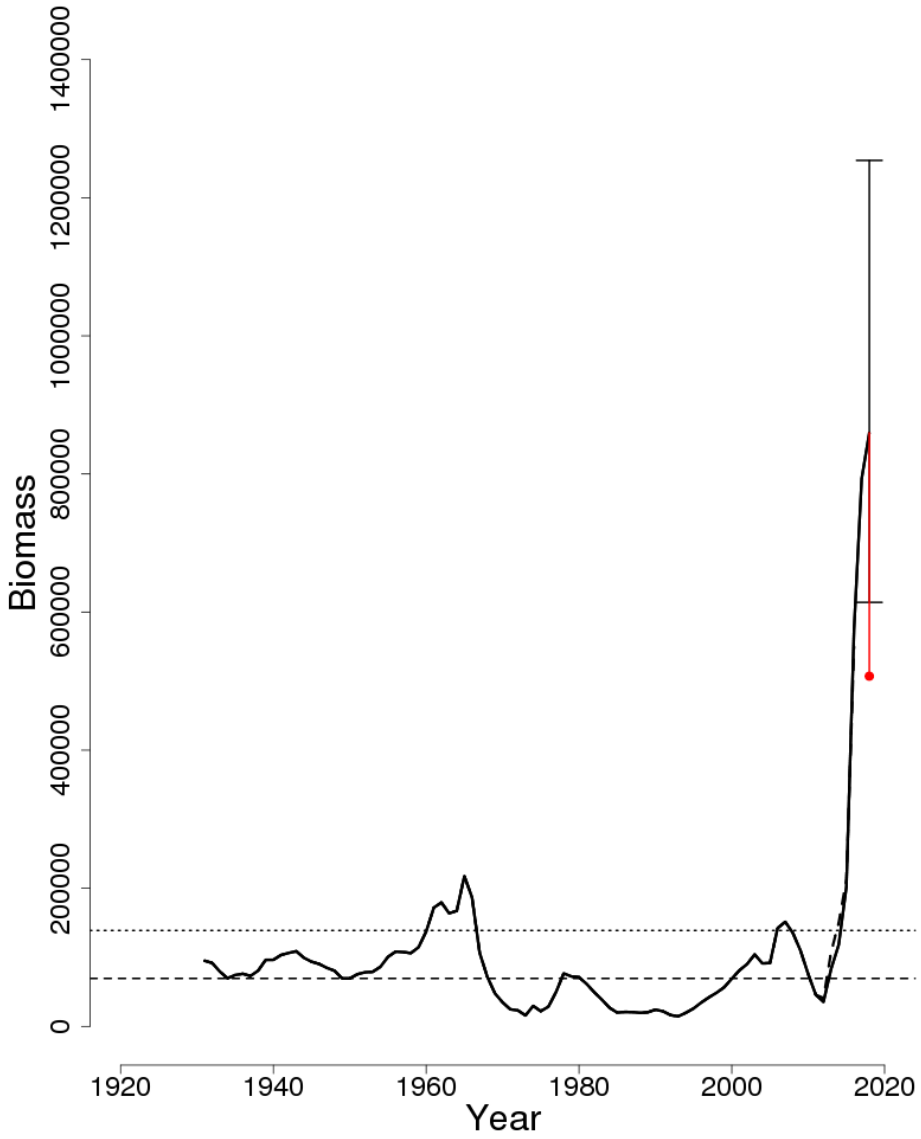

Figure 1: Trends in spawning stock biomass of Georges Bank haddock between 1931 and 2018 from the current (solid line) and previous (dashed line) assessment and the corresponding $SSB_{Threshold}$ ($\frac{1}{2}$ SSB_{MSY} *proxy*; horizontal dashed line) as well as SSB_{Target} (SSB_{MSY} *proxy*; horizontal dotted line) based on the 2019 assessment. Biomass was adjusted for a retrospective pattern and the adjustment is shown in red. The 90% bootstrap probability intervals are shown.

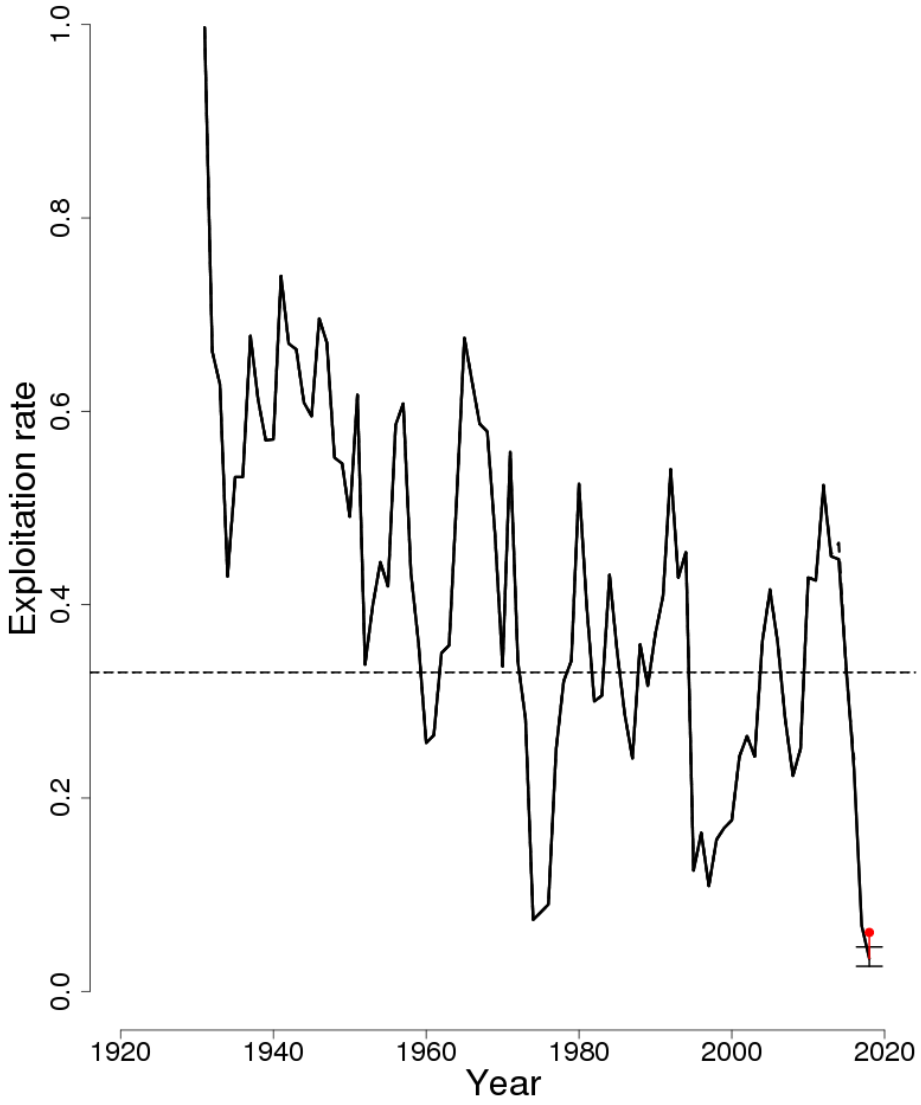

Figure 2: Trends in the average fishing mortality ($\bar{F}_{5-7}$) of Georges Bank haddock between 1931 and 2018 from the current (solid line) and previous (dashed line) assessment and the corresponding $F_{Threshold}$ (F_{MSY} *proxy*=0.33; horizontal dashed line) based on the 2019 assessment. $\bar{F}_{5-7}$ was adjusted for a retrospective pattern and the adjustment is shown in red. The 90% bootstrap probability intervals are shown.

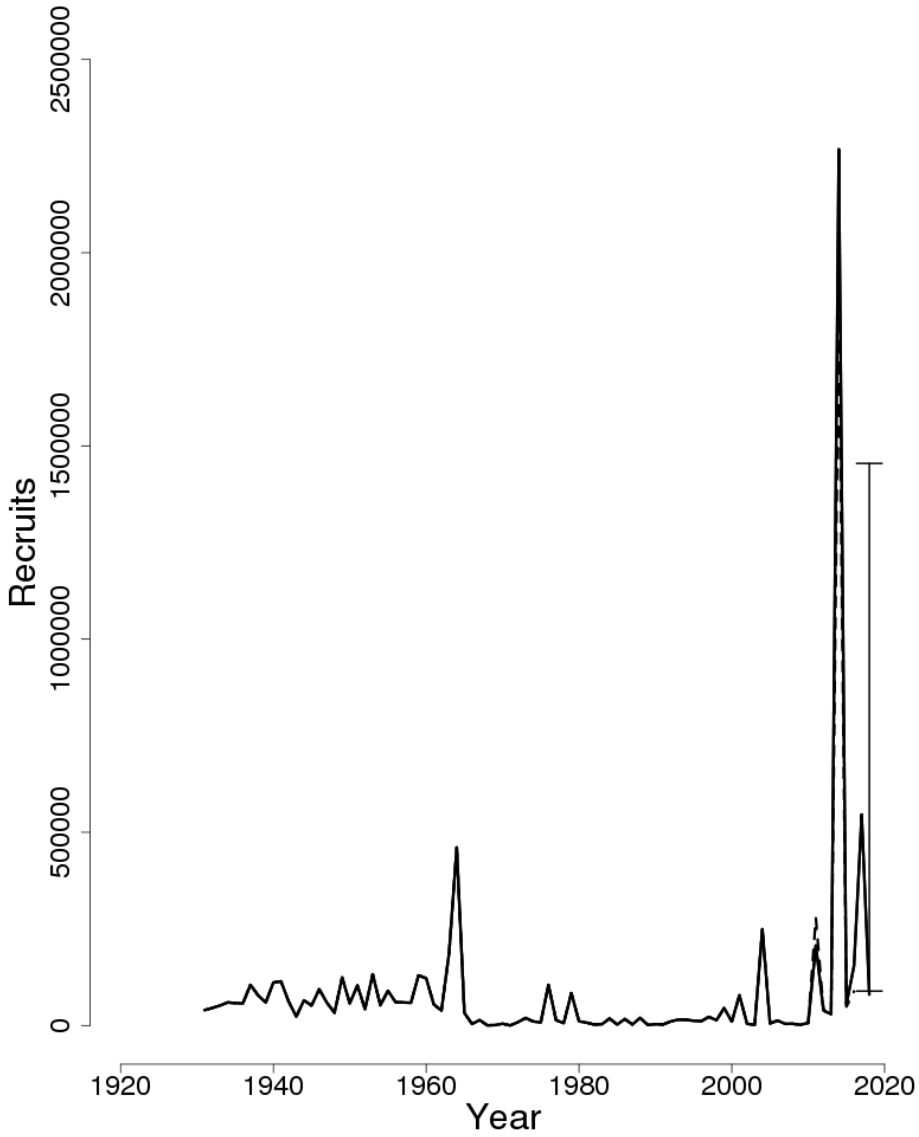

Figure 3: Trends in Recruits (age 1) (000s) of Georges Bank haddock between 1931 and 2018 from the current (solid line) and previous (dashed line) assessment. The 90% bootstrap probability intervals are shown.

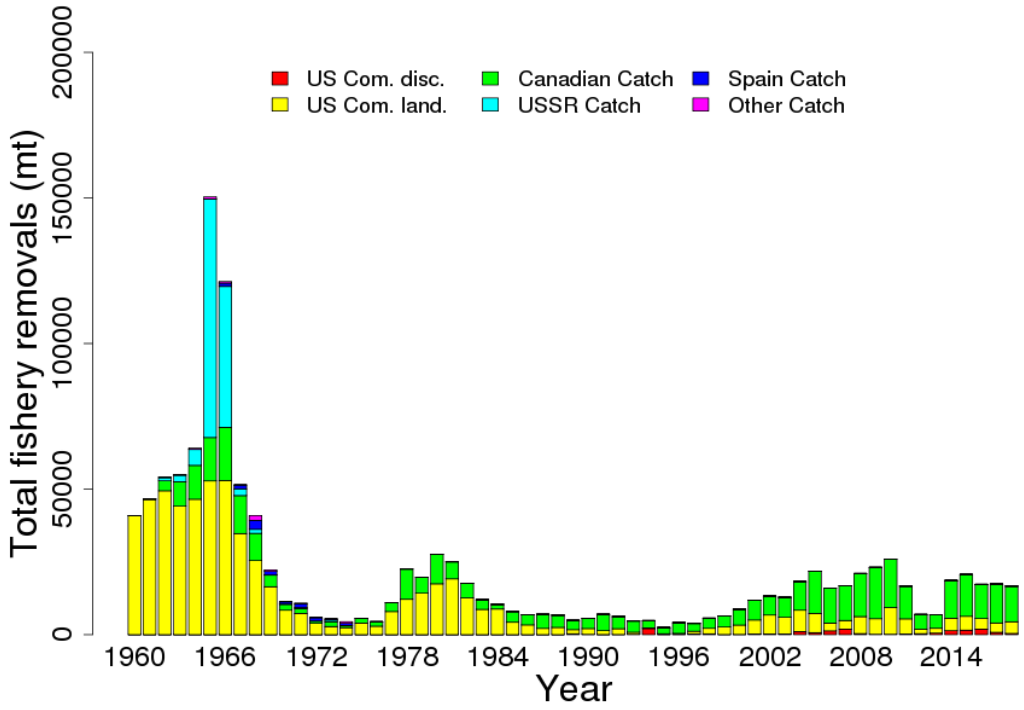

Figure 4: Total catch of Georges Bank haddock between 1931 and 2018 by fleet (US Commercial, Canadian, or foreign fleet) and disposition (landings and discards).

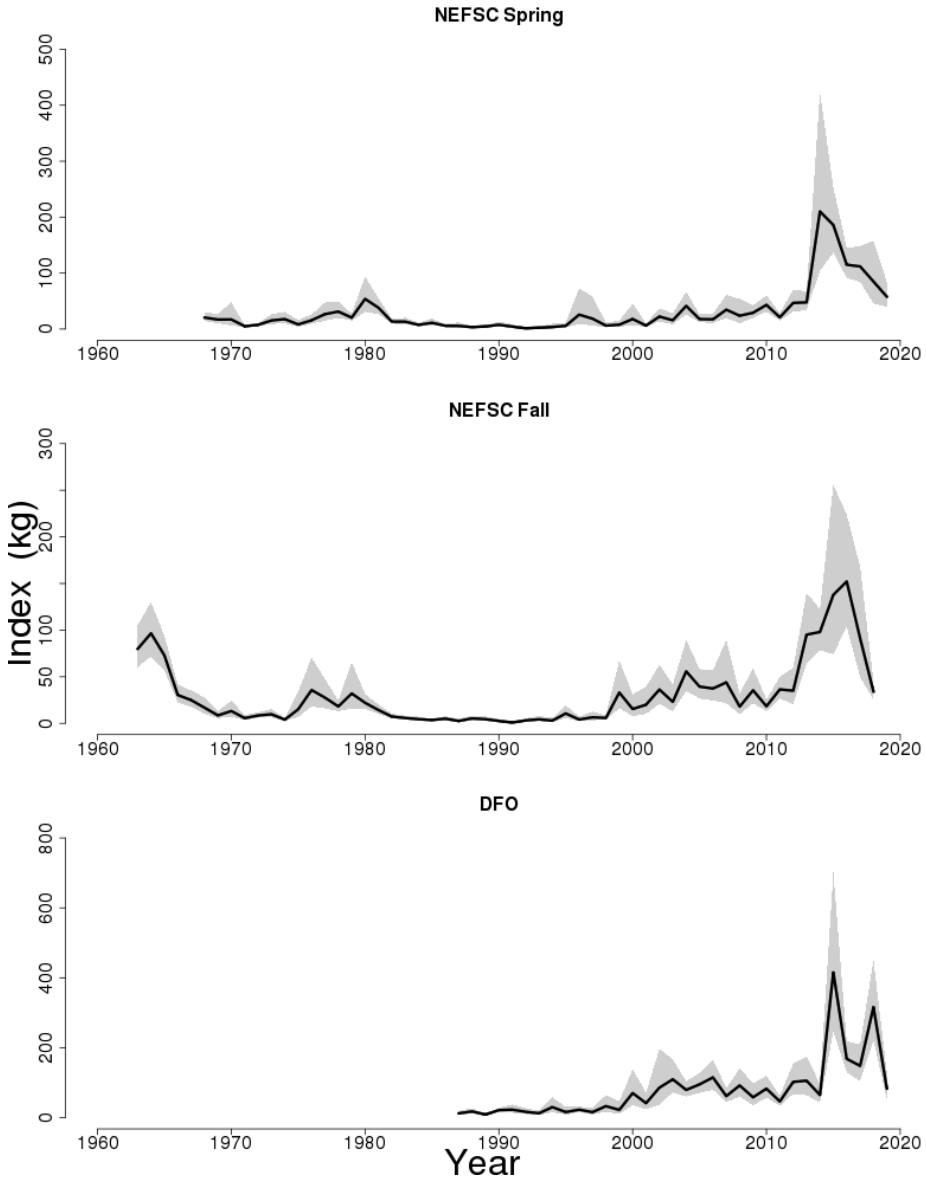

Figure 5: Indices of biomass (Mean kg/tow) for the Georges Bank haddock stock between 1963 and 2019 for the Northeast Fisheries Science Center (NEFSC) spring and fall bottom trawl surveys and the DFO winter bottom trawl survey. The approximate 90% lognormal confidence intervals are shown.