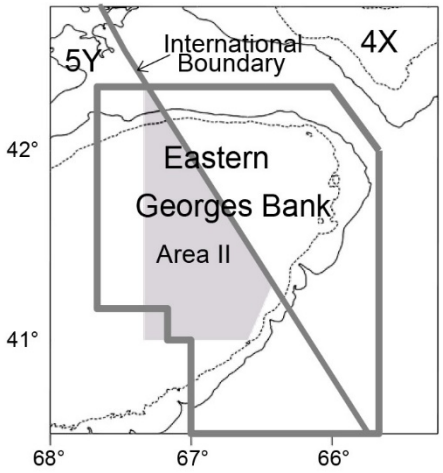
Status Report 2018/01

EASTERN GEORGES BANK COD

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



Summary

- Combined Canada/United States of America (USA) catches in 2017 were 526 mt, which included 18 mt of discards.
- Survey biomass indices decreased for all three surveys and 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 2018 from the Virtual Population Analysis (VPA) "M0.8" model was 9,502 mt. Recruitment at age 1 has been low in recent years, but the 2013 year class estimated from the VPA model at 4.4 million fish shows the highest estimated recruitment since 2000.
- Fishing mortality (ages 4-9) in 2017 was estimated from the VPA model to be 0.04. In 2017, only 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.
- 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 neutral risk catch advice is 676 mt and the low risk catch advice is 602 mt. According to the VPA model, even in the absence of fishing, the stock is not expected to increase from 2019 to 2020 or 2020 to 2021 due to the 2013 cohort entering the ages of high natural mortality. The Transboundary Resource Assessment Committee (TRAC) recommends remaining consistent with the Transboundary Management Guidance Committee (TMGC) harvest strategy.

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http://www.bio.gc.ca/info/intercol/trac-cert/index-eng.php

Canada

July 2017

- The TRAC provides the results of the analyses this year, but cautions that the results are increasingly unreliable for management purposes, and an alternative approach for stock status advice is urgently required.

TRAC Review Process

In 2017, TRAC introduced a new process of review for eastern Georges Bank cod and haddock and Georges Bank yellowtail flounder. This process was reviewed by TRAC and TMGC following its first implementation in 2017, and some modifications were made to further improve clarity in the process. An overview of the entire process applied in 2018 is available at https://www.nefsc.noaa.gov/saw/trac/. Following the updated process, the TRAC review involved three steps for each stock: (1) presentation of the assessment by the assessment lead(s), followed by scientific and technical review by science assessment staff, designated reviewers and two identified resource managers (one from the USA and one from Canada); (2) contributions by all meeting participants, including stakeholders from the fishing industry, representatives from non-government organizations, and representatives from other levels of government (State, Federal, and Provincial) as well as the general public; (3) science assessment staff, reviewers, and resource managers then considered these additional contributions to inform the development of final conclusions and catch advice, adjusting their initial conclusions if appropriate and necessary.

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

		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Avg[1]	Min[1]	Max[1]
Canada[9]	Quota	1.2	1.0	0.9	0.5	0.5	0.5	0.5	0.5	0.6	0.7			
	Catch	1.2	0.8	0.7	0.5	0.4	0.5	0.5	0.4	0.5		5.2	0.4	17.9
	Landed	1.0	0.7	0.7	0.4	0.4	0.4	0.5	0.4	0.5		5.1	0.4	17.8
	Discard	0.2	0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	0.4
USA[9]	Quota[2]	0.5	0.3	0.2	0.2	0.1	0.2	0.1	0.1	0.1	0.3			
	Catch[2]	0.5	0.3	0.2	<0.1	<0.1	0.1	0.1	<0.1	<0.1				
	Landed	0.4	0.4	0.3	0.1	<0.1	<0.1	<0.1	<0.1	<0.1		3.2	<0.1	10.6
	Discard	0.2	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	0.3
Total[9]	Quota	1.7	1.3	1.1	0.7	0.6	0.7	0.7	0.6	0.7	1.0			
	Catch[3,4]	1.7	1.1	0.9	0.5	0.4	0.5	0.6	0.5	0.5				
	Catch	1.8	1.3	1.0	0.6	0.4	0.6	0.6	0.5	0.5		8.5	0.5	26.5
From VPA "M 0.8" model														
Adult Biomass[5]		9.4	7.4	6.0	5.0	6.0	7.6	8.1	12.5	13.9	9.5	25.2	5.9	59.7
Age 1 Recruits		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]		0.17	0.21	0.26	0.14	0.08	0.06	0.06	0.05	0.04		0.33	0.05	0.66
Exploitation Rate[7]		18%	23%	51%	44%	6%	6%	6%	7%			26%	6%	44%
Exploitation Rate[8]		24%	23%	17%	11%	32%	11%	5%	1%			23%	1%	46%

[1]1978-2017
[2]for fishing year from May 1-April 30
[3]for Canadian calendar year and USA fishing year May 1-April 30
[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 2017 were 526 mt, which included 18 mt of discards, with a quota of 730 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 increased from 440 mt in 2016 to 488 mt in 2017. Discards were estimated at 7 mt from the mobile gear fleet. Estimated discards of cod by the Canadian scallop fishery were 7 mt in 2017.

USA catches decreased from 97 mt in 2016 to 38 mt in 2017. Estimated discards of cod for 2017 were 4 mt, entirely from the otter trawl groundfish fishery. Preliminary estimates of the USA catches (landings plus discards) for fishing year 2017 were 44 mt, 30.2% of the 146 mt quota.

The combined Canada/USA 2017 **fishery age composition** (landings + discards) was dominated by the 2013 year class at age 4, both by number and by weight. The contribution to the catch of fish older than age 7 continues to be small in recent years: 0.4% by number and 0.9% by weight in 2017. Both the Canadian and the USA fisheries were adequately sampled to determine length composition of the catch.

Harvest Strategy and Reference Points

The 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 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 model than F_{ref}, whereas the ASAP model continues to apply F_{ref}=0.18 for the consequence analysis. During the 2016 TRAC meeting, it was noted that due to recent dome-shaped fishery selectivity, comparing $F_{4\text{-}9}$ to F=0.11 may no longer be appropriate (Curran and Brooks, 2016).

State of Resource

Survey biomass indices decreased 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 model), which used fishery catch statistics and sampling for size and age composition of the catch for 1978 to 2017 (including discards). The VPA was calibrated to trends in abundance from three research bottom trawl survey series: Fisheries and Oceans Canada (DFO), National Marine Fisheries Service (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 biomass values were lower for the ASAP results but both models showed low recent biomass, poor recent recruitment, and high recent total mortality.

The estimated **adult population biomass** at the beginning of 2018 from the VPA model was 9,502 mt, which was approximately 20% 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 model at 4.4 million fish shows the highest estimated recruitment since 2000. The current estimate of the 2016 year class from the VPA model is 1.0 million fish at age 1, which is one of the lowest recruitment estimates on record (Figure 4), although model estimates are highly uncertain.

Fishing mortality (population weighted average of ages 4-9) in 2017 was estimated from the VPA model to be 0.04 (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 2017, only ages 3 and 4 were fully recruited, with F values of 0.03 and 0.04, 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 and the current estimate of the 2013 year class at 4.4 million fish is the highest estimated recruitment since 2000, but is still about half the average recruitment seen between 1978 and 1990. Survey weights at age of cod on eastern Georges Bank decreased gradually throughout the 1990s and early 2000s, and have remained stable at a low level since then. Total mortality on older age groups has remained high throughout the assessment time period, while relative F (fishery catch at age per survey abundance indices) has declined significantly since the 1990s. The research survey **spatial distribution** patterns of adult (3+) cod have not changed over the past decade. 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.

Outlook

This outlook is provided in terms of consequences with respect to the harvest reference points for alternative catch quotas in 2019 and 2020.

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

Benchmark formulation (VPA 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 2019 to 2020 and from 2020 to 2021. 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, or 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 2019-2021. The 2018-2020 partial recruitment pattern was based on the most recent five years of estimated partial recruitment. The 2012-2016 average of recruitment at age 1 was used for 2019-2021 projections. The projection could be optimistic if the abundance of the 2017 and 2018 year classes is lower. Catch in 2018 was assumed to be equal to the 2018 quota (951 mt), and F=0.11 in 2019 and 2020.

In 2019, a 50% risk of not exceeding F=0.11 corresponds to catches less than 860 mt, and a lower (25%) risk of not exceeding F=0.11 corresponds to catches less than 743 mt (Figure 6, Table 2a). Due to the 2013 year class progressing through the ages of high natural mortality, there is a >90% risk that the adult biomass will decrease from 2019 to 2020, even with no fishing (Figure 6, Table 2b).

In 2020, a 50% risk of not exceeding F=0.11 corresponds to catches less than 668 mt, and a lower risk (25%) of not exceeding F=0.11 corresponds to catches less than 599 mt (Table 2a). Even with no catch in 2020, conditional on a 2019 F=0.11, there is a >90% risk of a decrease in adult biomass from 2020 to 2021 (Table 2b).

Table 2a. Risk of fishery catch exceeding F reference point 0.11 in 2019 and 2020 for VPA "M 0.8".

Probability	**0.25**	**0.5**	**0.75**
2019	743 mt	860 mt	991 mt
2020 (if F_{2019}=0.11)	599 mt	668 mt	752 mt

Table 2b. Catch for associated risk that ages 3+ biomass will not increase from 2019 to 2020 and from 2020 to 2021 for VPA "M 0.8".

Probability	**0.25**	**0.5**	**0.75**
2019 to 2020	0 mt	0 mt	0 mt
2020 to 2021 (if F_{2019}=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 2018 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 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 2019, a catch of 860 mt (see Table 2a; neutral risk) would result in an decrease of 15% in the VPA "true state" and a decrease of 14% in the ASAP "alternate state" in the 2020 biomass. A catch of 524 mt (median ASAP result at F_{ref}=0.18) would result in a 4% decrease in the 2020 biomass based on the ASAP "true state" and a decrease of 13% based on the VPA "alternate state".

In 2020, a catch of 668 mt (see Table 2a; neutral risk) would result in a decrease in the 2021 biomass of 14% in the VPA "true state" and an increase of 26% in the ASAP "alternate state". A catch of 568 mt (median ASAP result at F_{ref}=0.18) would result in a 25% increase in the 2021 biomass based on the ASAP "true state", and a decrease of 13% 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 model with F=0.11 and rho-adjusted ASAP "M=0.2" model with Fref=0.18 during 2019 - 2020 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.

Catch 2017	526 mt		
Quota 2018	951 mt		
		VPA 0.8	**ASAP**
2018 biomass (3+)		11,520	3,311
2019 biomass (3+)		9,502	3,478
Projected catch			
VPA F=0.11 at neutral risk		"true state"	"alternate state"
2019 catch = 860 mt	2019 F	0.11	0.31
	2020 Biomass (mt)	9,058	3,006
	% B from 2019	-15.3%	-14%
2020 catch = 668 mt	2020 F	0.11	0.24
	2021 Biomass (mt)	7,823	3,778
	% B from 2020	-13.6%	26%
ASAP F=0.18 median		"alternate state"	"true state"
2019 catch = 524 mt	2019 F	0.07	0.18
	2020 Biomass (mt)	9,290	3,339
	% B from 2019	-13.2%	-4%
2020 catch = 568 mt	2020 F	0.09	0.18
	2021 Biomass (mt)	8,060	4,189

% B from 2020	-13.2%	25%

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 log-scale *loess* smooth (2016-2018), 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 (2015-2017) 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 (668 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%**
2019	566	600	644	697	763

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 results from the VPA model, ASAP model and the Empirical Approach are summarized in Table 5.

Table 5. Summary from the three approaches (VPA, rho-adjusted ASAP and Empirical). Analytical model (VPA, rho-adjusted ASAP) results are presented in term of low (25%), neutral (50%) and high (75%) risk of exceeding the model-specific F reference point. Empirical results are presented as the median (50th percentile) and the associated uncertainty (25th and 75th percentiles), rather than risk. The percentiles 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).

Model	25% Catch Advice	50% Catch Advice	75% Catch Advice
VPA	743 mt	860 mt	991 mt
ASAP	418 mt	524 mt	631 mt

Model	Catch Advice: 25th Percentile	Median	75th Percentile
Empirical	600 mt	644 mt	697 mt

The TRAC recommends remaining consistent with the TMGC harvest strategy. The neutral risk catch advice of 676 mt is the average of the VPA and ASAP 50% risk of exceeding model-specific reference F (860 mt and 524 mt) and the empirical approach median (644 mt). The low risk catch advice of 602 mt is derived from the VPA and ASAP 25% risk (743 mt and 418 mt) and the empirical approach median (644 mt) because risk associated with the empirical approach is not well defined. Even in the absence of fishing, the stock is not expected to increase from 2019 to 2020 or 2020 to 2021 in the VPA due to the 2013 cohort entering the ages of high natural mortality.

A decrease in quota advice from 2018 is consistent with the continued absence of older fish, no signs of incoming strong recruitment since the 2013 year class, a general trend of lower weights at age, high unaccounted for mortality and a decrease in biomass for all three surveys in the most recent year.

Special Considerations

The TRAC found several problems with the input data and results of the three approaches. For the VPA and ASAP, these issues include uncertainty in the landings information, an increasing retrospective pattern in the estimates of population biomass, and diagnostics that may indicate model misspecification. For the empirical approach, concerns were raised about the significant change in slope from last year (terminal year sensitivity) and inability of the method to predict progression of the year classes. The TRAC provides the results of the analyses this year, but cautions that the results are becoming increasingly unreliable for management purposes, and an alternative approach for stock status advice is urgently required.

The TRAC noted that there are research initiatives underway that could inform a future benchmark assessment, including work on cod stock structure. There is also a requirement to validate other forms of input data, such as catch information. The benchmark assessment should not be scheduled until this work is complete. With the serious misgivings about the performance of the VPA and ASAP, and the terminal year sensitivity of the empirical method, the TRAC questioned the appropriateness of continuing to run these models. There was no consensus as to what analyses should be conducted in 2019 in order to provide catch advice for 2020; however, there was consensus that research time to explore model performance issues would be limited by time spent on the status quo.

Source Documents

Andrushchenko, I., C.M. Legault, R. Martin, E.N. Brooks and Y. Wang. 2018. Assessment of Eastern Georges Bank Cod for 2018. TRAC Reference Document 2018/01.

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.

Curran, J.J. and E.N. Brooks, editors. 2016. Proceedings of the Transboundary Resources Assessment Committee (TRAC): Eastern Georges Bank Cod and Haddock, and Georges Bank Yellowtail Flounder. Report of Meeting held 12-14 Jul. 2016. TRAC Proceedings 2016/01.

Wang, Y. 2016. A comparison of VPA, ASAP and Empirical Approach applications to Eastern Georges Bank Cod (*Gadus morhua*). TRAC Reference Document 2016/04.

Correct Citation

TRAC. 2018. Eastern Georges Bank Cod. TRAC Status Report 2018/01.

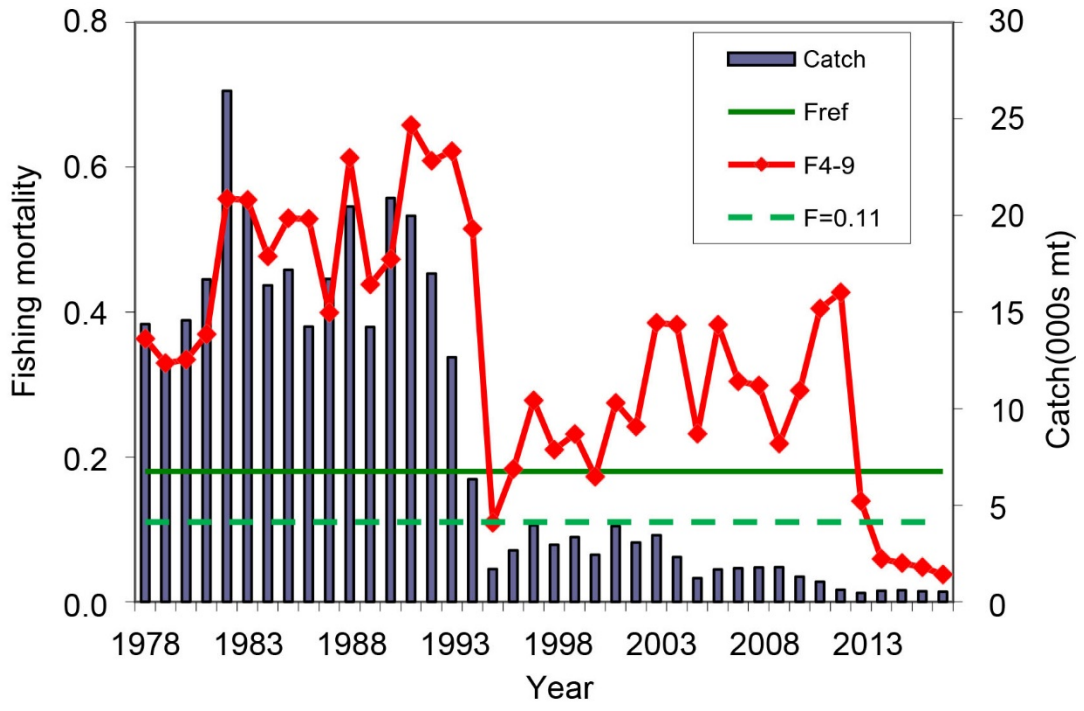

Figure 1. Fishing mortality (F) for EGB cod from VPA and catches.

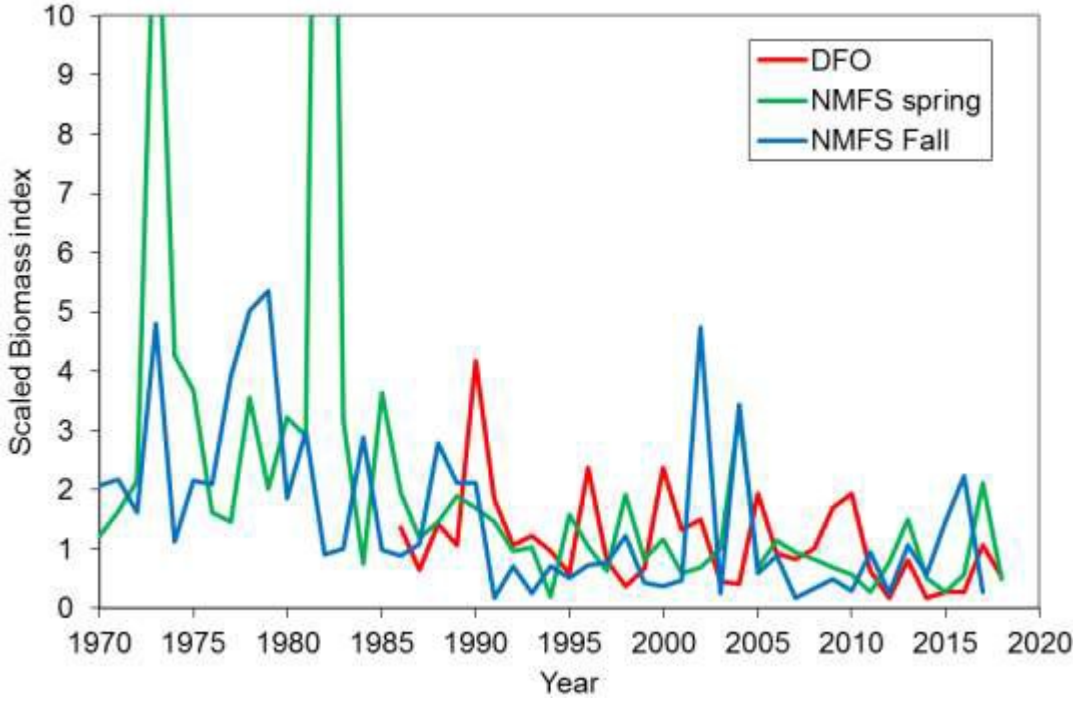

Figure 2. Survey biomass indices (ages 1+) for EGB cod from the DFO spring, NMFS spring and NMFS fall surveys scaled to their respective time series means.

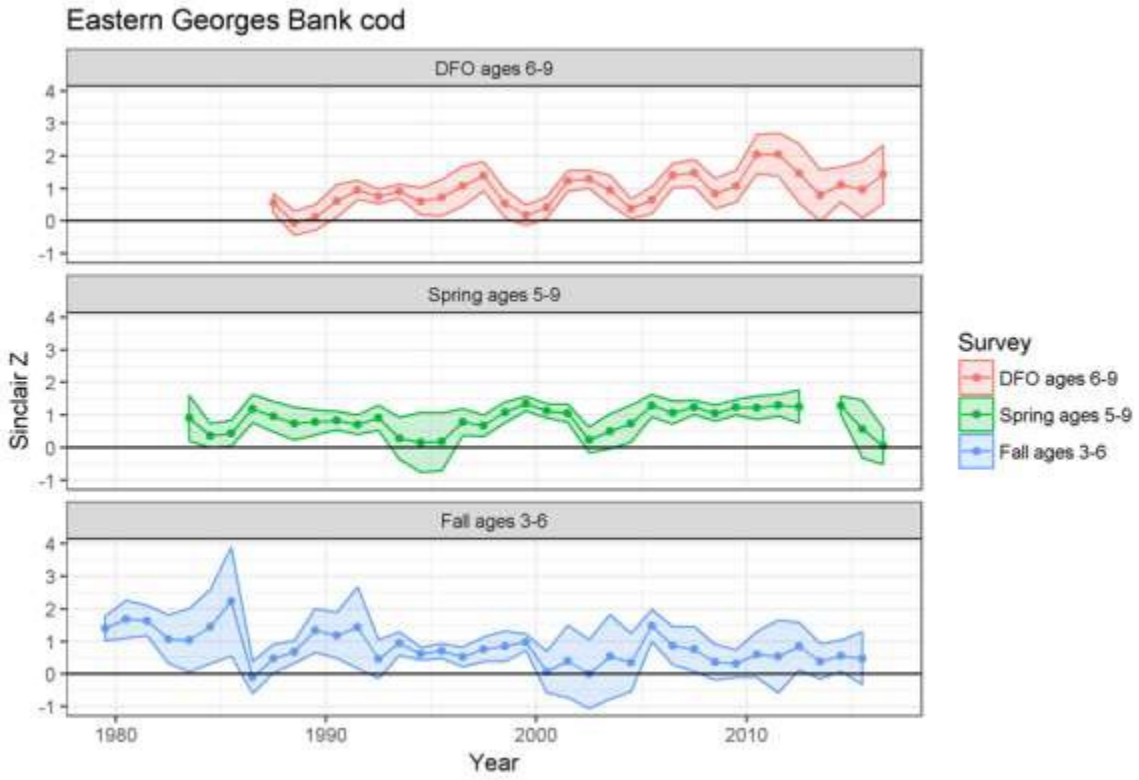

Figure 3. Empirical estimate of total mortality for the DFO (ages 6-9), NMFS spring (ages 5-9) and NMFS fall (ages 3-6) surveys.

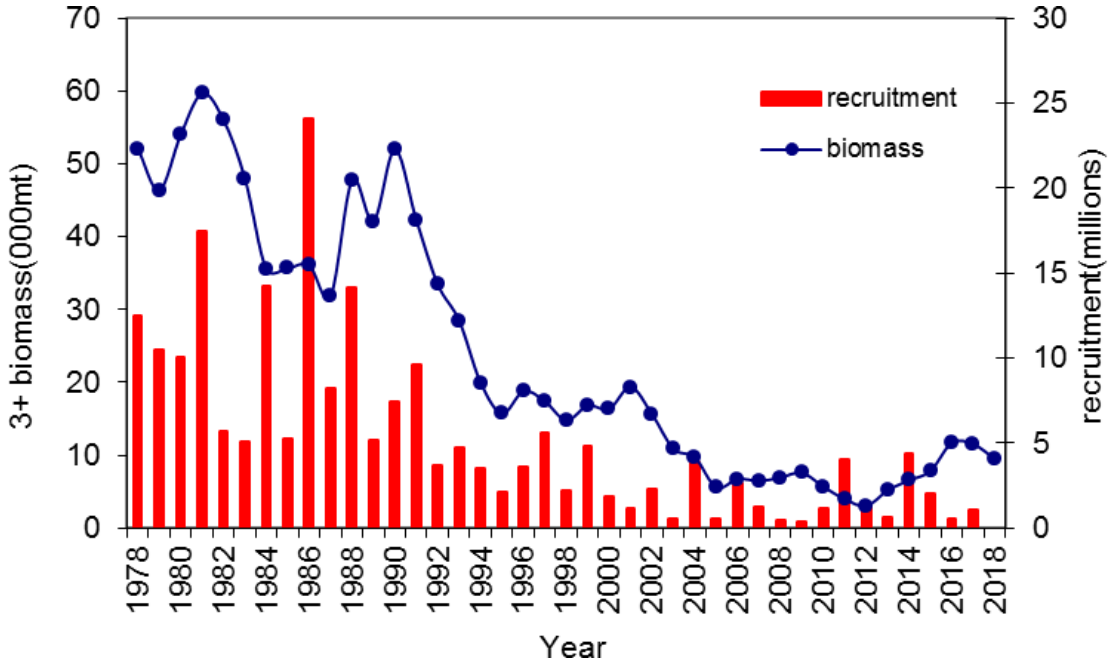

Figure 4. Biomass and recruitment for EGB cod from VPA model.

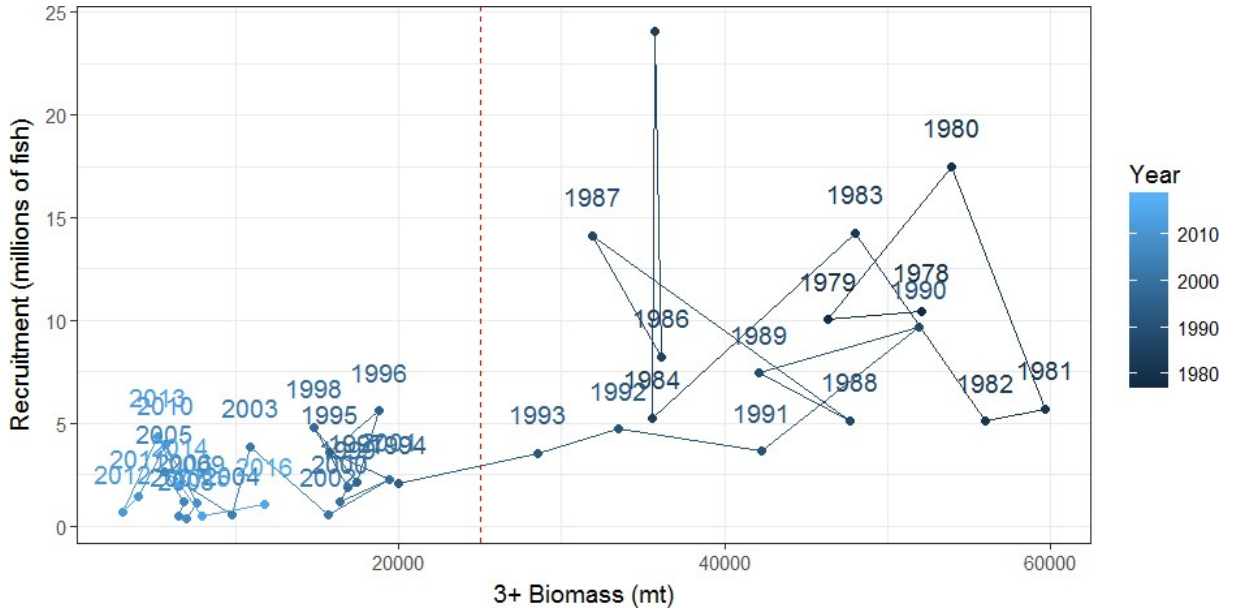

Figure 5. Relationship between adult biomass (ages 3+) and recruits at age 1 for EGB cod from VPA model.

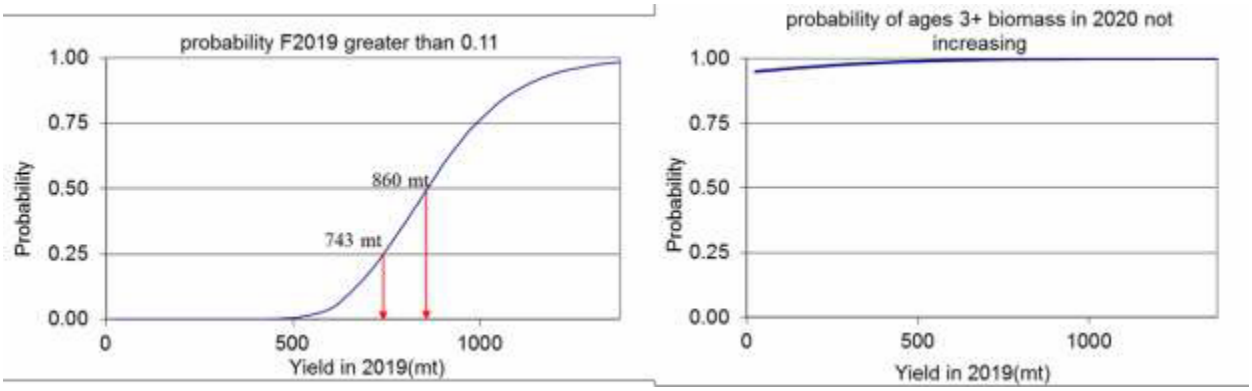

Figure 6. 2019 Projections of catch and associated risks with the probability that F in 2019 will be greater than the reference F of 0.11 and the probability of no increase in the 3+ biomass assuming a 2018 catch of 951mt from the VPA model.

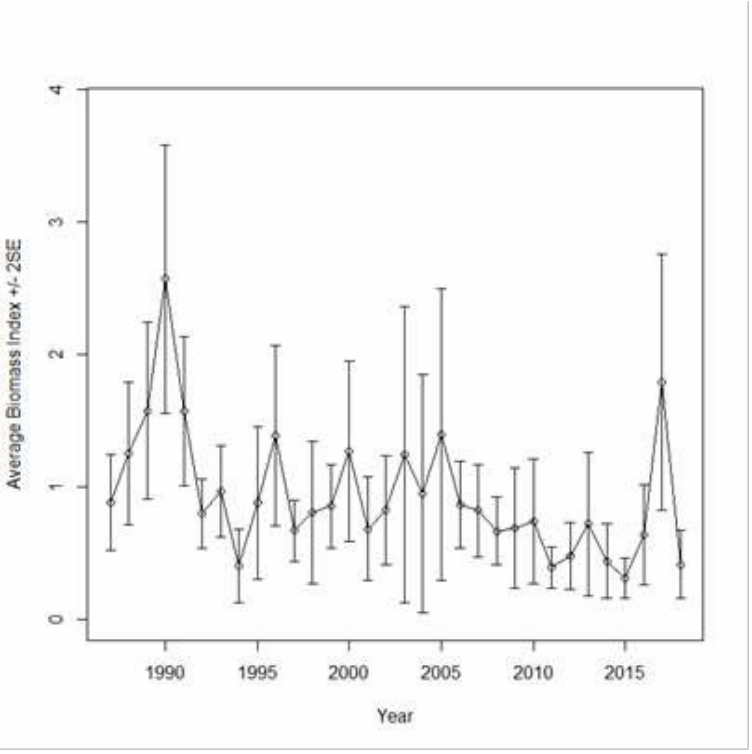

Figure 7. Combined index from coefficient of variation-weighted average of the three surveys (NMFS fall, DFO, and NMFS spring).

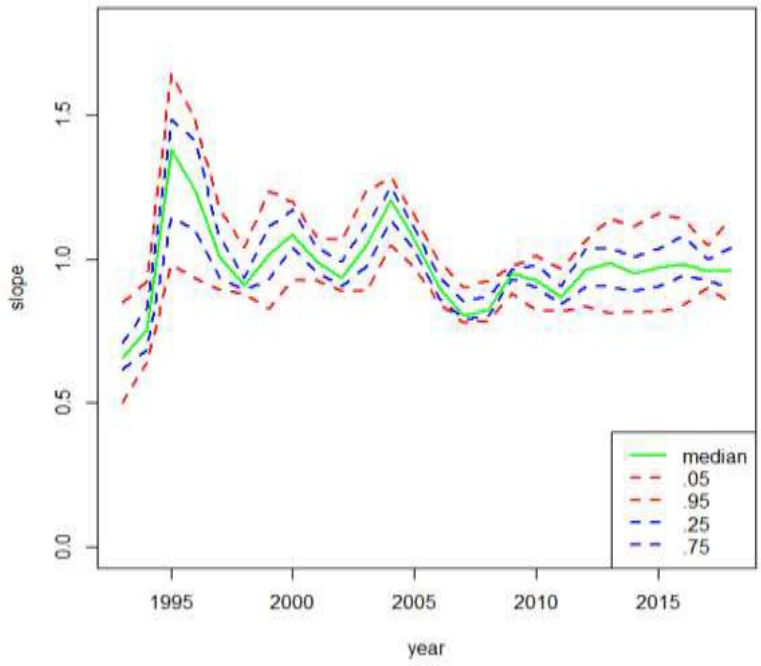

Figure 8. Bootstrap confidence interval on the estimated 3-year slope from the average survey biomass index. A value of 1.0 means no change, values<1 indicate a decrease, values>1 indicate an increase.