

### 3 Georges Bank Atlantic cod

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*The results from the assessment model were not accepted as a basis for scientific advice for management. Details on this decision may be found in section 3.1. Assessment results that follow reflect conclusions based on the current model configuration but are not used for estimation of overfishing limits in 2016. No attempts were made to refine model configuration to improve model performance. Under the Terms of Reference, such changes were beyond the scope of the Operational Assessment guidelines. Nonetheless the results below provide valuable summaries of fishery-dependent and fishery-independent data, information on model performance, and analyst's insights.*

*This assessment of the Georges Bank Atlantic cod (*Gadus morhua*) stock is an operational assessment of the existing 2012 benchmark assessment (NEFSC 2013). Based on the previous assessment the stock was overfished, and overfishing was occurring. This 2015 assessment updates commercial fishery catch data, research survey indices of abundance, the analytical ASAP assessment model, and reference points through 2014. Additionally, stock projections have been updated through 2018.*

**State of Stock:** Based on this updated assessment, the Georges Bank Atlantic cod (*Gadus morhua*) stock is overfished and overfishing is occurring (Figures 16-17). Retrospective adjustments were made to the model results. Spawning stock biomass (SSB) in 2014 was estimated to be 1,804 (mt), which is 1% of the biomass target for this stock ( $SSB_{MSY\ proxy} = 201,152$ ; Figure 16). The 2014 fully selected fishing mortality was estimated to be 1.68, which is 994% of the overfishing threshold proxy ( $F_{MSY\ proxy} = 0.169$ ; Figure 17).

Table 12: Catch and model results for Georges Bank Atlantic cod. All weights are in (mt), recruitment is in (000s), and  $F_{Full}$  is the fishing mortality on fully selected ages (ages 5-8). Model results are from the current updated ASAP assessment.

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
<i>Data</i>										
Commercial landings	2,754	2,700	3,699	3,255	2,999	2,688	3,387	2,007	1,312	1,514
Commercial discards	394	232	728	309	385	253	122	120	83	19
Recreational landings	966	59	11	69	48	153	177	56	6	88
Recreational discards	101	4	3	1	5	23	17	1	1	2
CA landings	630	1,097	1,107	1,390	1,003	748	702	395	384	430
CA discards	226	350	117	140	206	94	43	75	39	28
Catch for Assessment	5,072	4,441	5,665	5,164	4,646	3,959	4,449	2,653	1,824	2,081
<i>Model Results</i>										
Spawning Stock Biomass	9,438	9,362	9,202	7,978	7,672	6,108	5,231	4,066	5,202	6,180
$F_{Full}$	0.703	0.583	0.825	0.903	0.898	0.916	1.33	1	0.483	0.463
Recruits <i>age</i> 1	1,298	2,935	3,412	2,214	2,405	1,908	3,248	2,107	929	1,151

Table 13: Comparison of reference points estimated in the previous assessment and from the current assessment update. An  $F_{40\%}$  proxy was used for the overfishing threshold and was based on long-term stochastic projections.

	2012	Current
$F_{MSY}$ proxy	0.177	0.169
$SSB_{MSY}$ (mt)	186,535	201,152 (157,963 - 247,517)
MSY (mt)	30,622	30,569 (23,910 - 37,712)
Median recruits (age 1) (000s)	8,765	7,118
<i>Overfishing</i>	Yes	Yes
<i>Overfished</i>	Yes	Yes

**Projections:** Short term projections of biomass were derived by sampling from a two-stage cumulative distribution function of recruitment estimates from ASAP model results, using a 50,000 mt cutpoint. The annual fishery selectivity, maturity ogive, and mean weights at age used in projections are the most recent 5 year averages; retrospective adjustments were applied in the projections.

Table 14: Short term projections of total fishery catch and spawning stock biomass for Georges Bank Atlantic cod based on a harvest scenario of fishing at  $F_{MSY}$  proxy between 2016 and 2018. Catch in 2015 was assumed to be 1,784 (mt).

Year	Catch (mt)	SSB (mt)	$F_{Full}$
2015	1,784	1,552 ( 539 - 3,192)	1.510
2016	135	932 ( 152 - 2,508)	0.169
2017	263	2,134 (787 - 6,250)	0.169
2018	799	7,001 (3,054 - 24,931)	0.169

### 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 major source of uncertainty is presumably the estimate of catch or of natural mortality, considering the magnitude of the retrospective bias. These both affect the scale of the biomass, fishing mortality estimates, and the reference point estimates. The catch estimates do not include all discards (e.g., lobster gear) and includes uncertain estimates of recreational landings and discards, and of some commercial discards (e.g., small mesh). Natural mortality (M) of Georges Bank Atlantic cod is not well understood and is assumed constant over time in the model. Other sources of uncertainty include possible changes in growth parameters in recent years and how this affects fecundity, the viability of eggs/sperm, and the success rate of hatching - all influencing recruitment survival and year class strength.*

- 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  $F_{Full}$ ; see Table 8).  
*The 7-year Mohn's  $\rho$ , relative to SSB, was 0.68 in the 2012 assessment and was 2.43 in 2014. The 7-year Mohn's  $\rho$ , relative to F, was -0.46 in the 2012 assessment and was -0.72 in 2014. There was a major retrospective pattern for this assessment because the  $\rho$  adjusted estimates of 2014 SSB ( $SSB_{\rho}=1,804$ ) and 2014 F ( $F_{\rho}=1.68$ ) were outside the approximate 90% confidence region around SSB (3,922 - 10,596) and F (0.251 - 0.815). A retrospective adjustment was made for both the determination of stock status and for projections of catch in 2016. The retrospective adjustment changed the 2014 SSB from 6,180 to 1,804 and the 2014  $F_{Full}$  from 0.463 to 1.68.*
- Based on this stock assessment, are population projections well determined or uncertain?  
*Population projections for Georges Bank Atlantic cod are uncertain and likely optimistic. The projections are based on a biomass cutpoint of 50,000 mt, which has not been produced since 1992. The average recruitment since 1992 has been 4.9 million age 1 fish, whereas during the last 10 years, average recruitment has been about 2.7 million age 1 fish. A sensitivity projection using the most recent 10 years of recruitment was conducted and results presented in the *SASINF* database.*
- 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.  
*No major changes, other than the addition of recent years of data, were made to the Georges Bank Atlantic cod assessment for this update. However, recreational catch and commercial discard estimates were revised slightly due to minor changes in the databases, and the application of length frequencies (annual instead of half year) in one instance.*
- If the stock status has changed a lot since the previous assessment, explain why this occurred.  
*As in recent assessments for Georges Bank Atlantic cod the stock remains in an overfishing and overfished status.*
- Indicate what data or studies are currently lacking and which would be needed most to improve this stock assessment in the future.  
*The Georges Bank Atlantic cod assessment could be improved with additional studies on natural mortality, growth, and fecundity. Additionally, more precise estimates of recreational landings and discards, sampling of fish caught by individual recreational anglers, and incorporation of discards in the lobster fishery would decrease uncertainty in the discard estimates.*
- Are there other important issues?  
*The differences in model assumptions of natural mortality between the SARC GB cod assessment and the TRAC EGB cod assessment is problematic for the recovery of the entire GB cod stock. Model results of the TRAC VPA  $M=0.8$  model are used to determine quota for the EGB management unit, so by default, proportionally more cod are being removed from eastern GB than what the GB cod ASAP model would predict.*

### 3.1 Reviewer Comments: Georges Bank Atlantic cod

**Recommendation:** The Panel concluded that the updated assessment model (i.e., the SAW55 benchmark configuration) was not acceptable as a scientific basis for management advice. Several diagnostics that indicated problems in the SAW55 benchmark assessment are considerably worse in the updated assessment. The magnitude of retrospective inconsistency in estimates of SSB increased from 70% in the SAW55 assessment to 240% in the operational assessment. The SAW55 benchmark assessment accounted for the retrospective pattern using a retrospective adjustment. When the retrospective adjustment was attempted in the update assessment for projections, a substantial number (24.2%) of the projected realizations were not feasible, because they could not support the preliminary estimate of 2015 catch.

The pattern and magnitude of predominantly positive aggregate survey residuals in the last decade also increased, indicating that the updated assessment does not fit survey trends well, and conflicts between information in fishery and survey age composition and survey trends increased. Some alternative model configurations were explored to help understand the problems in the updated assessment. Model explorations suggest that the “M 0.8” scenario assumed for Eastern Georges Bank cod (TRAC 2015) and some alternative approaches to recruitment estimation do not resolve the lack-of-fit problems in the updated assessment.

The Panel agreed to provide results from the updated assessment as one interpretation of the available information. However, the panel concluded that stock status and catch advice should be based on an alternative approach. The SAW55 benchmark assessment concluded that the stock was overfished and overfishing continued in 2011. All information available in the update assessment indicates that stock size has not increased. Therefore, the Panel recommends that the SAW55 assessment is the best scientific information available for determining overfishing definitions, and the stock is still overfished. In the absence of an acceptable assessment and fishing mortality estimates that can be compared to the overfishing threshold, the overfishing status is currently unknown.

**Alternative Assessment Approach:** The Assessment Oversight Panel recommended that the ‘fallback’ if the updated ASAP is not accepted is to provide the average of recent (3 years) quota or catches. However, the Operational Assessment Panel is concerned that status quo catch may not be appropriate for the current stock status and survey trends. Projections from the updated assessment had indicated that status quo catch would not end overfishing, even taking into account that past projections have been optimistic. Recent catches have not allowed the stock to rebuild. Mean length at age, the proportion of old fish in the fishery and surveys, and recruitment indices all remain relatively low. None of these indicate stock recovery. Therefore, the Operational Assessment Panel recommends that the overfishing limit (OFL) should be a proportion of the most recent 3-year average catch, and that proportion should be determined by recent survey trends.

The Panel considered the use of the TRAC algorithm of smoothing swept-area biomass from surveys for catch allocations. However, incomplete coverage of Georges Bank by the DFO survey in recent years made this algorithm inappropriate. Therefore, the recent survey trend was derived from a combination of NEFSC spring and fall survey indices (methods described below). The recent survey trend (-24% per year), was applied to the status quo catch (2,186 mt per year 2012-2014) to derive the 2016 overfishing limit (1665 mt).

**Sources of Uncertainty:** The major sources of uncertainty are the retrospective error in the updated assessment, the conflicts in data, and the potential sources of retrospective patterns (mis-specified natural mortality, changes in natural mortality, mis-reported catch, unaccounted catch, changes in survey catchability and mis-specified selectivity). The Canadian survey has not sampled all strata every year and there have been apparent changes in growth rates. The assumed recreational discard mortality rate is considered to be a minor source of uncertainty for the Georges Bank cod stock. The Gulf of Maine cod assessment considered new information on discard mortality from the recreational fishery in that stock area, but the Panel agreed that the new information is less relevant for the Georges Bank cod stock and the assumption should not be revised for the update assessment. The panel also noted that the SAW55 projection method has overestimated recruitment.

**Research Needs:** The Panel recommends that a new assessment is needed to resolve the problems in the updated assessment model application. This operational assessment process did not allow for many possible revisions to the assessment method. An operational process with broader terms of reference may be able to resolve the problems in the update assessment. However, the data conflicts may require a full benchmark assessment or a research track process. If models cannot reconcile apparent conflicts in data, then empirical approaches may be needed. Recent information on cod stock structure and recommendations from the SAW55 benchmark should be considered in future assessments. Stock assessment approaches for the Georges Bank stock and the Eastern Georges Bank management unit should be harmonized. The causes of low productivity, relative to historical productivity, should be considered in the next assessment, including the investigation of ecosystem effects. Alternative methods for estimating recruitment and projecting recruitment are needed.

### 3.2 Methods for estimating catch as proportion of the most recent 3-year average catch

1. Create a new time series as average of NEFSC spring and fall bottom trawl surveys:  
$$Y_t = \frac{SPR_{t+1} + FAL_t}{2}$$
2. Create a LOESS smooth of the  $Y_t$ , using 33 years (1982-2014), with 0.3 span in LOESS:  
$$Y_{t,smo} = LOESS[Y_t]$$
3. Obtain smoothed predictions for 2012 to 2014:  
$$\{Y_{2012,smo}, Y_{2013,smo}, Y_{2014,smo}\}$$
4. Use a log linear regression to estimate slope over last 3 years of smoothed estimates (2012-2014):  
$$Ln(Y_{t,smo}) = \alpha + \beta t$$
5. Compute proportional change in recent average catch as:  
$$R = e^\beta$$
6. Compute recommended OFL for 2016 as function of average catch from 2012-2014:  
$$C_{OFLproxy,2016} = R * \bar{C}_{2012-14}$$

#### References:

Northeast Fisheries Science Center. 2013. 55<sup>th</sup> Northeast Regional Stock Assessment Workshop (55<sup>th</sup> SAW) Assessment Summary Report. Northeast Fisheries Science Center Reference Document 13-11; 43 p. [CRD13-11](#)

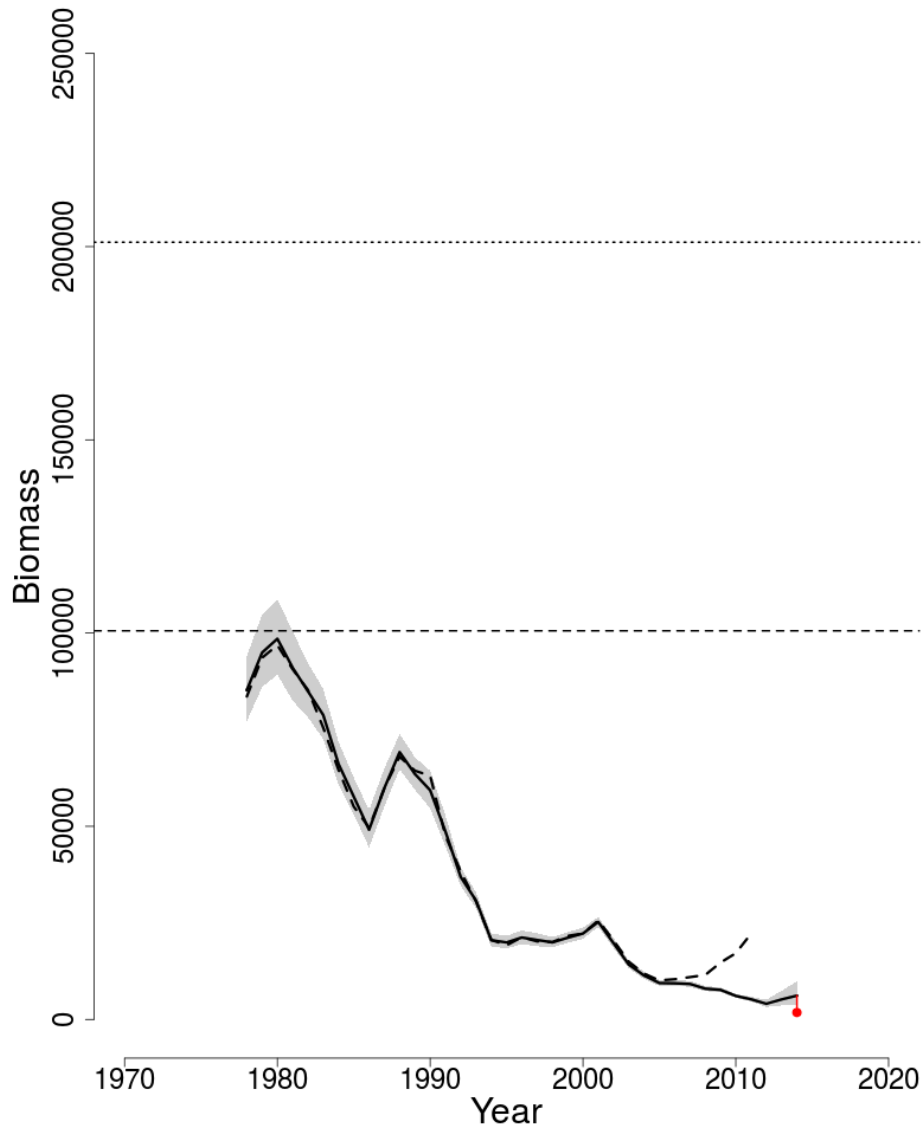


Figure 16: Trends in spawning stock biomass of Georges Bank Atlantic cod between 1978 and 2014 from the current (solid line) and previous (dashed line) assessment and the corresponding  $SSB_{Threshold}$  ( $\frac{1}{2} SSB_{MSY}$  proxy; horizontal dashed line) as well as  $SSB_{Target}$  ( $SSB_{MSY}$  proxy; horizontal dotted line) based on the 2015 assessment. Biomass was adjusted for a retrospective pattern and the adjustment is shown in red. The approximate 90% lognormal confidence intervals are shown.

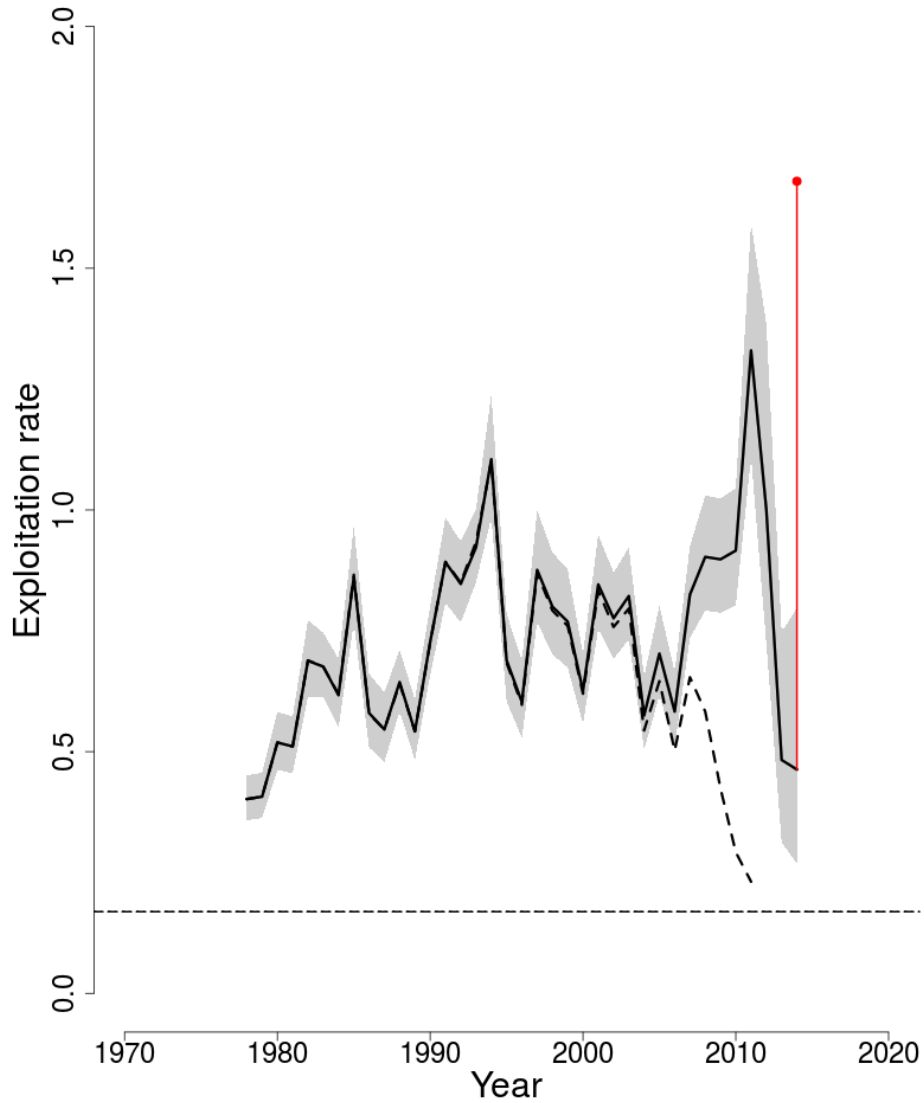


Figure 17: Trends in the fully selected fishing mortality ( $F_{Full}$ ) of Georges Bank Atlantic cod between 1978 and 2014 from the current (solid line) and previous (dashed line) assessment and the corresponding  $F_{Threshold}$  ( $F_{MSY}$  proxy=0.169; horizontal dashed line).  $F_{Full}$  was adjusted for a retrospective pattern and the adjustment is shown in red, based on the 2015 assessment. The approximate 90% lognormal confidence intervals are shown.



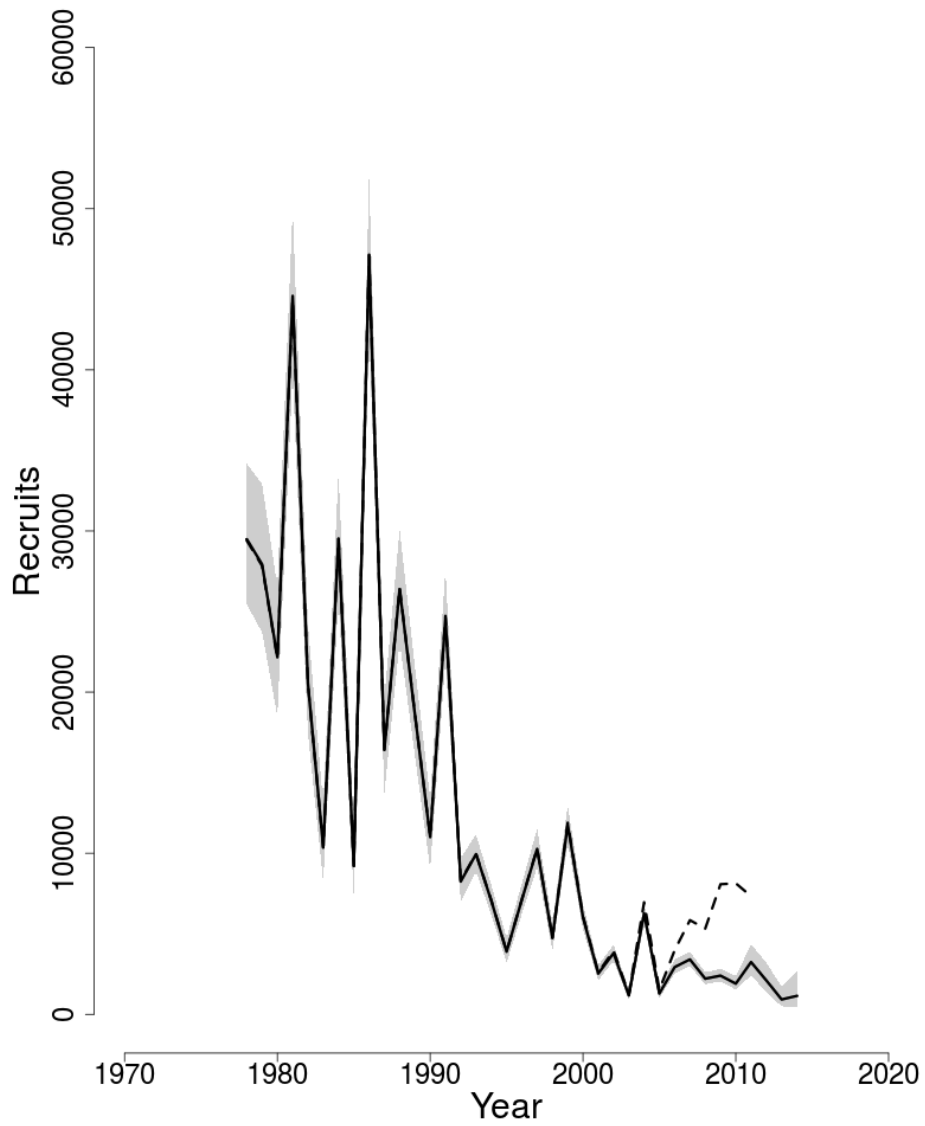


Figure 18: Trends in Recruits (age 1) (000s) of Georges Bank Atlantic cod between 1978 and 2014 from the current (solid line) and previous (dashed line) assessment. The approximate 90% lognormal confidence intervals are shown.

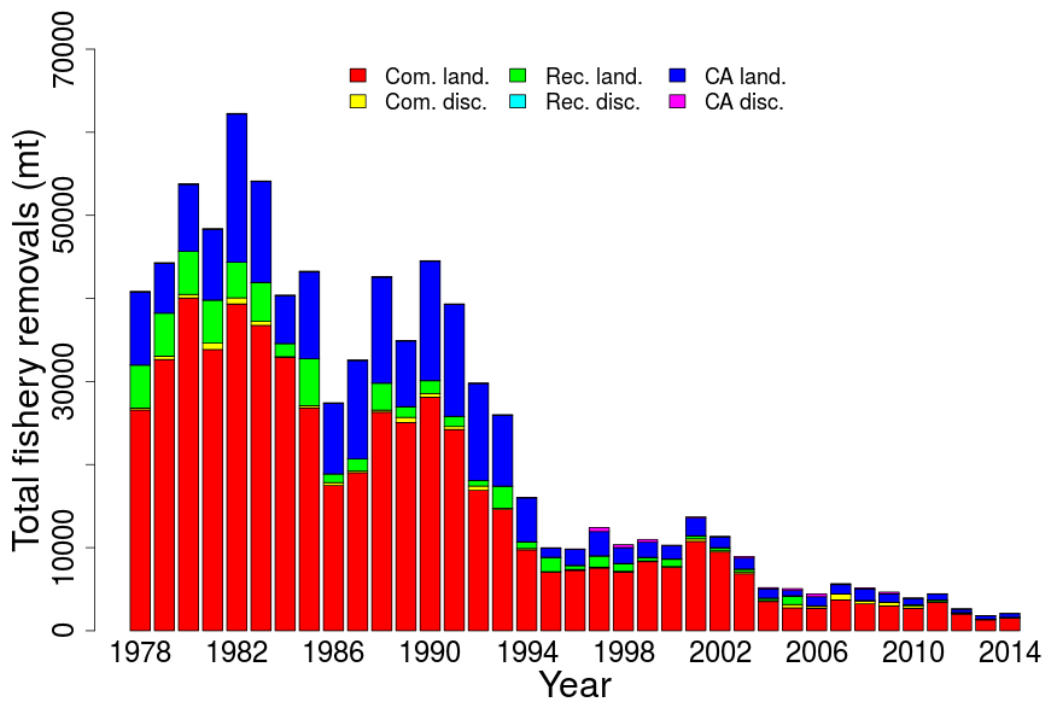


Figure 19: Total catch of Georges Bank Atlantic cod between 1978 and 2014 by fleet (US commercial, US recreational, or Canadian) and disposition (landings and discards).

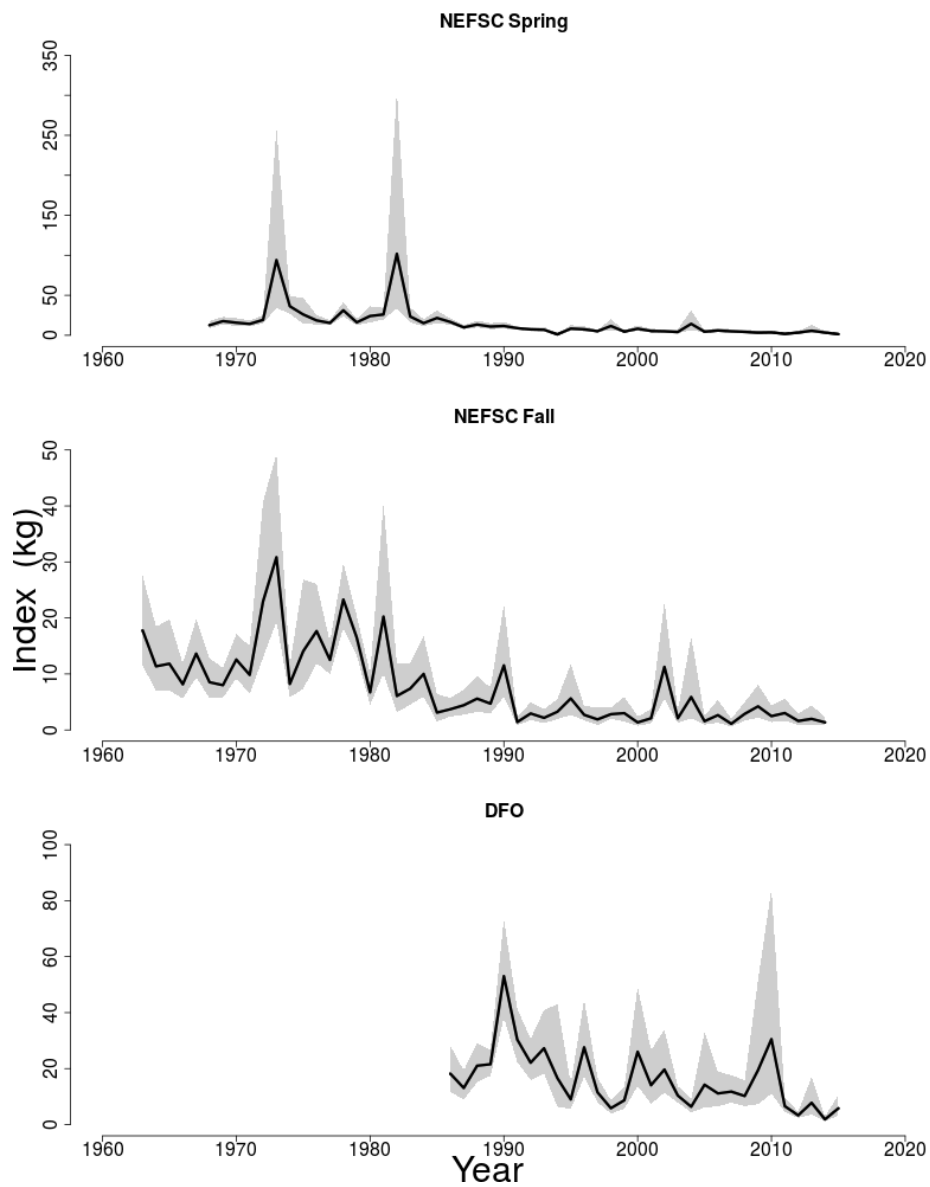


Figure 20: Indices of biomass for the Georges Bank Atlantic cod between 1963 and 2015 for the Northeast Fisheries Science Center (NEFSC) spring and fall trawl surveys, and the DFO research bottom trawl surveys. The approximate 90% lognormal confidence intervals are shown.