4 Georges Bank haddock

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This assessment of the Georges Bank haddock (Melanogrammus aeglefinus) stock is an operational update of the existing 2015 update VPA assessment (NEFSC, 2015). The last benchmark for this stock was in 2008 (Brooks et al., 2008). Based on the previous assessment in 2015, 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 2016. Stock projections have been updated through 2020. This report reflects decisions made during the Peer Review September 11, 2017.

State of Stock: Based on this updated assessment, the Georges Bank haddock (*Melanogrammus aeglefinus*) stock is not overfished, and overfishing is not occurring (Figures 19-20). Retrospective adjustments were made to the model results. Spawning stock biomass (SSB) in 2016 was estimated to be 290,324 (mt) which is 278% of the biomass target (SSB_{MSY} *proxy* = 104,312; Figure 19). The 2016 numbers weighted average fishing mortality on ages 5-7 was estimated to be 0.309 which is 88% of the overfishing threshold proxy (F_{MSY} *proxy* = 0.353; Figure 20). The F_{MSY} *proxy* is expressed as a numbers weighted average F on ages 5-7 for compariability with the VPA estimated F.

Table 14: Catch and status table for Georges Bank haddock. All weights are in (mt), recruitment is in (000s), and $\bar{F}_{5-7}$ is the numbers weighted 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.

	2009	2010	2011	2012	2013	2014	2015	2016
			Data					
US Commercial discards	142	130	212	321	538	1,409	1,552	1,880
US Commercial landings	5,335	9,180	5,210	1,550	1,659	4,240	4,762	3,682
Canadian Catch	17,648	16,592	11,248	5,064	4,631	12,953	14,374	11,713
Catch for Assessment	23,126	25,903	16,670	6,935	6,828	18,601	20,687	17,274
			Model Results					
Spawning Stock Biomass	109,334	75,519	45,732	41,227	107,671	150,185	212,734	549,938
$\bar{F}_{5-7}$	0.226	0.394	0.485	0.537	0.468	0.34	0.141	0.113
Recruits (age 1)	1,773	6,366	278,296	41,319	23,598	1,839,273	48,629	88,436

Table 15: 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 (numbers weighted average for the current assessment, simple 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 $F_{40\%}$.

	2015	2017
F_{MSY} *proxy*	0.39	0.35
SSB_{MSY} (mt)	108,300	104,312 (52,248 - 209,377)
MSY (mt)	24,900	24,372 (12,404 - 48,332)
Median recruits (age 1) (000s)	53,400	52,249 (2,378 - 174,419)
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 2015 and 2016). The extremely large 1963, 2003, 2010, and 2013 year classes were included in the cdf. The annual fishery selectivity was a recent 5 year average. Selectivity for the 2013 year class was not assigned the same selectivity at age as the 2010 year class, because the projected selectivity at ages 5 and 6 (in years 2018 and 2019) appeared unreasonably low. 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 age (2017) in the projections.

Table 16: 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 2018 and 2020. Catch in 2017 was assumed to be 18,920 mt.

Year	Catch (mt)	SSB (mt)	$\bar{F}_{5-7}$
2017	18,920	308,304 (214,535 - 454,442)	0.140 (0.098 - 0.197)

Year	Catch (mt)	SSB (mt)	$\bar{F}_{5-7}$
2018	94,274 (64,109 - 141,160)	324,547 (220,458 - 481,224)	0.414
2019	93,569 (62,519 - 138,829)	329,516 (221,969 - 487,070)	0.414
2020	85,292 (57,025 - 127,046)	246,774 (163,125 - 382,012)	0.414

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 largest 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. The rho adjusted projections reduce all starting numbers at age to 53% of unadjusted values (i.e., all 2017 numbers at age are multiplied by 0.528). The assumed values for selectivity and weights at age in the 2015 update were mostly overestimates when comparing to the observed weights and estimated selectivity for 2015 and 2016. The assumptions for this update try to refine assumptions for those values in the current projections. Catch at age in 2016 is another source of uncertainty. Specifically, the catch at age 7 seems larger than one would expect for such a small year class. The catch at age 6 in 2016 is a small fraction of the large 2010 year class. In relative terms, the large proportion of fish caught at age 7 drives the average fishing mortality calculated for ages 5-7. Given the large difference in magnitude of ages 5, 6, and 7, it was decided that use of a numbers weighted average F was a more appropriate reflection of the fishing mortality experienced by the stock. Therefore, all fishing mortalities in this report refer to numbers weighted F on ages 5-7 (including the reference points and retrospective bias).

- 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 0.50 in the 2015 assessment and was 0.89 in 2016. The 7-year Mohn's ρ, relative to F, was -0.34 in the 2015 assessment and was -0.55 in 2016. There was a major retrospective pattern for this assessment because the ρ adjusted estimates of 2016 SSB (SSB_ρ=290,324) and 2016 F (F_ρ=0.309) were outside the approximate 90% confidence regions around SSB (383,166 - 801,643) and F (0.079 - 0.164). A retrospective adjustment was made for both the determination of stock status and for projections of catch in 2018. The retrospective adjustment changed the 2016 SSB from 549,938 to 290,324 and the 2016 $\bar{F}_{5-7}$ from 0.113 to 0.309.

- 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 and assumed future values of selectivity and weights at age. 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) were dropped from the VPA analysis. For this update, fishing mortality is reported as a numbers weighted average of ages 5-7 to deal with catch of two adjacent year classes of very different magnitude. In previous assessments, a simple average F on ages 5-7 was reported.

- 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). While indices 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 two more extremely large (2010 and 2013) and one very large (2012) year classes. 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.

4.1 Reviewer Comments: Georges Bank haddock

Assessment Recommendation:

The panel concluded that the operational assessment with adjustments for retrospective bias was acceptable as a scientific basis for management advice. The panel provided recommendations that were adopted, including the use of a numbers-weighted average to calculate the fishing mortality rate (as opposed to an unweighted average), and supported the projection scenario that assumes slow growth and the recent 5-year average for selectivity.

Alternative Assessment Approach:

Not applicable

Status Recommendation:

Based on this updated assessment, the panel supports the conclusion that the Georges Bank haddock stock is not overfished, and overfishing is not occurring. The Georges Bank haddock stock 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 spawning stock biomass in recent years. Also, catches in recent years have been well below the total quota (US and Canada). While indices 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.

Key Sources of Uncertainty:

The largest sources of uncertainty for this stock include the retrospective bias, and assumptions in the projections about weights and selectivity at age.

Research Needs:

The panel recommends that future work focus on recruitment forecasting and providing robust catch advice. Additional future work could continue examining performance of projected values with realized values.

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 3rd 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. 2015. Operational Assessment of 20 Northeast Groundfish Stocks, Updated Through 2014. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 15-24; 251 p.

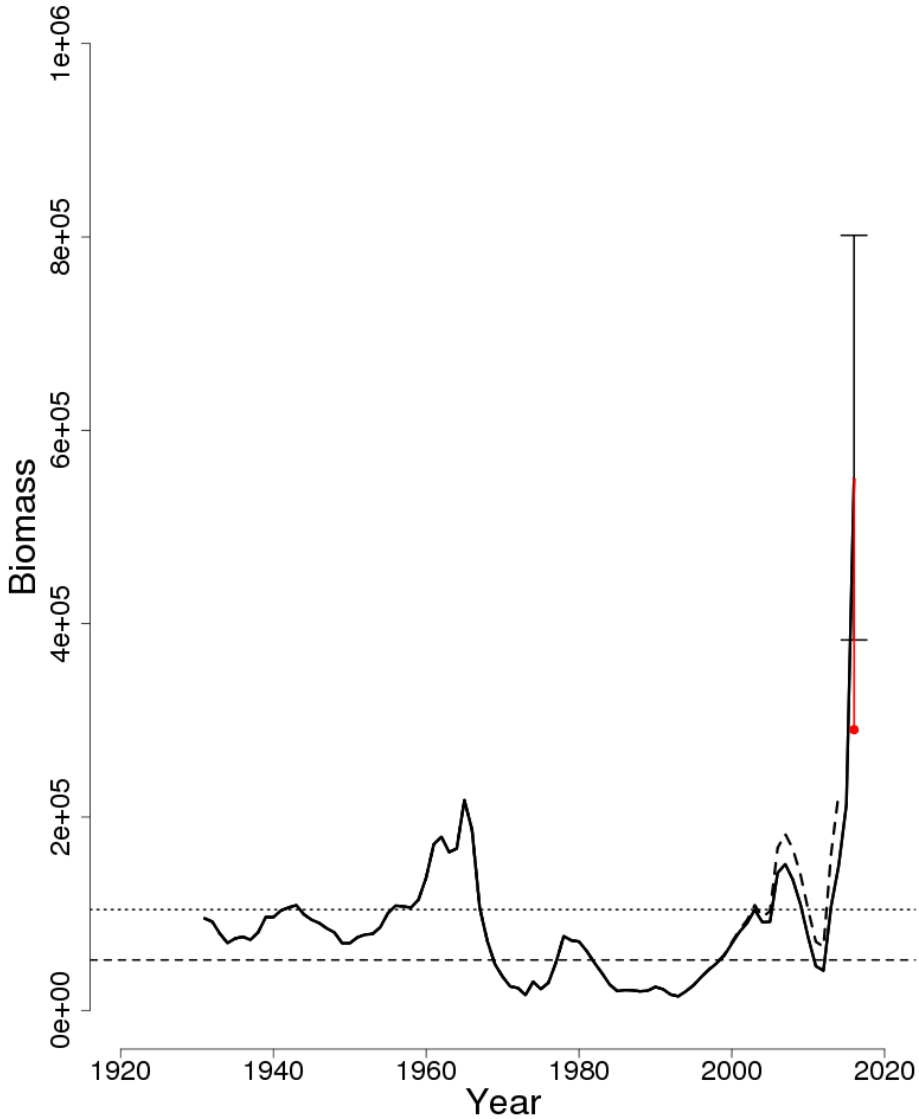

Figure 19: Trends in spawning stock biomass of Georges Bank haddock between 1931 and 2016 from the current (solid line) and previous (dashed line) assessment and the corresponding $SSB_{Threshold}$ ($\frac{1}{2}$ SSB_{MSY} *proxy*; horizontal dashed line) as well as SSB_{Target} (SSB_{MSY} *proxy*; horizontal dotted line) based on the 2015 assessment. Biomass was adjusted for a retrospective pattern and the adjustment is shown in red. The 90% bootstrap probability intervals are shown.

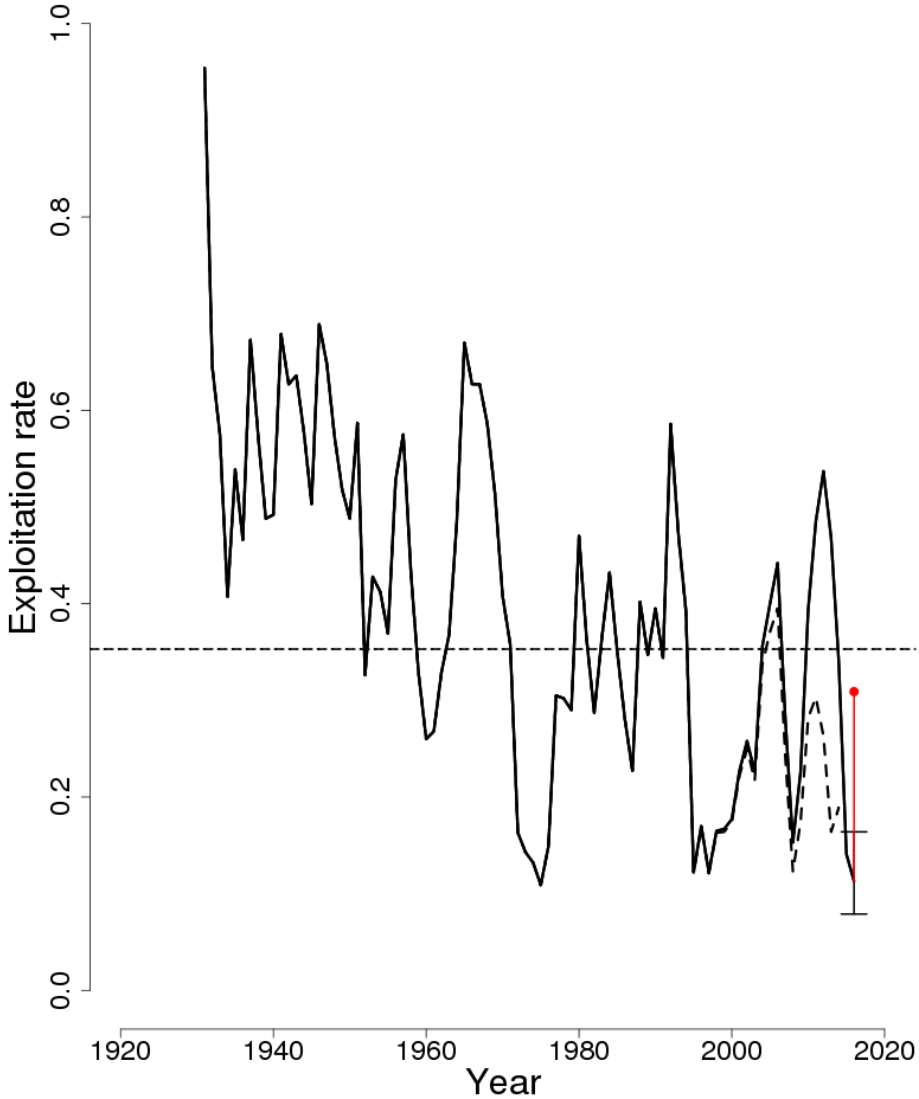

Figure 20: Trends in the numbers weighted fishing mortality ($\bar{F}_{5-7}$) of Georges Bank haddock between 1931 and 2016 from the current (solid line) and previous (dashed line) assessment and the corresponding $F_{Threshold}$ (F_{MSY} *proxy*=0.353; horizontal dashed line) based on the 2015 assessment. $\bar{F}_{5-7}$ was adjusted for a retrospective pattern and the adjustment is shown in red. The 90% bootstrap probability intervals are shown.

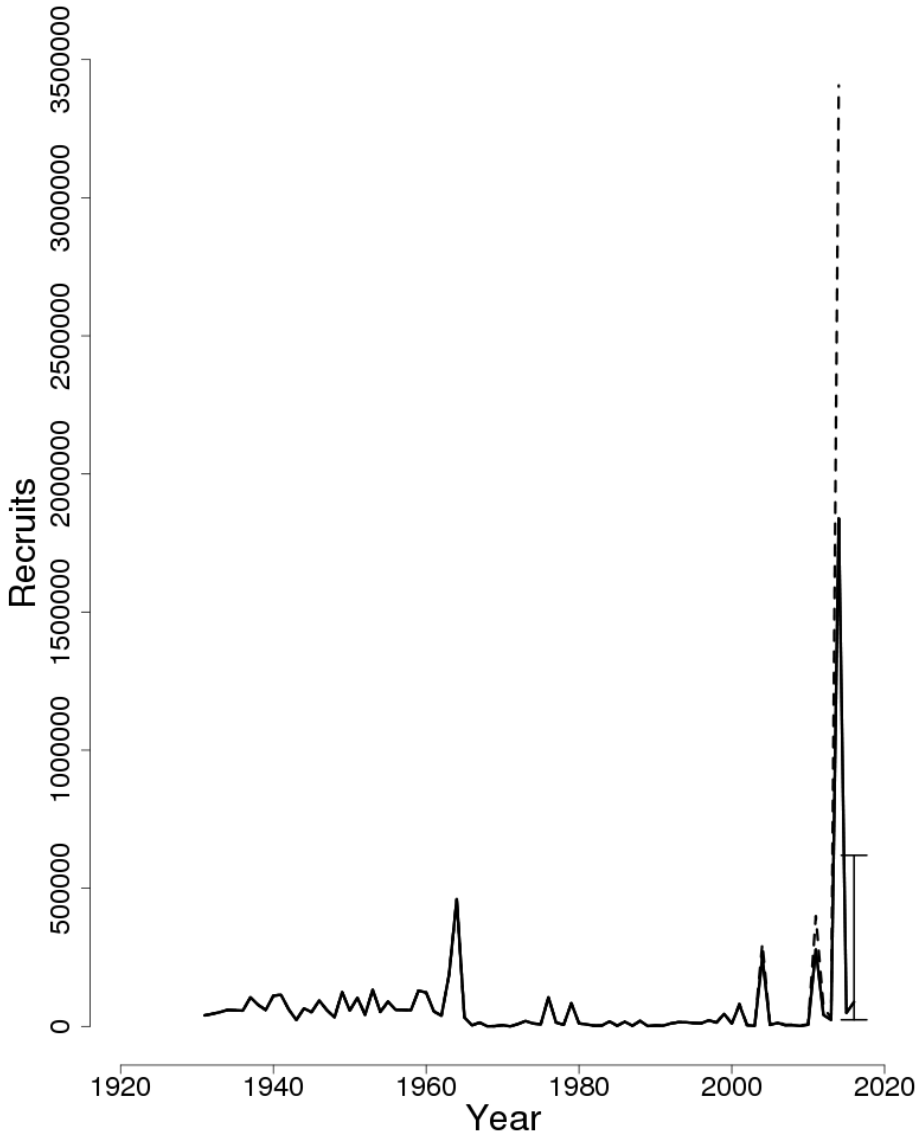

Figure 21: Trends in Recruits (age 1) (000s) of Georges Bank haddock between 1931 and 2016 from the current (solid line) and previous (dashed line) assessment. The 90% bootstrap probability intervals are shown.

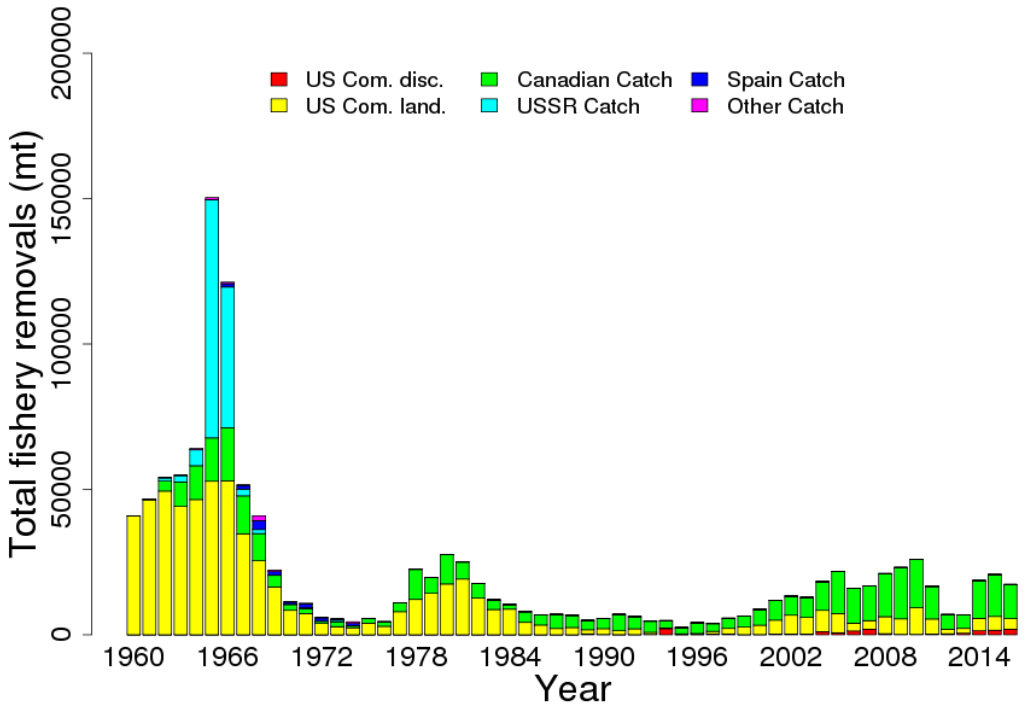

Figure 22: Total catch of Georges Bank haddock between 1931 and 2016 by fleet (US Commercial, Canadian, or foreign fleet) and disposition (landings and discards).

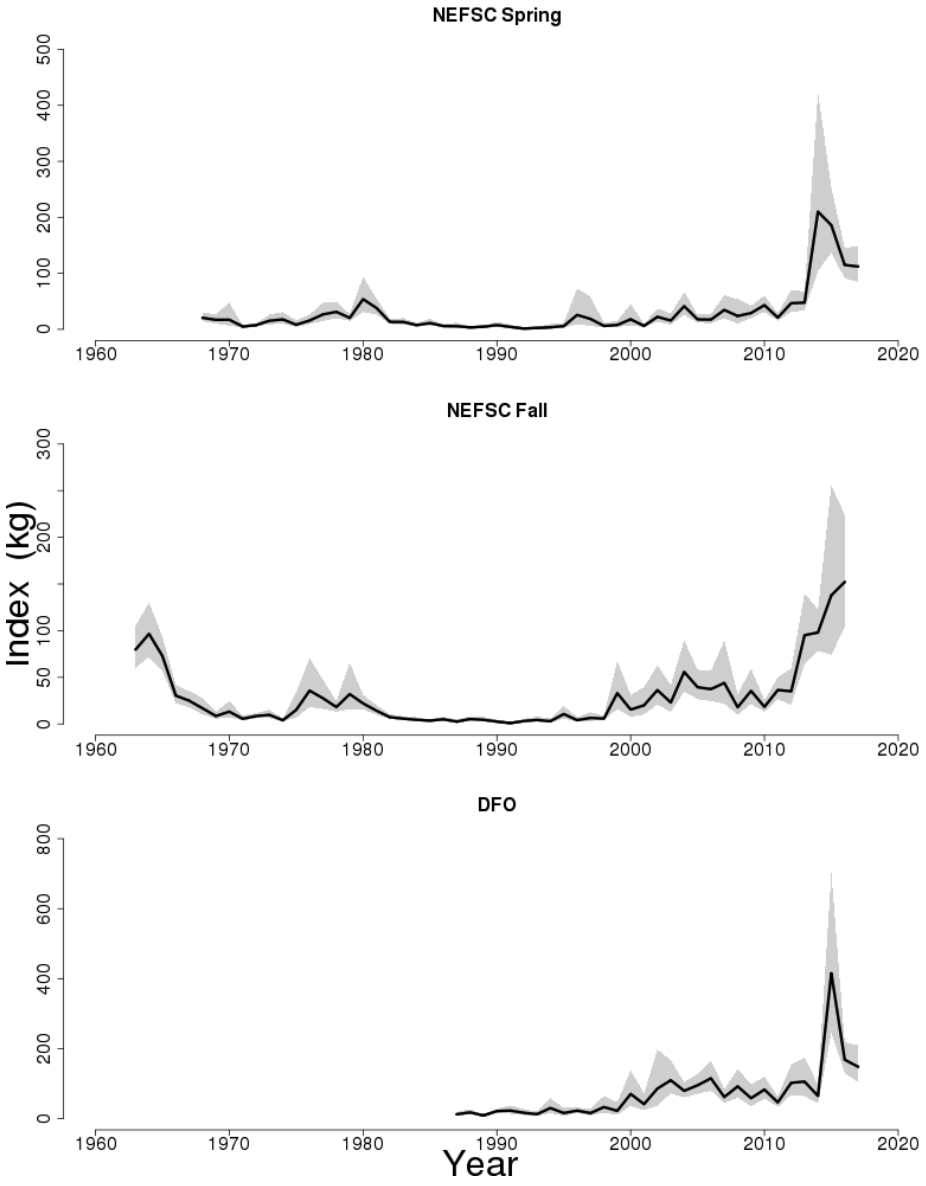

Figure 23: Indices of biomass (Mean kg/tow) for the Georges Bank haddock stock between 1963 and 2017 for the Northeast Fisheries Science Center (NEFSC) spring and fall bottom trawl surveys and the DFO winter bottom trawl survey. The approximate 90% lognormal confidence intervals are shown.