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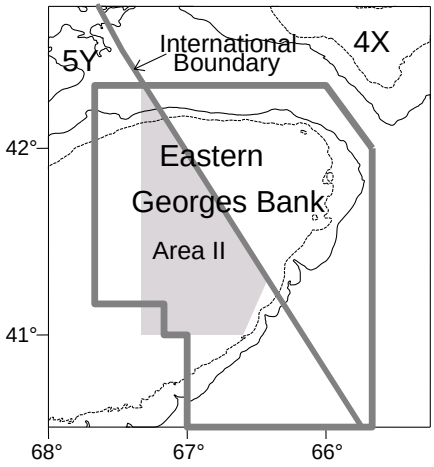
#3b

Transboundary Resources Assessment Committee

Status Report 2017/01

EASTERN GEORGES BANK COD

[5Zjm; 551,552,561,562]



Summary

- Combined Canada/USA catches in 2016 were 537 mt, which included 17 mt of discards.
- Survey biomass indices increased for all three surveys, while recruitment has been poor for the last 25 years. Relative fishing mortality has declined since 1995, although total mortality from all sources has remained high.
- The estimated adult population biomass at the beginning of 2017 from the Virtual Population Analysis (VPA) "M 0.8" model was 13,944 mt.
- Recruitment at age 1 has been low in recent years, but the 2013 year class estimated from the VPA "0.8" model at 6 million fish shows the highest estimated recruitment since 1990.
- Fishing mortality (ages 4-9) in 2016 was estimated from the VPA "M 0.8" model to be 0.05. In recent years, ages 6+ are not fully selected to the fishery. In 2016, ages 3 and 4 were fully recruited. Consequently, the average fishing mortality on ages 4-9 cannot be directly compared to the model reference F=0.11, so it is difficult to conclude whether a low risk of exceeding F=0.11 is being achieved.
- The survey weight at age has been declining since the 1990s. Lower weights at age in the population in recent years, a truncated age structure, poor recruitment, and high total mortality have contributed to the lack of rebuilding.
- The Transboundary Resources Assessment Committee (TRAC) recommends catch advice in the range of 730 mt to 900 mt.

TRAC Review Process

In the interest of transparency and in order to avoid any perceived conflict of interest, in 2017 TRAC introduced a new process of review for Eastern Georges Bank Cod and Haddock and Georges Bank Yellowtail Flounder. An overview of the entire process is available at https://www.nefsc.noaa.gov/saw/trac/trac-process-overview-2017.pdf. After the presentation of each assessment by the lead authors, there was initial scientific and technical review by the invited external reviewers (referred to as external reviewers in this document), followed by scientific and technical review by the science assessment staff and a USA and Canadian resource manager (referred to as science in this document) and then review and contributions by all meeting participants, including stakeholders, external non-government organizations and the general public (referred to as the broader TRAC in this document). At the completion of each level of review, consensus was sought and there was discussion as to whether or not revisions to the initial conclusions were warranted. In the absence of consensus, the advice from the science group will be provided along with the perspective from the broader TRAC.

Table 1. Catches and Biomass (thousands mt); Recruits (millions).

		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Avg[1]	Min[1]	Max[1]
Canada[9]	Quota	1.6	1.2	1.0	0.9	0.5	0.5	0.5	0.5	0.5	0.6			
	Catch	1.5	1.2	0.8	0.7	0.5	0.4	0.5	0.5	0.4		5.2	0.4	17.9
	Landed	1.4	1.0	0.7	0.7	0.4	0.4	0.4	0.5	0.4		5.1	0.4	17.8
	Discard	0.1	0.2	0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	0.4
USA[9]	Quota[2]	0.7	0.5	0.3	0.2	0.2	0.1	0.2	0.1	0.1	0.1			
	Catch[2]	0.5	0.5	0.3	0.2	<0.1	<0.1	0.1	0.1	<0.1				
	Landed	0.2	0.4	0.4	0.3	0.1	<0.1	<0.1	<0.1	<0.1		3.2	<0.1	10.6
	Discard	<0.1	0.2	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	0.3
Total[9]	Quota	2.3	1.7	1.3	1.1	0.7	0.6	0.7	0.7	0.6	0.7			
	Catch[3,4]	2.0	1.7	1.1	0.9	0.5	0.4	0.5	0.6	0.5				
	Catch	1.7	1.8	1.3	1.0	0.6	0.4	0.6	0.6	0.5		8.5	0.5	26.5
From "M 0.8" model														
Adult Biomass[5]		8.3	9.4	7.4	6.0	5.0	6.0	7.6	8.1	12.5	13.9	25.2	5.9	59.7
Age 1 Recruits		0.5	1.1	1.2	3.2	1.7	0.8	6.0	2.6	0.3		5.6	0.5	24.1
Fishing mortality[6]		0.26	0.17	0.21	0.26	0.14	0.08	0.06	0.06	0.05		0.33	0.05	0.66
Exploitation Rate[7]		21%	18%	23%	51%	44%	6%	6%	6%	7%		26%	6%	44%
Exploitation Rate[8]		22%	24%	23%	17%	11%	32%	11%	5%	1%		23%	1%	46%

[1]1978-2016
[2]for fishing year from May 1st - April 30th
[3]for Canadian calendar year and USA fishing year May 1st - April 30th
[4]sum of Canadian landed, Canadian discard, and USA catch (includes discards)
[5]Jan 1 ages 3+
[6]ages 4-9
[7]ages 4-5; M=0.2
[8]ages 6-8; M=0.8
[9] unless otherwise noted, all values reported are for calendar year

Fishery

Combined Canada/USA catches in 2016 were 537 mt, which included 17 mt of discards, with a quota of 625 mt (Table 1). Historically, catches averaged 17,200 mt between 1978 and 1993, peaking at 26,463 mt in 1982. Catches declined to 1,683 mt in 1995, then fluctuated at about 3,000 mt until 2004, and have subsequently declined (Figure 1).

Canadian catches decreased from 492 mt in 2015 to 440 mt in 2016. Discards were estimated at 3 mt from the mobile gear fleet. Estimated discards of cod by the Canadian scallop fishery were 9 mt in 2016.

USA catches decreased from 116 mt in 2015 to 97 mt in 2016. Estimated discards of cod for 2016 were 5 mt, almost entirely from the otter trawl groundfish fishery. Preliminary estimates of the USA catches (landings plus discards) for fishing year 2016 were 82 mt, 59.4% of the 138 mt quota.

The combined Canada/USA 2016 **fishery age composition** (landings + discards), by number, was dominated by the 2013 year class. By weight, the 2013 and then the 2011 year classes dominated the 2016 fishery (ages 3 and 5). The contribution to the catch of fish older than age 7 continues to be small in recent years: 1.3% by number and 3% by weight in 2016. Both the Canadian and the USA fisheries were adequately sampled to determine length composition of the catch.

Harvest Strategy and Reference Points

The Transboundary Management Guidance Committee (TMGC) has adopted a strategy to maintain a low to neutral risk of exceeding the fishing mortality reference, F_{ref}. When stock conditions are poor, fishing mortality rates should be further reduced to promote rebuilding. At the 2013 eastern Georges Bank cod benchmark meeting, it was agreed that $F_{ref}=0.18$ is not consistent with the Virtual Population Analysis (VPA) "M 0.8" model. At the 2014 TRAC, it was agreed that F=0.11 was a more appropriate fishing mortality reference point for the VPA "M 0.8" model than F_{ref}, whereas the ASAP continues to apply $F_{ref}=0.18$ for the consequence analysis.

State of Resource

Survey biomass indices increased for all three surveys (Figure 2), while recruitment has been poor for the last 25 years. Relative fishing mortality (F) has declined since 1995, although total mortality from all sources (Z) has remained high (Figure 3).

Evaluation of the state of the resource was based on results from an age structured analytical assessment (i.e., VPA "M 0.8" model), which used fishery catch statistics and sampling for size and age composition of the catch for 1978 to 2016 (including discards). The VPA was calibrated to trends in abundance from three research bottom trawl survey series: DFO, NMFS spring, and NMFS fall. A statistical catch at age model (ASAP), which uses the same data as the VPA, was also examined. In addition, a suite of indicators derived solely from survey and fishery data were updated.

At the 2013 benchmark review, there was no consensus on an assessment model; however, it was agreed that the VPA "M 0.8" model would be used to provide catch advice (Claytor and O'Brien, 2013). Natural mortality (M) was fixed at 0.2 for all the ages in all years, except for ages 6 and older in years after 1994, where M=0.8. The scale of the values were much lower for the ASAP results, although the trend was comparable.

The estimated **adult population biomass** at the beginning of 2017 from the VPA "M 0.8" model was 13,944 mt, which was about 25% of the adult biomass at the start of the time series in 1978 (Figure 4).

Recruitment at age 1 has been low in recent years, but the 2013 year class estimated from the VPA "0.8" model at 6 million fish shows the highest estimated recruitment since 1990. The current estimate of the 2015 year class from the VPA "M 0.8" model is 0.3 million fish at age 1 which is the lowest recruitment estimate on record (Figure 4), although survey and model estimates are highly uncertain.

Fishing mortality (population weighted average of ages 4-9) in 2016 was estimated from the VPA "M 0.8" model to be 0.05 (Figure 1). In recent years, ages 6+ are not fully selected to the fishery. As a result, this average $F_{4\text{-}9}$ does not reflect exploitation on fully recruited ages. In 2016, ages 3 and 4 were fully recruited, with F values of 0.03 and 0.11, respectively. Consequently, the average F on ages 4-9 cannot be directly compared to the model reference F=0.11, so it is difficult to conclude whether a low risk of exceeding F=0.11 is being achieved.

Productivity

Recruitment, age structure, fish growth (as measured by length and weight at age), and spatial distribution typically reflect changes in productive potential. The current biomass is well below the threshold where higher recruitment is observed (Figure 5). The **population age structure** displays a low proportion of ages 7+ compared to the 1980s. However, the 2013 year class at 6 million fish is the highest recruitment estimate since 1990 and is expected to be the predominant year class in the catch until 2020. Average weight at length, used to reflect condition, declined throughout the time series, but has started to show improvement since 2009. The survey weight at age has been declining since the 1990s. Lower weights at age in the population in recent years, a truncated age structure, poor recruitment, and high total mortality have contributed to the lack of rebuilding. The research survey **spatial distribution** patterns of adult (3+) cod have not changed over the past decade.

Outlook

This outlook is provided in terms of consequences with respect to the harvest reference points for alternative catch quotas in 2018 and 2019.

The analytical models used in this assessment (VPA and ASAP) exhibit diagnostic problems with strong residuals and retrospective patterns. The retrospective pattern in both the VPA and ASAP models leads to an overestimation of SSB in the terminal year and an underestimate of fishing mortality.

Benchmark formulation (VPA "M 0.8" model)

Uncertainty about current biomass generates uncertainty in forecast results, which is expressed here as the probability of exceeding F=0.11 and change in adult (ages 3+) biomass from 2018 to 2019 and from 2019 to 2020. The risk calculations assist in evaluating the consequences of alternative catch quotas by providing a general measure of the uncertainties. However, risk calculations are dependent on the data and model assumptions and do not account for uncertainty

due to variations in weight at age, partial recruitment to the fishery, natural mortality, systematic errors in data reporting, the possibility that the model may not reflect stock dynamics closely enough, and retrospective bias. In particular, recent changes in partial recruitment to the fishery make it difficult to draw conclusions about exceeding F=0.11.

For **projections**, the average of the most recent three years of fishery and survey weight data were used for fishery weights and beginning year population weights, respectively, for 2018-2020. The 2017-2019 partial recruitment pattern (PR) was based on the most recent five years of estimated partial recruitment. The 2011-2015 average of recruitment at age 1 was used for 2018-2020 projections. The projection could be optimistic if the abundance of the 2016 and 2017 year classes is lower. Catch in 2017 was assumed to be equal to the 2017 quota (730 mt), and F=0.11 in 2018 and 2019.

In 2018, a 50% risk of not exceeding F=0.11 corresponds to catches less than 1,270 mt, and a lower (25%) risk of not exceeding F=0.11 corresponds to catches less than 1,072 mt (Figure 6, Table 2a). Due to the expected contribution of the 2013 year class, which is larger compared to other recent year classes, a catch of 1,558 mt has a low risk (25%) that 2019 age 3+ biomass will be lower than 2018 (Figure 6, Table 2b).

In 2019, a 50% risk of not exceeding F=0.11 corresponds to catches less than 1,032 mt, and a lower risk (25%) of not exceeding F=0.11 corresponds to catches less than 892 mt (Table 2a). Even with no catch in 2019, conditional on a 2018 F=0.11, there is a 90% risk of a decrease in adult biomass from 2019 to 2020. This is due to the 2013 year class entering the ages of high natural mortality (Table 2b).

Table 2a. Risk of fishery catch exceeding F reference point 0.11 in 2018 and 2019 for VPA "M 0.8".

Probability	**0.25**	**0.5**	**0.75**
2018	1,072 mt	1,270 mt	1,488 mt
2019 (if F_{2018}=0.11)	892 mt	1,032 mt	1,192 mt

Table 2b. Risk that ages 3+ biomass will not increase from 2018 to 2019 and from 2019 to 2020 for VPA "M 0.8".

Probability	**0.25**	**0.5**	**0.75**
2018 to 2019	1,288 mt	1,558 mt	1,854 mt
2019 to 2020 (if F_{2018}=0.11)	0 mt	0 mt	0 mt

Consequence Analysis

The consequence analysis is based on the VPA and ASAP models. Natural mortality is assumed to be higher for age 6+ in the VPA (M=0.8) since 1994 compared to M=0.2 for all ages in the ASAP model. Comparison of the 2017 assessment results of the two models indicates that biomass (ages 3+) is estimated to be higher in the VPA, in contrast to the ASAP model that estimated lower biomass. The consequence analysis, initiated in 2013 to understand the risks

associated with assumptions of the VPA "M 0.8" and ASAP "M 0.2" models, is shown in Table 3. This consequence analysis shows: 1) the projected catch (ages 3+) at F_{ref}=0.18 and F=0.11, and percent change in biomass, as if each model represented the "true state" of the resource; and 2) the consequences to fishing mortality and expected biomass (ages 3+) when 'true state' catch levels are removed under the assumptions of the other "alternate state" model.

In 2018, a catch of 1,270 mt (see Table 2a; neutral risk) would result in an increase of 2% in the VPA "true state" and a decrease of 40% in the ASAP "alternate state" in the 2019 biomass. A catch of 412 mt (median ASAP result at F_{ref}=0.18) would result in a 6% decrease in the 2019 biomass based on the ASAP "true state" and an increase of 7% based on the VPA "alternate state".

In 2019, a catch of 1,032 mt (see Table 2a; neutral risk) would result in a decrease in the 2020 biomass of 13% in the VPA "true state" and an increase of 15% in the ASAP "alternate state". A catch of 410 mt (median ASAP result at F_{ref}=0.18) would result in a 35% increase in the 2020 biomass based on the ASAP "true state", and a decrease of 10% based on the VPA "alternate state".

Table 3. Consequence analysis of different management actions taken for Atlantic cod from eastern Georges Bank. Projected catch and biomass (ages 3+) are presented for each of two 'true state of nature' management models: VPA "M 0.8" model with F=0.11 and rho adjusted ASAP "M=0.2" model with Fref=0.18 during 2017 - 2019 on the main diagonal ("true state"). The risks of the alternative management actions "alternate state" are on the counter diagonal (see text). Fishing mortality (F), January 1 stock biomass, and percent change in biomass (% B) from the previous year are presented for each projection.

Consequence Analysis

Catch 2016	537 mt		
Quota 2017	730 mt		
		VPA 0.8	**ASAP**
2017 biomass (3+)		12,433	2,433
2018 biomass (3+)		13,944	2,285
Projected catch			
VPA F=0.11 at neutral risk		"true state"	"alternate state"
2018 catch = 1270 mt	2018 F	0.11	0.68
	2019 Biomass (mt)	14,169	1,369
	% B from 2018	2%	-40%
2019 catch = 1032 mt	2019 F	0.11	0.90
	2020 Biomass (mt)	12,355	1579
	% B from 2019	-13%	15%
ASAP F=0.18 median		"alternate state"	"true state"
2018 catch = 412 mt	2018 F	0.04	0.18
	2019 Biomass (mt)	14,964	2,140
	% B from 2018	7%	-6%
2019 catch = 410 mt	2019 F	0.04	0.18
	2020 Biomass (mt)	13,487	2,885
	% B from 2019	-10%	35%

	F ≤ Fref & biomass increase > 10%
	F ≤ Fref & biomass increase < 10%
	F > Fref & biomass increase < 10%
	F > Fref & biomass increase > 10%

Empirical Approach

The empirical approach method was developed in 2016 to provide quota advice independently of the two models (Table 4). The method adjusts recent quotas by recent population biomass trends derived from fitting the average of the three surveys (DFO spring, NMFS spring, NMFS fall) (Figure 7) to a *loess* smoother. The trend used to adjust quota was estimated from the most recent 3-year block of the *loess* smooth (2015-2017), and uncertainty about the trend was derived by bootstrapping the original loess fit 1000 times to produce 90% probability intervals (Figure 8). This method relies on recent quotas (2014-2016) and assumes that these quotas reflect sustainable catch levels.

Table 4. Quota advice (mt) resulting from application of the empirical approach method, where recent average quota (658 mt) is multiplied by the most recent 3-year average biomass trend. Percentiles reflect uncertainty in the estimated 3-year average biomass trend from the robust loess smooth, rather than risk. The percentiles (50%=median) reflect the probability that the true average 3-year trend is within a given bound (e.g., between 5% and 95%, we expect the true average 3-year trend will fall within these bounds 90% of the time).

Year	5%	25%	50%	75%	95%
2018	1002	1133	1156	1164	1168

TRAC Advice

While management measures have resulted in a decreased relative exploitation rate since 1995, total mortality has remained high and adult biomass has fluctuated at a low level. The continuing poor recruitment since the early-1990s, and the apparent high unaccounted mortality on adult fish that is evident from the high Z and low recent relative F, are important factors for this lower productivity. Rebuilding will not occur without improved recruitment. Given the extremely low spawning stock biomass (SSB), TRAC advises that management aim to rebuild SSB.

The 2018 catch advice at low and neutral risk from the VPA "M 0.8" model median catch advice from the ASAP model and the median of the bootstrapped slope estimate from the Empirical Approach are shown in Table 5. The table also shows the percent difference between the 2018 advice from the three approaches and the 2017 quota of 730 mt. The Empirical model provides advice for increased catch, whilst the ASAP advice is for a decrease from the 2017 quota. The VPA provides advice for increased catch at both low and neutral risk, but for a small decrease if in the deterministic projections the 2017 F associated with the quota being fully caught is continued in 2018.

Table 5. 2018 catch advice from the three approaches for providing cod catch advice (VPA, median rho adjusted ASAP and Empirical) and the percent difference from the 2017 quota of the advice from each approach.

	Measure	Catch Advice	% Difference from 2017 Quota (730 mt)
VPA	Neutral Risk	1,270 mt	74%
	Low Risk (25%)	1,072 mt	47%
	$F_{2018}=F_{2017}$	711mt	3%
ASAP	Median	412 mt	-44%
Empirical	50^{th} Percentile	1,156 mt	58%

The TRAC recommends catch advice in the range of 730 mt to 900 mt. In order to provide a range of catch advice, the TRAC considered all three model results, risk projections, retrospective patterns and projection performance, as well as biological signals. Due to the presence of the stronger 2013 year class and the increase in biomass for all three surveys in the most recent year, the TRAC reached consensus that there was no reason to recommend reducing catch advice below the 2017 quota; therefore, it was agreed that 730 mt was an appropriate lower bound for the 2018 catch advice.

In recommending an upper bound, there were a number of concerns expressed against increasing quotas to the extent reflected by some of the catch values in Table 5. Specifically, there was concern that both analytical models (VPA and ASAP) continue to exhibit diagnostic problems (poor fit to surveys), and retrospective patterns that lead to overestimating terminal year SSB. For the empirical model, it was noted that the 2016 slope estimated at TRAC 2016 now falls outside of the confidence interval estimated at this TRAC for 2016 estimated slope, which reflects instability at the end of the smoother. Additionally, it was noted that the 2018 catch advice in Table 5 is largely driven by a single year class (2013), meaning that the projected catch will be very sensitive to estimates of that year class size. It was also felt that allowing that 2013 year class another opportunity for spawning in 2018 at age 5 would be beneficial, because in 2019 the assumed M on that cohort will increase from 0.2 to 0.8 in the VPA "M 0.8" model, thereby greatly reducing its contribution to the population and to the catch. Further biological considerations include low recruitment in all recent years other than 2013 in all three surveys, the fishery and surveys show truncated age distributions with a lack of older fish, high unaccounted for mortality, and a general trend of lower weights at age and a continued decline in condition.

The TRAC recommends an upper bound of 900 mt (23% increase). This reflects a reduction from the VPA F_{ref}, which is consistent with the TMGC Harvest Strategy, and recognizes the potential that 2018 VPA projected catches are likely to be optimistically high given past experience with VPA projections. It was also noted that a variety of methods to average catch advice produce a number around 900 mt, including an approach similar to what was done in TRAC 2016 (averaging the empirical median with the VPA catch advice at an F that did not increase from the F in the quota year.

Special Considerations

The consequence analysis reflects the uncertainties in the assessment model assumptions. Despite these uncertainties, all assessment results, and all biological and fishery indicators, suggest that low catches are needed to promote rebuilding.

Performance of the VPA and ASAP for EGB Cod was poor and seemed to be getting worse with time with regard to model diagnostics. Some of the diagnostic issues were poor fits to the survey data and significant retrospective patterns in biomass, fishing mortality, and recruitment, indicating an undiagnosed misspecification in the model. The VPA and ASAP modeling approaches are becoming increasingly unreliable for providing management advice.

Source Documents

Martin, R., C.M. Legault, Y. Wang, and E.N. Brooks. 2017. Assessment of Eastern Georges Bank Cod for 2017. TRAC Reference Document 2017/01.

Brooks, E.N., I. Andrushchenko, Y. Wang, and L. O'Brien. 2016. Developing an Emprical Approach for Providing Catch Advice for Eastern Georges Bank Cod . TRAC Reference Document 2016/04.

Claytor R., and L. O'Brien, editors. 2013. Proceedings of the Transboundary Resources Assessment Committee (TRAC): Transboundary Resources Assessment Committee Eastern Georges Bank Cod Benchmark Assessment. TRAC Proceedings 2013/01.

Clark K.J, and E.N. Brooks, editors. 2017. Proceedings of the Transboundary Resources Assessment Committee (TRAC): Eastern Georges Bank Cod and Haddock, and Georges Bank Yellowtail Flounder. Report of Meeting held 11-14 Jul. 2017. TRAC Proceedings 2017/01.

Wang, Y. 2016. A Comparison of VPA, ASAP and Empirical Approach Applications to Eastern Georges Bank Cod (*Gadus morhua*). TRAC Reference Document 2016/05.

Correct Citation

TRAC. 2017. Eastern Georges Bank Cod. TRAC Status Report 2017/01.

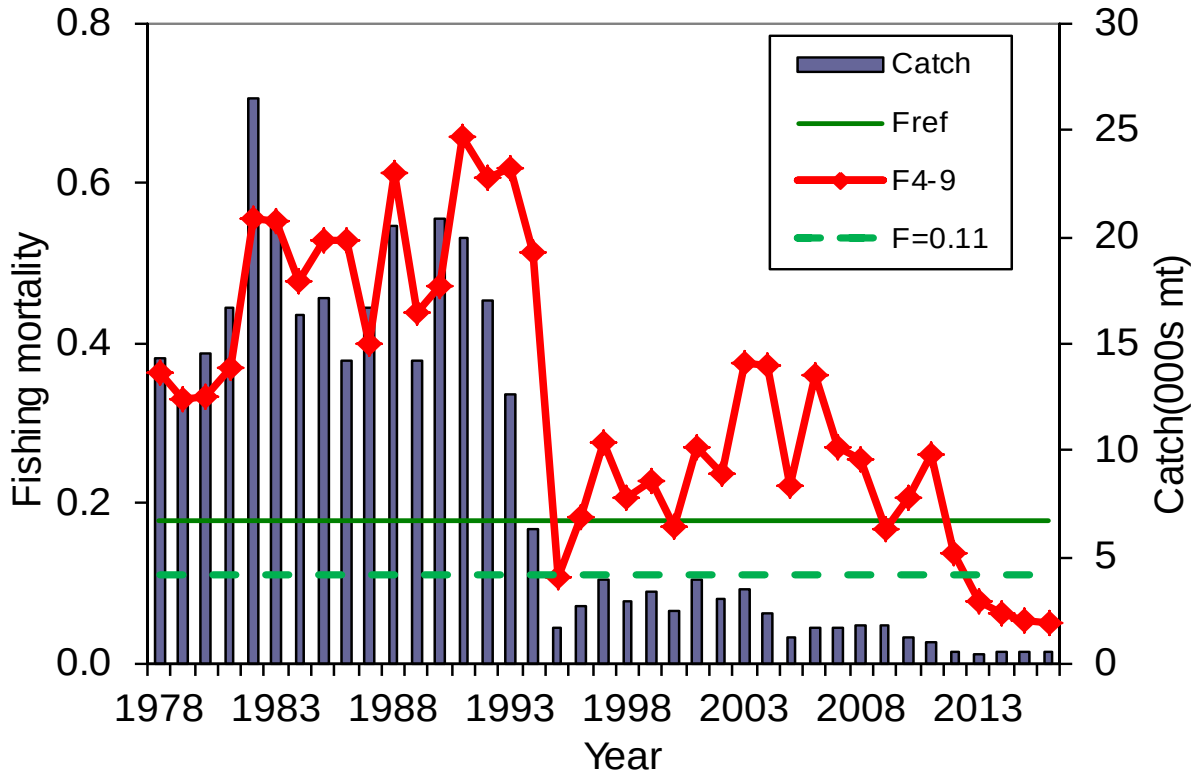


Figure 1. Fishing mortality (F) for EGB cod from VPA "M 0.8" and catches.

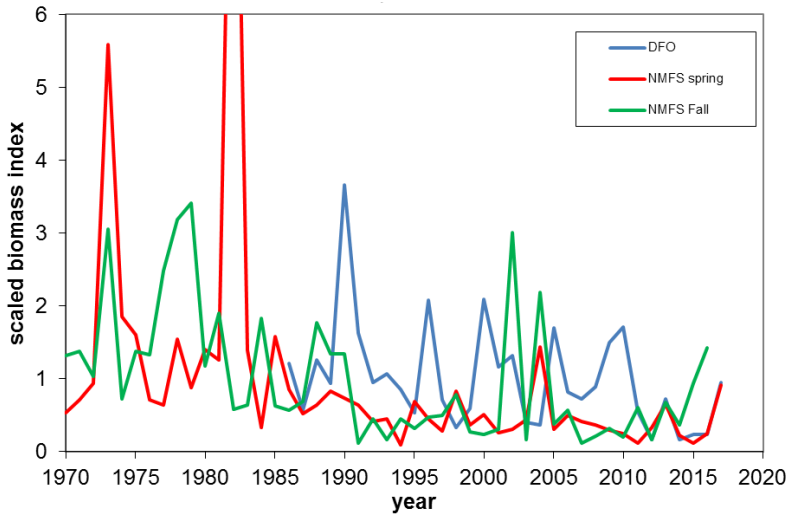


Figure 2. Survey biomass indices (ages 1+) for eastern Georges Bank cod from the DFO spring, NMFS spring and NMFS fall surveys scaled to their respective time series means.

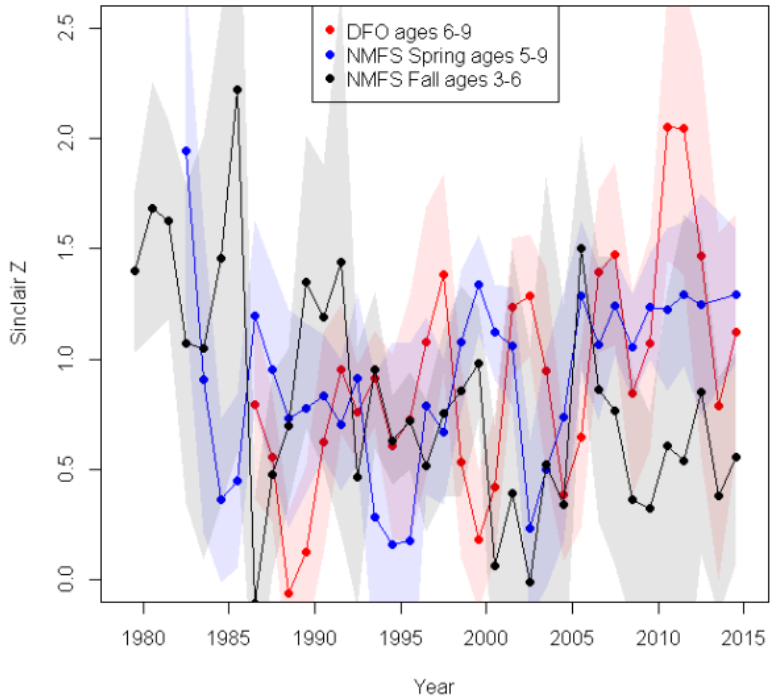


Figure 3. Empirical estimate of total mortality for the DFO (ages 6-9), NMFS spring (ages 5-9) and NMFS fall (ages 3-6) surveys.

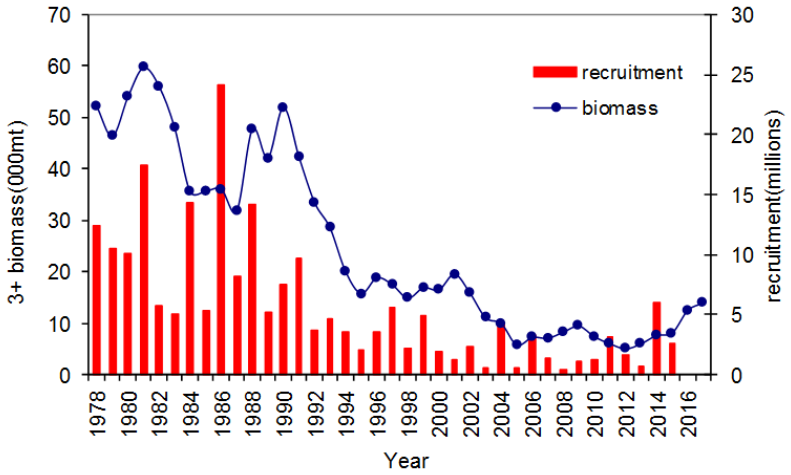


Figure 4. Biomass and recruitment for EGB cod from VPA "M 0.8".

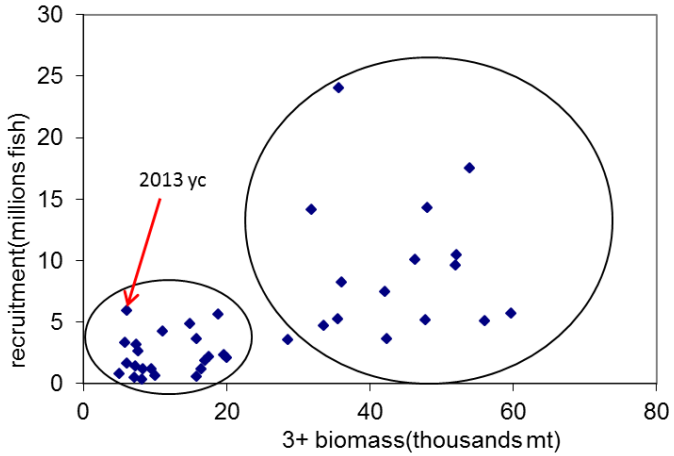


Figure 5. Stock recruitment patterns for EGB cod from VPA "M 0.8".

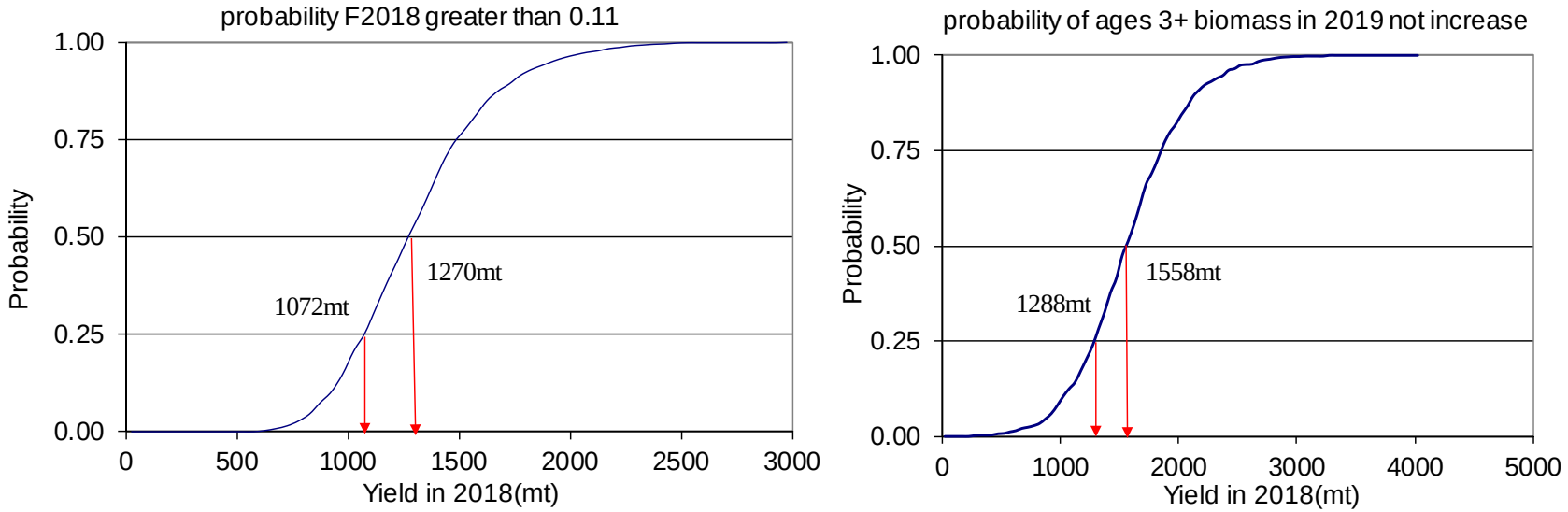


Figure 6. 2018 Projections of catch and associated risks with the probability that F2018 will be greater than the reference F of 0.11 and the probability of no increase in the 3+ biomass assuming a 2017 catch of 730 mt.

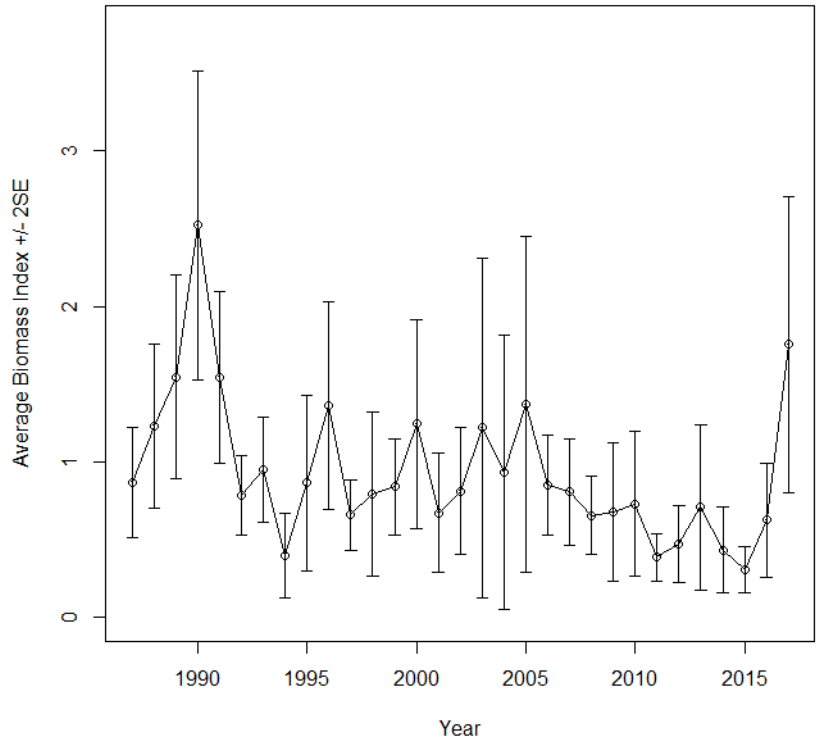


Figure 7. Combined index from CV weighted average of the three surveys (NMFS fall, DFO, and NMFS spring).

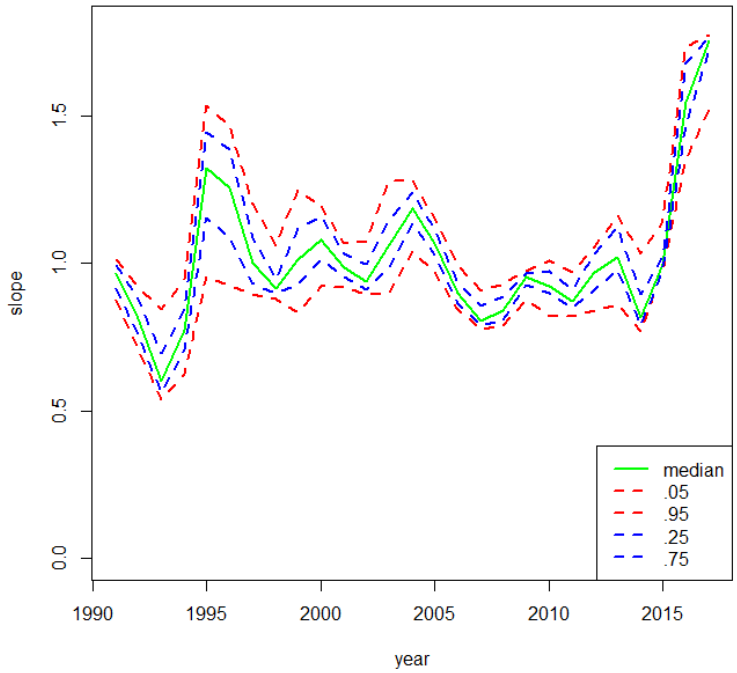


Figure 8. Bootstrap CI on the estimated 3-year slope from the average survey biomass index. A value of 1.0 means no change, values<1 indicate a decrease, values>1 indicate an increase.