Fisheries and Oceans Canada | Pêches et Océans Canada

NOAA FISHERIES
NATIONAL MARINE FISHERIES SERVICE

CERT

Comité d'évaluation des ressources transfrontalières

Document de referénce 2019/##

Ne pas citer sans autorisation des auteurs

TRAC

Transboundary Resources Assessment Committee

Reference Document 2019/##

Not to be cited without permission of the authors

Assessment of Haddock on Eastern Georges Bank for 2019

M.Finley[1], E.N. Brooks[2], Q. McCurdy[1], M.A. Barrett[1] and Y. Wang[1]

[1]Fisheries and Oceans Canada
125 Marine Science Drive
St. Andrews, New Brunswick E5B OE4
Canada

[2]NOAA/NMFS
Northeast Fisheries Science Center
166 Water Street
Woods Hole, MA 02543
USA

Ce document est disponible sur l'Internet à : This document is available on the Internet at :
http://www.bio.gc.ca/info/intercol/trac-cert/index-eng.php

Canada

ABSTRACT

The total catch of eastern Georges Bank (EGB) haddock in 2018 was 12,495mt of the 40,000 mt combined Canada/United States of America (USA) quota. The 2018 Canadian catch decreased from 13,377 mt in 2017 to 12,216 in 2018 mt while the USA catch in 2018 was 253 mt, a increase from the 2017 catch of 214 mt. Haddock discards from the Canadian scallop fishery and the USA groundfish fishery were estimated at 5 and 21 mt, respectively.

The 2019 beginning of year adult population biomass (ages 3+) is estimated at 167,476 mt. A preliminary estimate for the 2017 and 2018 year class is 11,000 million and 13,000 fish at age 1, respectively. The current age 1 estimate of the 2013 year class is 589 million fish, which is the highest in the time series (1931-1955 and 1969-2019). The exceptional 2003 and 2010 year classes, estimated at 196 million and 96 million age-1 fish, respectively, are the second and third largest. Except for the strong 2000, 2011, and 2016 year classes and the exceptional 2003, 2010, and 2013 year classes, recruitment has fluctuated between 1.6-26.1 million since 1990. Fully recruited fishing mortality increased to levels above F_{ref} = 0.26 from 2010-2017. In 2018, F was estimated at 0.05. Positive signs of productivity include expanded age structure, broad spatial distribution, large biomass and three exceptional year classes and three strong year classes since 2000. On the negative side, condition has decreased substantially (some improvement in 2019) and size at age has declined.

Assuming a 2019 catch equal to the 30,000 mt total quota and F=0.26 (F_{ref}) in 2020 and 2021, a combined Canada/USA catch of 33,000 mt in 2020 results in a neutral risk (50%) that the 2020 fishing mortality rate would exceed F_{ref} = 0.26. The 2016 year class at age 4 is expected to contribute 4% of the catch biomass and the 2013 year class at age 7 is expected to contribute the highest percentage at 89%. Adult biomass is projected to be 105,225 mt, at the beginning of 2021 at the F_{ref} catch level.

A combined Canada/USA catch of 18,000 mt in 2021 results in a neutral risk (50%) that the 2019 fishing mortality rate would exceed F_{ref} = 0.26. The 2016 year class at age 5 is expected to contribute 7% of the catch biomass and the 2013 year class at age 8 is expected to contribute 41%. Adult biomass is projected to be 105,190 mt at the beginning of 2022 at the F_{ref} catch level.

Retrospective analyses indicated that the benchmark model has a tendency to underestimate F and overestimate biomass and age 1 recruitment when additional years of data are added. To account for the retrospective bias, a sensitivity forecast using the rho adjusted 2019 population numbers (ages 0-9+) for deterministic projections and risk assessments was conducted to beginning year 2022. Assuming a 2019 catch equal to the 30,000 mt total quota and F=0.26 (F_{ref}) in 2020 and 2021, a combined Canada/USA catch of 8,500 mt in 2020 results in a neutral risk (50%) that the 2020 fishing mortality rate would exceed F_{ref} = 0.26. A combined Canada/USA catch of 7,000 mt in 2021 results in a neutral risk (50%) that the 2021 fishing mortality rate would exceed F_{ref} = 0.26.

RÉSUMÉ

<< Abstract or Résumé may be sent to CSAS for translation at the e-mail address below.
(csas@dfo-mpo.gc.ca)

Le Résumé ou Abstract peut être envoyé au SCCS pour traduction à l’adresse ci-haut >>

INTRODUCTION

For the purpose of developing a sharing proposal and consistent management by Canada and the United States of America (USA), an agreement was reached that the transboundary management unit for haddock would be limited to the eastern portion of Georges Bank (EGB; DFO statistical unit areas j and m in NAFO sub-division 5Ze; USA statistical areas 551, 552, 561 and 562 in NAFO sub-division 5Ze; Figure 1; DFO 2002). This assessment applies the approach used by Van Eeckhaute and Brooks (2014) to Canadian and USA fisheries information updated to 2018. Results from the Fisheries and Oceans Canada (DFO) survey, updated to 2019, the USA National Marine Fisheries Service (NMFS) spring survey, updated to 2019 and the NMFS autumn survey, updated to 2018, were also incorporated. The NMFS surveys since 2009, which use a new vessel (NOAA ship *Henry B. Bigelow*), a new net and protocols, were made equivalent to surveys undertaken by the former NOAA ship *Albatross IV* by applying length-based conversion factors (Brooks *et al*. 2010).

FISHERY

Commercial Catches

Haddock on Georges Bank have supported a commercial fishery since the early 1920s (Schuck 1951; Clark *et al*. 1982). Catches from EGB during the 1930s to 1950s ranged between 17,000 - 41,000 mt (Figure 2). Records of catches by unit area for 1956 to 1968 are not available, however, based on records for NAFO Subdivision 5Ze, catches from EGB probably attained record high levels of about 60,000 mt during the early 1960s. Catches during the late 1970s and early 1980s reached a maximum of 23,344 mt and were associated with good recruitment (Table 1; Figure 3). Substantial quantities of small fish were discarded in those years (Overholtz *et al*. 1983). Catches subsequently declined, fluctuating around 5,000 mt during the mid to late 1980s. Under restrictive management measures (Table 2), combined Canada/USA catches declined from 6,504 mt in 1991 to a low of 2,150 mt in 1995, varied between 3,000-4,000 mt until 1999, and increased to 15,257 mt in 2005. Catches varied between 5,066 mt and 19,855 mt from 2006 to 2016. In 2017, the total catch was 13,679 mt and represented 27% of the combined 50,000 mt quota. In 2018, the total catch was 12,495 mt and represented 31% of the combined 40,000 mt quota. Canada caught 51% of its 24,000 mt allocation while the USA caught 1% of its 16,000 mt allocation in 2018.

Canadian

Some elements of the management measures used on EGB are described in Table 2. Quotas are the principal means used to regulate the Canadian groundfish fisheries on Georges Bank. Quota regulation requires effective monitoring of fishery catch. Weights of all Canadian landings since 1992 have been monitored at dockside. Canadian catches since 1995 have usually been below the quota due to closure of some fleet sectors when the cod quotas were reached. In 2018, at-sea observer coverage represented 64.1% of otter trawl (OTB) and 11.2% of longline landings, which amounted to an overall observed level of 63% of haddock landings for the Canadian fishery. For OTB, coverage was 100% from June to August and 50% from September to December.

Between 1994 and 2004, the Canadian fishery for groundfish on EGB was closed from 1 January to 30 May. In 2005, increasing haddock abundance led to permission to conduct an exploratory Canadian groundfish fishery in January and February that has continued since that time. Observer coverage for the winter fishery remains high (i.e. 50% by weight in 2018). So as not to adversely

affect the rebuilding of cod on EGB, the winter fishery was closed February 4th in 2018 based on determinations of active cod spawning in the previous years (i.e. when 30% of cod were in "spawning" or "post-spawning" stages based on analysis of maturity data collected by observers).

Following several studies that compared cod end mesh size and retention of haddock in 2014, for 2017 and 2018 the Canadian fleet has been required to fish with a 125 mm (minimum) square or 145 mm diamond mesh size.

Canadian Landings

Canadian landings decreased from 13,377 mt in 2017 to 12,216 mt in 2018. In recent years, the Canadian fishery has been conducted primarily by small otter trawlers (i.e. Tonnage Classes 1-3, < 150 mt) followed by longline, with minimal landings by gillnet (Table 3). The percentage of landings taken by longline has steadily declined since 1992 whereas the small otter trawl share has increased (Figure 4). Over the past 10 years, small otter trawlers have taken an average of about 93% of the catch and longline vessels about 7%. There has been a declining trend in longline catches since 2012, with the 2018 catch representing <1% of total landings, and is attributed to the difficulties in avoiding cod bycatch. Large otter trawlers (TC 4+) contributed 40-80% of total landings in the 1970's but there are few left in the fishery at present (their contribution is currently low). In 2018, the highest landings occurred in December with highest percentage of total Canadian landings occurring in Quarter 4 (34%) (Table 4; Figure 5). The 2018 January/February winter fishery landed 2,250 mt of haddock, accounting for 18% of total Canadian landings.

Canadian Discards

Before 1996, Canadian landings included haddock catches reported by the scallop fishery. Landings of haddock by the scallop fleet were low (Table 3) with a maximum of 38 mt reported in 1987. Since 1996, the scallop fishery has been prohibited from landing haddock and so this species is discarded. Haddock discards from the scallop fleet have ranged between 5 and 186 mt since 1969 (Table 1). A 3-month moving window was used to calculate the discard rate and included December of the previous year for the January discard rate and January of the following year for the December rate (Van Eeckhaute *et al.* 2011). Discards from 2005 onward have been recalculated to reflect a change in the effort measure used (i.e. from freezer trawler hours to hours x meters; Sameoto *et al.* 2013). The effect on haddock discards was minimal. In 2018 there were 23 observed scallop trips available for calculating discards which were estimated at 5 mt, lower than the 8 mt calculated in 2017 (Table 5).

Compliance with mandatory retention is thought to be high since 1992, so haddock discards in the groundfish fishery are considered to be negligible. The mandatory use of separator panels for bottom trawls was implemented in 1999 to help reduce the bycatch of cod. Currently, all vessels in the fleet are using separator panels.

USA

Management measures for the USA fishery have been primarily effort based since 1994; however, in 2004, quota management was introduced to regulate the USA groundfish fishery for EGB haddock (Table 2). From 2008 to 2010, the USA portion of the EGB management area was closed to vessels fishing with trawl gear from May 1 to July 31. From 2011 onwards, the regulation only applies to the common pool which is a miniscule fraction of USA boats that fish on EGB (the common pool received between 0.28%-0.89% of the EGB quota since).

The minimum size for landed haddock had been reduced to 18 inches (45.7 cm) in October 2007 but reverted back to 19 inches (48.2 cm) in August 2008. On May 1, 2009, the minimum size was again reduced to 18 inches through a NMFS interim action. This minimum size limit was retained in Amendment 16, which went into effect on May 1, 2010. On September 15, 2008 the Ruhle trawl (previously called the Eliminator Trawl) was authorized for use in the USA portion of EGB management area. The Ruhle trawl is intended to reduce by-catch of cod. Also, beginning on May 1, 2010, many participants in the multispecies groundfish fishery organized into sectors, with each unique sector receiving a portion of the overall quota known as an Annual Catch Entitlement (ACE). Those vessels not joining a sector remained in the common pool, which received a portion of the overall quota. A discard provision went into effect on May 1, 2010 requiring that all legal sized fish be retained by vessels in a sector. On May 11, 2011, the Closed Area II Special Access Permit (SAP) was modified to allow targeting of haddock from August 1 to January 31. Also, on September 14, 2011, the haddock catch cap regulation for the herring midwater trawl fishery increased to 1% of the Georges Bank Annual Biological Catch (ABC). Beginning July 1, 2013, the minimum size was reduced from 18 inches to 16 inches (40.64 cm).

USA Landings

USA landings of EGB haddock in 2016 were derived from mandatory fishing vessel trip reports (VTRs) and dealer reports. Statistical methodology was applied to allocate unknown landings to statistical area from 1994 to 2016 (Wigley *et al*. 2008a; Palmer 2008). Some of the landings for trawl gear that were reported in 2008 to 2010, during the months when EGB was closed to trawl gear, come from the allocation algorithm which assigns a statistical area when area is missing or there are inconsistencies in reported areas on logbooks. Trawl landings that were allocated to EGB during May to July for 2008-2010 comprised 3% to 5% of total annual US landings.

USA calendar year landings (Table 1) of EGB haddock decreased from 341 mt in 2016 to 214 mt in 2017 and 253 mt in 2018. The 2017 USA landings were greatest in March and April, while in 2018 peaked in February and December (Table 6). As in other years, otter trawl gear accounted for nearly all of USA landings (99% or more, Table 7), more than 75% of which was landed by tonnage class 4 vessels.

For USA fishing year May 1, 2017 to April 30, 2018, the USA catch quota for sectors was 29,288 mt of which only 1.1% was realized in landings (1.4% of quota, including discards). The catch quota for the common pool was 206 mt, none of which was caught. For USA fishing year May 1, 2018 to April 30, 2019, the USA catch quota for sectors was 15,488 mt of which only 3.6% was realized in landings (4% of quota, including discards). The catch quota for the common pool was 111 mt, none of which was caught. In recent years, landings have been constrained in part by the low cod quota, the closed area, as well as the delayed opening of the EGB area to trawlers until August 1, in effect from 2008 to 2010 for all USA trawl gear and, since 2011, for the common pool only. The use of the Ruhle and Separator trawls may have reduced interactions with the cod quota.

USA Discards

Discards were estimated from the ratio of discarded haddock to kept of all species, a new methodology that was first applied for the 2009 Eastern Georges Bank haddock assessment. This ratio is calculated by year-quarter (or other suitable time step)-gear-mesh and prorated to the total landings of all species in the same time-gear category to obtain total discards (mt) (Wigley et al. 2008b). Where time steps within the year are sparse, imputation is carried out.

Total discards in 2017 and 2018 were 81 mt and 21 mt, respectively, a decrease from 125 mt in 2016 (Table 1). Discards were similar during the first and second half of the year in 2017 and 2018. Discards from the otter trawl fishery accounted for 98% and 99% of the USA haddock discards in 2017 and 2018, respectively. Large mesh otter trawl discards were 6.7% and 52.1%, while separator trawl discards accounted for 79% and 92%, and small mesh otter trawl discards reflected 8% and 4% of total discards in 2017 and 2018, respectively. Minor amounts of discards were estimated for gillnets (0.06, 0.001 mt) and scallop dredge (1.8, 0.1 mt). Zero discards were estimated for midwater trawl and lobster gear.

Size and Age Composition

Ageing Precision and Accuracy

D. Knox provided ages for the 2018 Canadian fishery and 2019 DFO survey and S.J. Sutherland provided ages for the 2018 US fishery and the NMFS 2018 autumn and 2019 spring surveys. Age testing was conducted between the DFO reader and the NMFS reader and intra-reader testing was conducted at both labs (Table 8; http://www.nefsc.noaa.gov/fbp/QA-QC/hd-results.html). The NMFS reader also completed a test against the haddock reference collection which resulted in 90% agreement. Inter-lab agreement ranged from 89% to 95%. No bias was detected for the exchange. Intra-reader agreement on non-reference collection samples for the NMFS reader ranged between 97% and 100%. For the DFO reader, intra-reader agreement ranged between 88% and 98%. Age determinations at both labs were considered to be reliable for characterizing catch at age.

Canadian

The size and age composition of haddock in the 2018 Canadian groundfish fishery was determined using port and at-sea samples from all principal gears with 430,475 length measurements and 1,044 ages available to characterize the catch (Table 9). For trips that were sampled by both at-sea observers and port samples, the length frequencies from the two sources were combined with appropriate weighting from each source to ensure that samples were used in a consistent manner. Gillnet landings were low and only 37 length samples were available; these landings were added in at the quarter level. Landings were applied to length samples combined by gear-month, then combined to calendar quarters before applying quarterly age length keys. Canadian fishery weights were derived from fishery lengths using a length-weight relationship derived from commercial fishery samples (round weight (kg) = 0.0000158 x length $(cm)^{2.91612}$; Waiwood and Neilson 1985).

The size composition of haddock discards in the 2018 Canadian scallop fishery was characterized by quarter using length samples obtained from 23 observed scallop trips which comprised #% of the total trips (23 of ###). Discards at age for 2005-2012 were updated to reflect changes in estimated amounts due to a change in the effort measure used and changes made to the observer data (Sameoto *et al*. 2013). DFO survey ages (*n*=62) for sets located in the Canadian portion of 5Zjm in 2018 were combined with port sample ages and applied to first quarter landings and discard length compositions. Fishery age samples for quarters 2, 3 and 4 were applied to the corresponding length compositions for both the groundfish fishery and discards (Table 9).

Otter trawl contributed most to the 2018 catch at size (99% by number), followed by longline (<1%) and dredge discards (<1%) (Figure 6). Haddock captured by longline had the highest average size, followed by otter trawl and dredge (most common/peak fork length: Longline- 44.5

cm; OTB- 40.5 cm; Dredge- 26.5 and 38.5 cm). For 2018, 78% of the catch was dominated by age 5 (2013 year class) and a small contribution (4%) of age 8 (2010 year class) while dredge catches consisted of 52% at age 5 (2013 year class) and 14% at age 2 (2016 year class). Over 36% of dredge catches consisted of catch at age 2 or less. Overall, the 2018 CDN CAA was dominated by age 5 (2013yc), then ages 2 (2016 yc), 4 (2014 yc), 3 (2015 yc), and 8 (2010 yc) representing 78%, 6%, 4%, 4% and 4% of the total catch. The 9+ age group represented 1% of quarter 2 Canadian landings, but less than 1% in all remaining quarters (Table 10).

USA

USA landings of EGB haddock are sorted into “large”, “scrod” and “snapper” market categories at sea and are sampled in port for lengths and ages (Table 11). In 2018, landings of large haddock totaled 7 mt, scrod haddock 129 mt and snapper 112 mt. Length sampling for USA EGB landings in 2018 was available for all market categories except for the “large” category in quarter 4. Length and age samples were pooled to estimate catch at age by half-year rather than by quarter, and were augmented with length and age samples from US statistical areas 522 and 525. After augmenting samples, there was a total of 3,777 lengths and 1,375 ages for calculating the 2018 USA commercial fishery CAA. USA fishery weights were derived from fishery lengths using a length-weight relationship for each half year. For quarters 1 and 2, that equation is (round weight (kg) = 6.07E-06*length (cm)$^{3.10782}$); for quarters 3 and 4, that equation is (round weight (kg) = 7.12E-06*length (cm)$^{3.08054}$).

USA fishermen are required to discard haddock under the legal size limit (18 inches/45.7 cm from January-June 2013, then 16 inches since July 2013). A new regulation for the 2010 fishing year required vessels participating in a sector to retain all legal sized haddock. USA discards at age of EGB haddock for calendar year 2018 were estimated by half-year from at-sea observer data. In calendar year 2018, the number of observed trips from the at-sea monitoring program was 51, a decrease from the previous year when there were 108. There were 379 trips to EGB in 2018 for all groundfish gear types, however the fraction of trips sampled varied by gear: 59% of standard otter trawl trips, 67% of separator trawl trips, 0% of mid-water trawl trips (out of 6 total trips), 17% of scallop trips, 67% for gillnet, 0% for lobster pot trips (0 out of 222 trips), and 0% for long line trips (out of 1 trip).

As nearly all of the discarding was due to the otter trawl fleet, there were few length samples from remaining gears (scallop dredge and gillnett). Therefore, length samples were combined across gears. The resulting combined length frequencies by half-year were converted to discarded number at age by applying the age length keys from the NMFS spring bottom trawl survey (803 ages) to quarters 1 and 2 and from the autumn bottom trawl survey (1369 ages) to quarters 3 and 4.

USA landings in 2018 had a modal size of 44 cm (Figure 7; upper panel). There were several modal sizes for discards depending on gear type. Haddock discards from otter trawl with a separator panel peaked at 40 cm, while without the panel they peaked at 38 cm. Scallop dredge discards had a modal size between 30-34 cm. The 2010 year-class (Age 8) represented ~4% of the catch at age (CAA) as landings while the 2013 year class (Age 5) represented 81% of the catch at age as discards (Figure 7; lower panel). Landings of the 9+ age group represented < 1% of the CAA (Table 10).

Combined Canada/USA Catch at Age

The 2018 Canadian and USA landings and discards at age estimates (Table 1) were summed to obtain the combined annual catch at age and appended to the 1969 to 2018 catch at age data (Table 12; Figure 8). The catch at age tracks strong year classes well (i.e. 2000, 2003, 2010, 2013) and showed an expansion in age structure in the mid-2000s with the contribution of the strong 2000 and 2003 year classes. The 2018 fishery was dominated by the 2013 year class (Age 5) which represented 80% of the total catch by number, followed by the 2016 (Age 2) year class at 6% by number. Catches of older fish (7-9+) in 2018 were low, no fish >9 years old was aged. The 2013 year class was expected to dominate the 2018 catch, however projections in 2017 predicted a higher percentage (89%).%) than was realized. Observed catch of the 2010 yc was lower than the 8% predicted in 2017, for numbers and weight (Figure 9).

There has been a declining trend in the combined Canada/USA commercial fishery weight at age and length at age since 2000 (Figure 10). Noteworthy is that the 2018 average fishery weights at age (WAA; Table 13) and lengths at age (LAA; Table 14) are currently at or near the lowest values in the CAA time series (1969-2018). The average weight of age 4 haddock caught by the fishery in 2000 was 1.9 kg with an average length of 55 cm. In 2018, the average weight and length of an age 4 haddock caught by the fishery was 0.77 kg and 40 cm.

ABUNDANCE INDICES

Research Surveys

Surveys of Georges Bank have been conducted by DFO each year (February/March) since 1986 and by NMFS each autumn (October/November) since 1963 and each spring (April) since 1968. All surveys use a stratified random design (Figures 11 and 12). The *CCGS Alfred Needler* is the standard vessel used for the DFO Georges Bank survey, but when unavailable, the *CCGS Wilfred Templeman*, a sister ship to the *Needler*, was used in 1993, 2004, 2007 and 2008. In 2016 and 2017, the CCGS *Teleost* was used and in 2018 the Mersy Venture, an industry vessel, was used instead of the DFO survey vessel (the *Venture* is also considered a sister ship to the *Needler*) for the DFO Georges Bank survey. No conversion factors are available for the *Templeman,Teleost or Venture*, however, these vessels are considered to be similar in fishing strength to the *Needler*. For the NMFS surveys, two vessels have been employed from 1963 to 2008 and there was a change in the trawl door type in 1985. Vessel and door type conversion factors, derived experimentally from comparative fishing, have been applied to the survey results to make the series consistent (Forrester *et al*. 1997). Additionally, two different trawl nets have been used on the NMFS spring survey, a modified Yankee 41 during 1973-81 and a Yankee 36 in other years, but no conversion factors are available for haddock so the indices are treated as separate series.

Since spring 2009, with one exception, the NMFS surveys have been conducted with the NOAA *FSV Henry B. Bigelow* using a new net (4-seam, 3-bridle) and revised protocols. Length based conversion factors have been calculated and were applied by dividing *Bigelow* catches at length by the length specific conversion value to make the *Bigelow* survey catches equivalent to the FRV *Albatross IV* catches for both spring and fall surveys (Brooks *et al.* 2010). The NMFS fall survey in 2017 was conducted with the *FSV Pisces* due to mechanical delays for the *FSV Bigelow*. The *FSV Pisces* is a sister ship of the *FSV Bigelow*, was outfitted with the same gear, and the same calibration factors were applied.

The spatial distributions of catches by age group (1, 2, and 3+ for spring and 0, 1 and 2+ for autumn) for the 2018 NMFS fall survey, and the 2019 DFO winter and NMFS spring surveys are shown in comparison to the average distribution over the previous 10-years (Figure 13-15). During the fall 2018, ages 0 and 1 were generally spread throughout the 5Zjm area similar to the 10 year average. Age 2+ were found on the northern half of the bank in 2018, remaining consistant with the 10 year average. Usually, in March, age 1 and 2 haddock are distributed throughout the 5Zjm management unit with higher catches in southern areas similar to the 10-year average, however, in the 2019 DFO survey they were more evenly dispersed across the bank. In the Canadian survey ages 3+ occurred mostly in Canadian waters along the northern part of the bank similar to the 10-year average. In April-May (2019 NMFS spring survey), age 1-3+ fish occurred throughout the stock area, generally similar to the 10-year average.

Scaled total biomass indices (with various conversion factors applied to NMFS surveys for doors, vessels and nets) show that the three surveys are consistent and track each other well (Figure 16). Some year effects are evident but all three surveys show low biomass from the early 1980s to mid-1990s, followed by a steady increase to 2007, a decline to 2010-2011, an increase from 2012-2015 (2012-2016 for DFO survey) and a decrease for the most recent survey for both the DFO and NMFS fall surveys. The 2016 DFO survey index was the highest value for the time series (1986-2019) but decreased by 48% in 2017, and continued to decrease in 2018 and 2019. The NMFS fall survey index was highest in 2015 but decreased by 53% in 2016, the decreasing trend in this index continues for 2017 and 2018.

Age-specific total abundance indices for the three bottom trawl surveys track strong year classes (i.e. 2000, 2003, 2010 and 2013) quite well (Figure 17). The 2019 indices of abundance for the 2013 year class (age 6) from the DFO and NMFS spring surveys were at the highest levels observed for age 6 haddock over the time series (Table 15 and Table 16). The 2018 yc and 2013 yc contributed similarily (in numbers) to the index of abundance for the NMFS fall survey (Age 0 and Age 5; Table 17).

Weights at age from the DFO survey are used as beginning of year population weights and are calculated using the method described in Gavaris and Van Eeckhaute (1998) in which weights observed from the survey are weighted by population numbers at length and age. Similar to the commercial fishery, the DFO survey WAA and LAA exhibit a declining trend from 2000 to present, especially for ages 3 and older (Figure 18; Tables 18 and 19).

HARVEST STRATEGY

The Transboundary Management Guidance Committee (TMGC) has adopted a strategy to maintain a low to neutral risk of exceeding the fishing mortality limit reference, F_{ref} = 0.26 (TMGC 2003). When stock conditions are poor, fishing mortality rates should be further reduced to promote rebuilding. The TMGC agreed to a common F strategy at its December 2002 TMGC meeting. The F references used by both countries for “healthy” or “rebuilt” stocks were virtually identical, i.e., 0.25 for Canada and 0.26 for the USA (TMGC Meeting Summary, Oct. 2, 2003).

The current fishing mortality reference (F_{ref}) of 0.26 for EGB Haddock was calculated from per-recruit analysis and by coincidence $F_{0.1}$=$F_{40\%}$=0.26. Since 2003, both survey and fishery have shown substantial fish growth changes. Together with continued changes in fishery management measures in both countries, there was some concern if the F_{ref}=0.26 is still reflective of the current fishery (Appendix A).

ESTIMATION OF STOCK PARAMETERS

Calibration of Virtual Population Analysis (VPA)

Calibrated Virtual Population Analysis (VPA) was used to estimate stock parameters. The adaptive framework, ADAPT, (Gavaris 1988) was used to calibrate the VPA with the research survey data. Details of the model formulations and model assumptions can be found in the 1998 benchmark assessment (Gavaris and Van Eeckhaute 1998). Data and model changes to the eastern Georges Bank haddock assessment framework from 1998 to 2019 are summarized in Appendix B.

The VPA was based on an annual catch at age, $C_{a,t}$ for ages a = 0, 1, 2…8, 9+, and time t = 1969, 1970…2018 where t represents the beginning of the time interval during which the catch was taken. Catch discards were included in the catch at age. The population was calculated to the beginning of 2019. The VPA was calibrated to bottom trawl survey abundance indices, $I_{s,a,t}$ for

s = DFO, ages a = 1, 2, 3…8, time t = 1986.17, 1987.17… 2018.17, 2019.00

s = NMFS spring (Yankee 36), ages a = 1, 2, 3…8, time t = 1969.28…1972.28 and 1982.28… 2018.28, 2019.00

s = NMFS spring (Yankee 41), ages a = 1, 2, 3…8, time t = 1973.28, 1974.28…1981.28

s = NMFS autumn, ages a = 0, 1, 2…5, time t = 1969.79, 1970.79… 2018.79.

Since the population is calculated to beginning year 2019, the NMFS and DFO spring surveys in 2019 were designated as occurring at time 2019.00.

Statistical properties of estimators were determined using conditional non-parametric bootstrapping of model residuals (Efron and Tibshirani 1993, Gavaris and Van Eeckhaute 1998). Population abundance estimates at ages 1 and 2 exhibit a large relative error of 62% and 43%, and a large relative bias of 15% and 8%, respectively. The relative error for other ages was between 23% and 38% with a relative bias between 1% and 4% (Table 20). While trends in the three surveys are generally consistent, the survey indices exhibit high variability which is reflected in the magnitude and direction (i.e. positive or negative) of residual values (Figure 19). Some year and cohort effects are present throughout the time series. Noteworthy is that residuals were mostly negative for the 2019 DFO and 2019 NMFS spring surveys (i.e. model predicts higher abundance than observed in the surveys). There was also a tendency for age 0 residuals from NMFS fall surveys to be positive for the past several years but smaller or negative for age 1 during the same period. This may contribute to the restospective pattern observed in this assessment over the past few years.

Retrospective Analysis

A retrospective analysis was conducted for 2019-2012 to detect any trends to consistently overestimate or underestimate age 3-8 biomass, age 5-8 fishing mortality and age 1 recruitment relative to the terminal year estimates (Figure 20). Over the past six years, the addition of an extra year of data has caused a bias to appear between the present assessment results and previous assessments. Retrospective analysis shows lower biomass, higher F, and lower recruitment for

several years of the analysis, while previous assessments remain consistent. A retrospective adjustment (denoted rho adjustment) based on the observed retrospective bias was applied to the terminal year estimates for comparisons of status determination following the methodology in Legault et al. (2010). Due to the recent increase in the retrospective pattern and the potential impact on assessment advice, a sensitivity projection was conducted using rho-adjusted age-specific stock abundance for 2019. Information on the relative change in age 3-8 biomass, age 5-8 F and age 1 recruits (Figure 21) was used to calculate a rho adjustment (Table 21) which was then applied to the terminal year estimates for comparisons of status determination. For the sensitivity projection, the age 3-8 biomass was multiplied by 0.363 to adjust age specific stock abundance (for all ages) at the start of 2019 which in turn was used to calculate 3+ biomass at the beginning of 2019. When the rho adjusted estimates for biomass and fishing mortality were plotted against the unadjusted values, they were found to be well outside the 80% and 95% confidence intervals for the unadjusted estimates (Table 22; Figure 22).

STATE OF RESOURCE

Evaluation of the state of the resource was based on results from the VPA for the years 1969 to 2019. For each cohort, the terminal population abundance estimates from ADAPT were adjusted for bias estimated from the bootstrap, and used to construct the history of stock status (Tables 23-24). This approach for bias adjustment was considered preferable to using potentially biased point estimates of stock parameters (O'Boyle 1998). The weights at age from the DFO survey (Table 18) were used to estimate beginning of year population biomass (Table 25). The adult (ages 3-8) population biomass trend generally reflects the q-adjusted survey biomass trends for the DFO (Ages 3-8) but was higher than indicated for the NMFS fall (Ages 2-7) and NMFS spring surveys (Figure 23).

Adult biomass increased during the late 1970s and early 1980s to 38,000 mt in 1981 (Table 25; Figure 24). The increase was due to recruitment of the strong 1975 and 1978 year-classes which were both estimated to be above 50 million age-1 fish. However, adult biomass declined rapidly in the early 1980s as these two cohorts were fished intensively at ages 2 and 3 and subsequent recruitment was poor. Improved recruitment in the 1990s and the strong 2000 year class (62 million at age 1), lower exploitation, and reduced capture of small fish in the fisheries allowed the biomass to increase from near a historical low of 10,100 mt in 1993 to 65,000 mt in 2003. Adult biomass decreased to 42,500 mt in 2005 but subsequently increased to 93,000 mt in 2007, higher than the 1931-1955 maximum adult biomass of about 90,000 mt. The doubling of the biomass from 2005 to 2007 was due to the exceptional 2003 year-class, estimated at 197 million age-1 fish. The biomass decreased after the 2007 high and in 2012 the adult biomass was 22,000 mt but increased in 2013, when the 2010 year class joined the 3+ group, to 43,000 mt and again in 2014 to 49,000 mt. After a slight decline in 2015 to 38,000 mt, adult biomass increased to 164,500 mt in 2016 The current estimate for 2019 is 167,476 mt (80% confidence interval: 134,600-214,892 mt; Figure 25).

Recruitment has fluctuated between 1.5 and 26.1 million age 1 fish since 1990 except for the strong year classes that typically exceed 100 million age 1 fish. The current estimate of the 2013 year class at age 1 is 589 million fish, which is the highest in the time series (1931-1955 and 1969-2019). The 2003 year class is the second highest in the series at 196 million fish.

Since 2003, the age at full recruitment to the fishery has been 5 (rather than age 4 as in previous years) due to a decline in size at age (Table 14). Fully recruited fishing mortality (population weighted average of fully recruited ages) is presented for ages 4-8 for pre-2003 and ages 5-8 for

2003 onwards (Table 24; Figure 26). Fully recruited fishing mortality fluctuated between 0.26 and 0.47 during the 1980s. After reaching a high of 0.55 in 1993, it decreased to well below F_{ref} in 1995, stayed below until 2003, fluctuated around 0.35 during 2004 to 2006, then declined to 0.15 in 2008. Fishing mortality increased to levels above F_{ref} from 2009-2017 before dropping below F_{ref} in 2018. In 2018, F was estimated at 0.05 (80% confidence interval: 0.07-0.09; Figure 25), well below F_{ref}.

Average partial recruitment estimates are less variable in a VPA when weighted by population numbers and are usually considered more appropriate than the unweighted average, however this calculation given exceptionally large 2013 yc caused neighbouring year classes to have very large PR (age 7 in 2018 PR value was 5). The calculation of F normalized to the maxium value for the year was utilized to estimate PR (Table 26). The 3 year average (excluding strong year classes) PR values for 2016-2018 were used for projections of stock abundance in 2020 and 2021 (Table 27; Figure 27), except for the 2013 year class where the PR value is fully recruited at age 7 and reflects the 2003 year class at age 8. During this projection period the large 2010 year class will comprise much of the 9+ group, therefore the PR for 9+ reflects the 2003 age class for 2020 and 2021.

PRODUCTIVITY

Recruitment, spatial distribution, age structure and growth generally reflect changes in the productive potential. Recruitment, while highly variable, has generally been higher when adult biomass has been above 40,000 mt (Figure 28). Since 1969, only the 1975, 1978, 2000, 2003, 2010, 2011, 2013 and 2015 year classes have been above the average abundance of 38.9 million age one fish for year classes observed during the period 1931-1955 and 1969-2016. The very high 3+ biomass (generally greater than about 80,000 mt) observed since 2006 has produced two exceptional year classes but has also produced eight below average year classes (Figure 28).

The spatial distribution patterns observed during the most recent bottom trawl surveys were similar to the average patterns over the previous ten years for the spring surveys. Consistent with the pattern observed for previous exceptional year-classes, the 2013 year-class was widely distributed throughout the survey area, especially during the NMFS spring and fall surveys (Figures 13-15). Age structure as reflected in the commercial fishery and RV survey catch at age composition (i.e. Figures 8 and 17) indicate higher abundance of older fish (ages 5+) since the mid-2000s.

An analysis of condition factor (Fulton's K; weight/length^3) was conducted using available individual length and weight data from the DFO (1987-2019), NMFS Spring (1992-2019) and NMFS fall (1992-2018) surveys for haddock 30-70 cm FL (i.e. where there was no change in condition at size) (Figure 29). The DFO survey data indicates that there has been a general decline in K over time with the 2017 value being the lowest in the series, the impact of the delayed DFO survey in 2017 is unknown due to lack of samples at this time of the year in the past. Since 2004, Fulton's K has generally been at or below the long term average (1987-2019) for most years except 2009. The NMFS spring survey data also shows a decline in condition with K falling below the series mean since 2000, with a decreasing trend since 2013. Fulton's K values from NMFS fall survey data are more variable but appear to have declined since 2003, with most values falling below the long term average since then, with the exception of 2008, 2013, 2014 and 2015. Since this is a time of year when haddock would be feeding, it appears that in some years since 2003 they did not gain enough weight to bring the condition factor back to a level above average. Given the size of the exceptional 2003, 2010 and 2013 year classes, there may also be density-

dependent effects which could be limiting the growth of several cohorts since 2003. The overall pattern is consistent with declining trends in WAA and LAA for haddock, and is similar to trends in condition observed in Eastern Georges Bank cod (Wang and O'Brien 2013) and Georges Bank yellowtail flounder (Legault *et al.* 2013). In 2018 (NMFS fall) and 2019 (NMFS spring) the condition increased above the time series mean as well as notable increase in the condition for the DFO survey.

Both fishery and survey average lengths and weights at age have declined considerably since 2000 (Figures 10 and 18) with some values currently at or near the lowest levels for the commercial fishery (Tables 13-14) and DFO survey (Tables 18-19) time series. The DFO survey mean lengths at age for selected cohorts indicate that maximum size has decreased compared to the 1987 year class and that the recent strong 2013 year class has average lengths at ages 5 and 6 that are well below the 2010 year class, values that were previously among the lowest in the time series (Figure 30). Changes in growth in response to changes in stock abundance and episodes of very strong recruitment have been observed throughout the history of this stock. Clark *et al.* (1982), reporting on Georges Bank haddock, observed "*a decline in mean weight for all age-groups following every period of very strong recruitment*" and a rapid increase in growth following the late 1960's and early 1970's reduction in stock size. As postulated by Clark *et al.* (1982), increased or decreased availability of food is probably the greatest determining factor for growth increases and decreases, respectively.

A comparison of total mortality (Z) calculated for ages 3-8 from the DFO survey with VPA estimates of fishing mortality from the current assessment indicates that Z has increased since the early to mid-2000s for ages 3-7 with a decrease in age 8 while F has generally decreased during this time (Figure 31), which would imply some inconsistency between the data and the model assumption of constant natural mortality. One explanation could be that M is increasing on older ages, although other explanations are possible, including irregularities in reported landings and discarding behavior, or some other as yet unidentified mechanism.

In summary, positive signs of productivity include increased abundance for older ages (2010 yc age 8 in 2019), a recent improvement in condition, broad spatial distribution and large biomass. This stock has produced three exceptional and three strong year classes in the last 20 years. On the negative side, growth has declined, and recruitment from the very large biomass has been extremely variable.

OUTLOOK

This outlook is provided in terms of consequences with respect to the harvest reference point for alternative catch quotas in 2018 and 2019. Uncertainty about standing stock generates uncertainty in forecast results which is expressed here as the risk of exceeding F_{ref}=0.26. The risk calculations assist in evaluating the consequences of alternative catch quotas by providing a general measure of the uncertainties. However, the risk calculations are dependent on the data and model assumptions and do not include uncertainty due to variations in weight at age, partial recruitment to the fishery, natural mortality, systematic errors in data reporting or the possibility that the model may not reflect stock dynamics closely enough.

Using a three year average is likely to overestimate the fishery and population weight at age due to the decreasing weight at age trend. For projections, the most recent survey (2019) average and the lowest values for the fishery time series (1969-2018) weights at age were used

for beginning year population (2020-2021) and fishery (2019-2020) weights at age, respectively, except as indicated below.

An evaluation of the 2016 EGB Haddock Interim Report (Barrett et al. 2017) indicated the importance of addressing the slow growth of strong year classes in the projections. Considering the substantial contribution of the 2013 year class to both biomass and fishery catch in the projections, a linear regression model which describes the relationship between survey weight and age (1 to 6) was estimated for the 2013 year class. The beginning year weights at age for 2019 (age 7) were predicted using this linear regression function for the 2013 year class; these values were lower than the 2010 yc values in the time series which is deemed to be more conservative than an average or assuming the same growth as the 2010 yc. However, this approach was applied to the strong 2010 year class weight at age data. The predicted weights at age 5 and 6 of the 2010 year class are similar to the observed values from survey, but overestimated the weight at age 7 as survey growth ceased at this age. Therefore, this method may it may result in a overestimate as well. The weight at age 7 of the 2013 year class in 2020 was assumed to be the same as weight at age 6 in 2019 (Figure 32). For 2013 yc fishery weights at age in the projection, the weight proportion of 77% of the 2010 yc was assumed to continue for the next two years (i.e. the 2010 was 1.282 kg at age 6, 0.99 kg was used for the 2013 yc at age 6). The fishery partial recruitment (PR) has become increasingly domed shaped and therefore was based on the 2016-2018 average, excluding large year classes. The PR used for the 2013 year class was from the 2003 year class at age 8 (Table 27). EGB haddock are considered 100% mature at ages 3 and older.

Standard Projections

Incorporating the patterns in growth and partial recruitment (Table 27), deterministic projections and risk assessments were conducted to beginning year 2022 (Table 28). Stock size estimates at the beginning of 2019 were used to start the forecasts. Abundance of the 2020, 2021 and 2022 year classes were assumed to be 13.42 million fish at age 1 (the 2010 to 2019 median from the 2019 VPA results). Natural mortality was assumed to be 0.2. Assuming a 2019 catch equal to the 30,000 mt total quota and F=0.26 (F_{ref}) in 2020 and 2021, a combined Canada/USA catch of 33,000 mt in 2020 results in a neutral risk (50%) that the 2020 fishing mortality rate would exceed F_{ref} = 0.26 (Figure 33). A catch of 28,000 mt in 2018 results in a low risk (25%) that the 2020 fishing mortality rate will exceed $F_{ref.}$ The 2016 year class at age 4 is expected to contribute 4% of the catch biomass and the 2013 year class at age 7 is expected to contribute the highest percentage at 89%. Even if no catch were taken in 2020, biomass is expected to decline. Adult biomass is projected to be 105,225 mt, at the beginning of 2021 at the F_{ref} catch level.

A combined Canada/USA catch of 18,000 mt in 2021 results in a neutral risk (50%) that the 2021 fishing mortality rate would exceed F_{ref} = 0.26 (Figure 34). A catch of 15,500 mt in 2021 results in a low risk (25%) that the 2021 fishing mortality rate will exceed F_{ref}. The 2016 year class at age 5 is expected to contribute 7% of the catch biomass and the 2013 year class at age 8 is expected to contribute 41%. A catch of 18,000 mt in 2020 results in a neutral risk that biomass will remain the same. Adult biomass is projected to be 105,190 mt at the beginning of 2022 at the F_{ref} catch level.

Sensitivity Projections

A sensitivity forecast using the rho adjusted 2019 population numbers (ages 0-9+) for deterministic projections and risk assessments was conducted to beginning year 2022 (Table 29). All other input values for the forecast were the same as in Table 27. Assuming a 2019 catch equal

to the 30,000 mt total quota and F=0.26 (F_{ref}) in 2020 and 2021, a combined Canada/USA catch of 8,500 mt in 2020 results in a neutral risk (50%) that the 2020 fishing mortality rate would exceed F_{ref} (Figure 35). A catch of 7,000mt in 2020 results in a low risk (25%) that the 2020 fishing mortality rate will exceed F_{ref}. The 2016 year class at age 5 is expected to contribute 5% of the catch biomass and the 2013 year class at age 8 is expected to contribute 88%. Even if no catch were taken in 2020, biomass is expected to decline. Adult biomass is projected to be 28,582mt, at the beginning of 2021 at the F_{ref} catch level.

A combined Canada/USA catch of 4,760 mt in 2021 results in a neutral risk (50%) that the 2021 fishing mortality rate would exceed F_{ref}=0.26 (Figure 36). A catch of 4010 mt in 2019 results in a low risk (25%) that the 2019 fishing mortality rate will exceed F_{ref}. The 2016 year class at age 6 is expected to contribute 9% of the catch biomass and the 2013 year class, now in the 9+ group, is expected to contribute 40%. A catch of 5,000 mt in 2021 results in a neutral risk that biomass will remain the same. Adult biomass is projected to be 28,832 mt at the beginning of 2022 at the F_{ref} catch level.

The F_{ref} catches from the sensitivity projections are considerably lower than the catches from standard projections but they do take into account the continuing retrospective pattern which has occurred over the past four years in this assessment. This method resulted in a 33% an underestimate of the 2019 biomass when compared to the 2019 VPA.

Management Advice

Both the standard and sensitivity projections are presented, however there is limited support for considering the standard projections. Although the survey biomass is above time series mean, recent recruitment (2013) is estimated to be the highest in the time series, and the projected age composition of the fishery catch was accurate, there are extreme problems with scale in the VPA model. Specifically, the overestimation of SSB and underestimation of F has consistently increased in the last five assessments (the current rho for SSB is 1.75), and F was above Fref from 2010-2017 in spite of the full quota not being caught. Authors agreed that the standard projection was not appropriate for providing catch advice. However, consensus was not reached among the authors on the degree to which the standard projections should be adjusted.

SPECIAL CONSIDERATIONS

Catch projections for this stock can be highly influenced by outstanding year classes. There is no direct evidence to indicate that age 9 and older haddock should be less available to the fishery than age 8 haddock, however, the domed partial recruitment at age 9 and older that the assessment model produces may be aliasing increased natural mortality, emigration outside of the management area or to areas inaccessible to the fishery. The decision to use the lower PR produced by the model, is also supported by the comparisons of percent predicted versus percent observed age 9+ from several recent assessments.

If the 2019 quota is caught, the projection indicates that the 2019 F will be 0.23 (Table 28). Moreover, if the rho adjusted projections are more appropriate, then catching the full 2019 quota would result in F > F_{ref} (0.73 for ages 5-8, Table 29). The retrospective pattern results in uncertainty around the estimates of F, the rho adjustment indicates that F may be 3 times the original estimate. From the 2017 assessment, F (5-8) for 2016 was estimated to be 0.102, but the updated value for this model run is an F (5-8) of 0.478. Neither of these F estimates are believed

to be more accurate than the other, they only demonstrate the challenges with the current model formulation. In the 2017 assessment, the estimated 3+ biomass for 2017 was 274.482 mt (208,936 – 359,157 mt 80% CI). In the 2019 assessment, the new estimated 3+ biomass for 2017 was 164,577 mt, which is outside the 80% confidence intervals estimated in 2017.

The beginning of year weight at age and fishery weight at age values selected for projection in 2017 were similar to the observed values for the first year (2018 for beginning of year WAA and 2017 for fishery WAA), however the values tended to overestimate WAA in the second year (Figure 37). The partial recruitment assumed in projection was flat topped (a value of 1 for ages 5, 6, 7, and 8) while the observed PR was domed shaped. This difference creates inconsistencies with the flat top assumed for Fref, and could overestimate projected catch if PR on the large year classes is <1, especially when large year classes reach the plus group. The 2018 observed PR exemplifies the challenges with estimating PR for extremely large year classes. The 2013 yc at age 5 is estimated to be fully recruited, however the 2014 yc at age 6 has a PR of only 0.2.

Given that the exceptional 2013 year class will be in the 9+ group for the beginning of year 2022, uncertainty around partial recruitment, continued and magnified retrospective pattern, consistent overestimates for second year WAA, as well as the projected overall decline in biomass, the current model formulation is not appropriate for providing two-year advice. We offer projected catch values, but emphasize that the second year value should be examined next year and adjusted if the survey biomass declines more strongly than it is projected to.
In 2019, a large proportion of the exceptional 2013 year class will be into the 9+ group, the continued contribution of this year class will be important to the fishery.

The terminal year rho adjusted SSB and rho adjusted F were well outside of both the 80% and 95% confidence intervals of the point estimates. This result indicates there is substantial unmeasured uncertainty, as seen in the 2017 assessment.

Cod and haddock are often caught together in groundfish fisheries, although their catchabilities to the fisheries differ and they are not necessarily caught in proportion to their relative abundance. With current fishing practices and catch quotas, the achievement of rebuilding objectives for cod may constrain the harvesting of haddock. Modifications to fishing gear and practices, with enhanced monitoring, may mitigate these concerns.

ACKNOWLEDGEMENTS

D. Frotten and D. D'entremont of DFO and at sea observers from Javitech Ltd. and Atlantic Catch Data Ltd. provided samples from the Canadian fishery. D. Knox and S. Sutherland provided ageing information for the DFO and NMFS surveys and Canadian and USA fisheries. We also thank NMFS reviewers for their suggestions to improve the document.

LITERATURE CITED

Barrett, M.A., E.N. Brooks, and Y. Wang. 2017. Assessment of Haddock on Eastern Georges Bank for 2017. TRAC Ref. Doc. 2017/02.

Barrett, M.A., M. Finley, E.N. Brooks, and Y. Wang. 2017. Evaluation of the 2016 Eastern

Georges Bank Haddock Interim Report. TRAC Ref. Doc. 2017/05: 21 p.

Brooks, E.N., T.J. Miller, C.M. Legault, L. O'Brien, K.J. Clark, S. Gavaris, and L. Van Eeckhaute. 2010. Determining length-based calibration factors for cod, haddock, and yellowtail flounder. TRAC Ref. Doc. 2010/08: 25 p.

Clark, S.H., W.J. Overholtz, and R.C. Hennemuth. 1982. Review and assessment of the Georges Bank and Gulf of Maine haddock fishery. J. Northw. Atl. Fish. Sci. 3: 1-27.

DFO. 2002. Development of a sharing allocation proposal for transboundary resources of cod, haddock and yellowtail flounder on Georges Bank. DFO Mar. Prov., Reg. Fish. Manag. Rep. 2002/01:59 p.

Efron, B., and R.J. Tibshirani. 1993. An Introduction to the Bootstrap. Chapman & Hall. New York. 436p.

Forrester, J.R.S., C.J. Byrne, M.J. Fogarty, M.P. Sissenwine, and E.W. Bowman. 1997. Background papers on USA vessel, trawl, and door conversion studies. SAW/SARC 24 Working Paper Gen 6. Northeast Fish. Sci. Cent., Woods Hole, MA.

Gavaris, S. 1988. An adaptive framework for the estimation of population size. CAFSAC Res. Doc. 88/29: 12 p.

Gavaris, S., and L. Van Eeckhaute. 1998. Assessment of haddock on eastern Georges Bank. DFO CSAS Res. Doc. 98/66: 75 p.

Legault, C.M., L. Alade and H.H. Stone. 2010. Stock assessment of Georges Bank (5Zjmnh) yellowtail flounder for 2010. Transboundary Resource Assessment Committee. Research Document. 2010/06, 96p.

Legault, C.M., L. Alade, W.E. Gross, and H.H. Stone. 2013. Stock Assessment of Georges Bank Yellowtail Flounder for 2013. TRAC Ref. Doc. 2013/01; 132 p.

O'Boyle, R.N. (Chair). 1998. Proceedings of the Transboundary Resource Assessment Committee; 20-24 April 1998. CSAS Proc. Ser. 98/10: 49p.

Overholtz, W.J., S.H. Clark, and D.Y. White. 1983. A review of the status of the Georges Bank and Gulf of Maine haddock stocks for 1983. Woods Hole Lab. Ref. Doc. 83-23, NOAA, NMFS, p.1-33.

Palmer, M. 2008. A Method to Apportion Landings with Unknown Area, Month and Unspecified Market Categories Among Landings with Similar Region and Fleet Characteristics. Groundfish Assessment Review Meeting (GARM III-Biological Reference Points Meeting). Working Paper 4.4. 9 p.

Sameoto, J., B. Hubley, L. Van Eeckhaute, and A. Reeves. 2013. A Review of the Standarization of Effort for the Calculation of Discards of Atlantic Cod, Haddock and Yellowtail Flounder from the 2005 to 2011 Canadian Scallop Fishery on Georges Bank. TRAC. Ref. Doc. 2013/04; 22 p.

Schuck, H.A. 1951. Studies of Georges Bank haddock, Part I: Landings by pounds, numbers and sizes of fish. Fish. Bull. U.S., 52: 151-176.

TMGC. 2003. Transboundary Management Guidance Committee Guidance Document 2003/1: 7 p.

Van Eeckhaute, L., Y. Wang, J. Sameoto and A. Glass. 2011. Discards of Atlantic cod, haddock and yellowtail flounder from the 2010 Canadian scallop fishery on Georges Bank. TRAC Ref. Doc. 2011/05 (in prep.). 14p.

Van Eeckhaute, L. and E.N. Brooks. 2014. Assessment of eastern Georges Bank haddock for 2014. TRAC Ref. Doc 2014/XX: 93 p.

Waiwood, K.G., and J.D. Neilson. 1985. The 1985 assessment of 5Ze haddock. CAFSAC Res. Doc. 85/95:49 p.

Wang, Y., and L. O'Brien. Assessment of Eastern Georges Bank Cod. TRAC Ref. Doc. 2013/02; 99 p.

Wigley S.E., P. Hersey, and J.E. Palmer. 2008a. A Description of the Allocation Procedure Applied to the 1994 to 2007 Commercial Landings Data. US Dept. Commer., Northeast Fish. Sci. Cent. Ref. Doc. 08-18; 61 p.

Wigley, S.E., M.C. Palmer, J. Blaylock, and P.J. Rago. 2008b. A Brief Description of the Discard Estimation for the National By-Catch Report. Northeast Fish. Sci. Cent. Ref. Doc. 08-02; 35 p.

Table 1. Nominal catches (mt) of haddock from eastern Georges Bank (EGB) during 1969-2018. For "Other" it was assumed that 40% of the total 5Z catch was in EGB. USA landings and 1989 to 2007 USA discards were revised (Van Eeckhaute et al. 2009). Canadian discards are from the scallop fishery and USA discards are from the groundfish fishery.

	Landings			Discards		Totals			Quotas	
Year	Canada	USA	Other	Canada	USA	Canada	USA	Catch	Canadian	USA[2]
1969	3941	6624	695	123		4064	6624	11382		
1970	1970	3154	357	116		2086	3154	5597		
1971	1610	3533	770	111		1721	3533	6024		
1972	609	1551	502	133		742	1551	2795		
1973	1565	1397	396	98		1663	1397	3455		
1974	462	955	573	160	757	622	1712	2907		
1975	1353	1705	29	186		1539	1705	3273		
1976	1355	974	24	160		1515	974	2513		
1977	2871	2428		151	2966	3022	5394	8416		
1978	9968	4725		177	1556	10145	6281	16426		
1979	5080	5213		186		5266	5213	10479		
1980	10017	5615		151	7561	10168	13176	23344		
1981	5658	9081		177		5835	9081	14916		
1982	4872	6286		130		5002	6286	11287		
1983	3208	4453		119		3327	4453	7780		
1984	1463	5121		124		1587	5121	6708		
1985	3484	1684		186		3670	1684	5354		
1986	3415	2201		92		3507	2201	5708		
1987	4703	1418		138		4841	1418	6259		
1988	4046[1]	1694		151		4197	1694	5891		
1989	3060	785		138	137	3198	922	4121		
1990	3340	1189		128	76	3468	1265	4732		
1991	5456	931		117	0	5573	931	6504		
1992	4058	1629		130	9	4188	1638	5826	5000	
1993	3727	424		114	106	3841	530	4371	5000	
1994	2411	24		114	1279	2525	1302	3827	3000	
1995	2065	15		69	0	2134	16	2150	2500	
1996	3663	26		52	5	3715	31	3746	4500	
1997	2749	55		60	1	2809	56	2865	3200	
1998	3371	271		102	0	3473	271	3744	3900	
1999	3681	359		49	5	3729	364	4093	3900	
2000	5402	340		29	3	5431	343	5774	5400	
2001	6774	762		39	22	6813	784	7597	6989	
2002	6488	1090		29	16	6517	1106	7623	6740	
2003	6775	1677		98	96	6874	1772	8646	6933	
2004	9745	1847		93	235	9838	2081	11919	9900	5100
2005	14484	649		49	76	14533	724	15257	15410	7590
2006	11984	313		58	275	12043	588	12630	14520	7480
2007	11890	256[3]		58	306[3]	11948	562	12510	12730	6270
2008	14781	1138[3]		33	52[3]	14814	1190	16003	14950	8050
2009	17595	2152[3]		53	55[3]	17648	2208	19855	18900	11100
2010	16578	2167		15	34	16593	2201	18794	17612	11988
2011	11232	1322		16	87	11248	1409	12656	12540	9460
2012	5034	443		30	126	5064	569	5633	9120	6880
2013	4621	344		10	91	4631	435	5066	6448	3952
2014	12936	1182		17	108	12953	1290	14243	16470	10530
2015	14631	1506		17	415	14648	1921	16148	19200	17800
2016	11935	341		8	125	11943	466	12409	21830	15170
2017	13377	214		8	81	13384	2361	13679	20500	29500
2018	12216	253		6	21	12222	2349	12496	24000	16000

[1] 1895 mt excluded because of suspected area misreporting.

[2]The USA quota pertains to the USA fishing year of May 1 to April 30 while the USA catches reported in this table pertain to the calendar year.

[3]USA landings and discards revised in 2011.

Table 2. Regulatory measures implemented for the 5Z and eastern Georges Bank (EGB) fishery management units by the United States (USA) and Canada, respectively, from 1977, when jurisdiction was extended to 200 miles for coastal states, to the present.

Year	USA	Canada
1977-82	Mesh size of 5 1/8" (140 mm), seasonal spawning closures, quotas and trip limits.	
1982-85	All catch controls eliminated, retained closed area and mesh size regulations, implemented minimum landings size (43 cm).	First 5Ze assessment in 1983.
Oct.1984	Implementation of the 'Hague' line, the boundary between Canada and the USA.	
1985	5 ½" mesh size, Areas 1 and 2 closed February-May.	
1989		Combined cod-haddock-pollock quota for 4X-5Zc.
1990		EGB adopted as management unit. For mobile gear (MG) < 65 ft. – trip limits with a 30% by-catch of haddock to a maximum of 8 trips of 35,000 lbs per trip between June 1 and Oct. 31 and minimum square mesh size 130 mm. Fixed gear required to use large hooks until June.
1991	Established overfishing definitions for haddock.	MG < 65 ft similar to 1990 but diamond mesh size increased to minimum 145 mm.
1992		Introduction of Individual Transferable Quotas (ITQ) and dockside monitoring. Total allowable catch (TAC) = 5000 mt.
1993	Area 2 closure in effect from Jan 1-June30.	Otter trawl (OT) fishery permitted to operate in Jan. and Feb. Increase in use of square mesh, minimum 130 mm. TAC = 5000 mt.
1994	Jan.: Expanded Area 2 closure to include June and increased extent of area. Area 1 closure not in effect. 500 lb trip limit. Catch data obtained from mandatory log books combined with dealer reports (replaces interview system). May: 6" mesh restriction. Dec.: Area 1,2 closed year-round.	Spawning closure extended to Jan. 1 to May 31. Fixed gear vessels must choose between 5Z or 4X for the period of June to September. Small fish protocol. Increased at sea monitoring. OT > 65 could not begin fishing until July 1. Predominantly square mesh, minimum 130 mm by end of year. TAC = 3000 mt.
1995		All OT vessels using square mesh, mimimum 130 mm. Fixed gear vessels with a history since 1990 of 25t or more for 3 years of cod, haddock, pollock, hake or cusk combined can participate in 5Z fishery. ITQ vessels require at least 2t of cod and 8t of haddock quota to fish Georges. TAC = 2500 mt. Restrictions on catching of cod and haddock under 43 cm (small fish protocol).
1996	July: Additional Days-at-Sea restrictions, trip limit raised to 1000 lbs.	Fixed gear history requirement dropped. TAC = 4500 mt.

Year	USA	Canada
1997	May: Additional scheduled Days-at-sea restrictions. September: Trip limit raised to 1000 lbs/day, maximum of 10,000 lbs/trip.	All OT vessels using square mesh, mimimum 130 mm. Vessels over 65 ft operated on enterprise allocations, otter trawlers under 65 ft on individual quotas, fixed gear vessels 45-65 ft on self-administered individual quotas and fixed gear vessels under 45 ft on community quotas administered by local boards. TAC = 3,200 mt.
1998	Sept. 1: Trip limit raised to 3000 lbs/day, maximum of 30,000 lbs/trip.	All OT vessels using square mesh, mimimum 130 mm. Fixed gear vessels 45-65 ft operated on individual quotas. TAC = 3,900 mt.
1999	May 1: Trip limit 2,000 lbs/day, max. 20,000 lbs/trip. Square mesh size increased to 6.5" (diamond is 6"). June 15: Scallop exemption fishery in Closed Area II. Nov. 5: Trip limit 5,000 lbs/day, max. 50,000 lbs/trip.	All OT vessels using square mesh, mimimum 130 mm. TAC = 3,900 mt; mandatory cod separator panel when no observer on board.
2000	October: Daily trip limit suspended to April 2001 but retained max. trip limit of 50,000 lbs/trip.	All OT vessels using square mesh, mimimum 130 mm. TAC = 5,400 mt.
2001-2002	Day and trip limit adjustments. Daily trip limit suspended July 5, 2002.	All OT vessels using square mesh, minimum 130 mm. TAC = 6,989 and 6,740 mt for 2001 and 2002 respectively.
2002-2003	30,000 – 50,000 lb/trip limit. Trip limit suspended in Oct. 2003.	All OT vessels using square mesh, minimum 130 mm. TAC = 6,933 mt for 2003.
Canada – USA Resource Sharing Agreement on Georges Bank		
2004	May 1, day and trip limits removed. Quota management introduced. (Used primarily effort based management from 1994 to 2003.) TAC[1] = 5,100 mt. Oct. 1: unit areas 561 and 562 closed to groundfish vessels. Nov. 19: Special Access Program (SAP) for haddock opened. Dec. 31: Haddock SAP closed.	All OT vessels using square mesh, minimum 130 mm. TAC = 9,900 mt.
2005	TAC[1]= 7,590 mt. Jan. 14: separator trawl required. Fishery was closed in August when cod by-catch quota reached.	All OT vessels using square mesh, minimum 130 mm. TAC = 15,410 mt; exploratory winter fishery Jan. to Feb. 18, 2005.
2006	TAC[1]= 7,480 mt; EGB area closed to USA fishery in first half of year when USA cod quota nearly reached.	All OT vessels using square mesh, minimum 130 mm. TAC = 14,520 mt; exploratory winter fishery Jan. to Feb. 6, 2006.
2007	TAC[1]=6,270 mt. June 20: EGB area closed to USA fishery due to USA cod catch nearing quota. August 9: Minimum haddock size reduced to 18 inches; October 20: EGB area opened to USA fishery.	All OT vessels using square mesh, minimum 130 mm. TAC = 12,730 mt; exploratory winter fishery Jan. to Feb. 15, 2007

Year	USA	Canada
2008	TAC[1]=8,050 mt. Minimum size reverts back to 19 inches in August. Prohibitions on yellowtail flounder fishing Jan 24 to April 30. Trawl fishery opening delayed until Aug. 1. Ruhle trawl (type of separator trawl) approved for use beginning Sept 15. Restrictions on cod catches.	All OT vessels using square mesh, minimum 130 mm. TAC = 14,950 mt; winter fishery Jan. 1 to Feb. 8, 2008.
2009	TAC[1]=11,100 mt. May 1: Interim action by NMFS set the minimum size at 18 inches. Trawl fishery opening delayed until Aug. 1.	All OT vessels using square mesh, minimum 130 mm. TAC = 18,900 mt; winter fishery Jan. 1 to Feb. 7, 2009. Industry test fishery/survey in deep water in February to assess spawning condition of haddock in deep water. Test fishery terminated after 2 trips.
2010	TAC[1]=11,988 mt May 1, 2010: Sector Management with Annual Catch Entitlements (ACEs) and accountability measures implemented (Amendment 16). Minimum haddock size limit of 18 inches retained in Amendment 16, effective May 1. All legal size fish must be retained by sector vessels. Trawl fishery opening delayed until Aug. 1.	All OT vessels using square mesh, minimum 130 mm. TAC = 17,612 mt; winter fishery Jan. 1 to Feb. 7, 2010.
2011	TAC[1]=9,460 mt Common pool fishery (very small percentage of quota) closed May 1 to July 31. On May 11 the Closed Area II Special Access Permit (SAP) modified to allow targeting of haddock from Aug. 1 to Jan 31. On Sept. 14 haddock catch cap regulation for herring midwater trawl fishery increased to 1% of the Georges Bank Annual Biological Catch (ABC).	All OT vessels using square mesh, minimum 130 mm. TAC = 12,540 mt; winter fishery Jan. 1 to Feb. 6, 2011.
2012	TAC[1]=6,880 mt Common pool fishery (very small percentage of quota) closed May 1 to July 31.	All OT vessels using square mesh, minimum 130 mm. TAC = 9,120 mt; winter fishery Jan. 1 to Feb. 4, 2012.
2013	TAC[1]=3,952 mt July: Minimum size reduced from 18” to 16”. Common pool fishery (very small percentage of quota) closed May 1 to July 31.	TAC = 6,448 mt; winter fishery Jan. 1 to Feb. 4, 2013. All OT vessels using square mesh, minimum 130 mm.
2014	TAC[1] = 10,530 mt Common pool fishery (very small percentage of quota) closed May 1 to July 31.	TAC = 16,470 mt; winter fishery Jan. 1 to Feb. 3, 2014. Experimental use of 145 mm diamond mesh in winter fishery. Starting in June, 145 mm diamond use continued and experimental use of 125 mm square. Continued use of 130 mm square.

Year	USA	Canada
2015	TAC[1] = 17,800 mt Common pool fishery (very small percentage of quota) closed May 1 to July 31. No trip allocated to CAII Yellowtail Flounder/Haddock SAP for FY 2015 for the purposes of targeting yellowtail flounder. Vessels may fish in the SAP to catch haddock when using a haddock separator trawl, a Ruhle trawl, or hook gear. Vessels may not fish in the SAP using flounder nets. The SAP closes on 1/31/2016. Eastern US/CA area opens on May 1 for sectors vessels fishing with trawl gear; common pool vessel can fish in area starting on May 1, must use a haddock separator trawl, a Ruhle trawl, or a flounder trawl in the area	TAC = 19,200 mt; winter fishery Jan. 1 to Feb. 1, 2015. All OT vessels using minimum of 125 mm square or 145 mm diamond (only for winter fishery) mesh size with a mandatory horizontal separator panel. Small fish protocol not enforced for the winter fishery. Small fish protocol enforced using a minimum size of 38 cm for all other months. Observer coverage for fixed gear will be 100% for June 1- July 14 and 50% for July 15- Aug 31. Observer coverage for mobile gear will be 100% for the winter fishery, 100% for June and July, 50% for August and 33% for September to December.
2016	TAC[1] = 15,170 mt Common pool fishery (very small percentage of quota) closed May 1 to July 31. Beginning October 27, 2016, the separator panel in a haddock separator trawl will be required to be a contrasting color to the portions of the net that it separates in order to make the panel highly visible Starting on May 1, 2016, common pool vessels using trawl gear may fish in the Eastern U.S/Canada Area. Common pool vessels must use a haddock separator trawl, a Ruhle trawl, or a flounder trawl in this area.	TAC = 21,830 mt; winter fishery Jan. 1 to Feb. 7, 2016. All OT vessels using square mesh, minimum of 125 mm square with a mandatory horizontal separator panel. Small fish protocol enforced using a minimum size of 38 cm for haddock. Observer coverage for fixed gear will be 100% for June 1- July14 and 50% for July 15- Aug 31. Observer coverage for mobile gear will be 80% for the winter fishery, 100% from June-August and 50% for September to December.

Year	USA	Canada
2017	EGB haddock quota=29,500	TAC = 20,500 mt; winter fishery Jan. 1 to Feb. ?, 2017. All OT vessels using square mesh, minimum of 125 mm square with a mandatory horizontal separator panel. Small fish protocol enforced using a minimum size of 38 cm for haddock was not enforced. Observer coverage for fixed gear will be 100% for June 1- July14 and 50% for July 15- Aug 31. Observer coverage for mobile gear will be 50% for January, 100% for February, 100% from June-July and 50% for August to December.
2018	EGB haddock quota=15,6000	TAC = 24,000 mt; winter fishery Jan. 1 to Feb. 4, 2018. All OT vessels using square mesh, minimum of 125 mm square with a mandatory horizontal separator panel. Small fish protocol of using a minimum size of 38 cm for haddock was not enforced. May test Fishery (100% coverage) Observer coverage for fixed gear (excludes GN) will be 100% for June 1- July14 and 50% for July 15- Aug 31. Observer coverage for mobile gear will be 50% for the winter fishery, 100% from June-July and 50% for August to December.

[1]For fishing year from May 1 to April 30

Table 3. Canadian landings (mt) of haddock from eastern Georges Bank during 1969-2018 by gear category and tonnage class.

		Stern Trawl					
Year	Side trawl	TC1-3	TC4+	Longline	Scal. Dredge	Misc[2]	Total
1969	777	1	3127	23	15	0	3943
1970	575	2	1312	78	2	1	1970
1971	501	0	955	151	3	0	1610
1972	148	1	262	195	1	2	609
1973	633	0	826	105	0	1	1565
1974	27	6	340	88	1	0	462
1975	222	1	1023	107	0	0	1353
1976	217	3	964	156	0	15	1355
1977	370	335	2043	94	1	28	2871
1978	2456	1049	5990	169	17	287	9968
1979	1622	994	2191	271	2	0	5080
1980	1444	713	7204	587	4	65	10017
1981	478	1078	3081	1019	1	1	5658
1982	115	517	3528	712	0	0	4872
1983	106	1046	1237	815	1	3	3208
1984	5	450	170	835	2	1	1463
1985	72	2242	503	626	2	39	3484
1986	51	2207	527	594	4	32	3415
1987	48	2231	1290	1046	38	50	4703
1988[1]	72	2599	584	695	16	80	4046
1989	0	1064	912	977	12	95	3060
1990	0	1824	587	853	7	69	3340
1991	0	3258	770	1309	8	111	5456
1992	0	1882	701	1384	4	87	4058
1993	0	1723	766	1143	2	93	3727
1994	0	1406	191	714	9	91	2411
1995	0	1419	228	390	7	21	2065
1996	1	2253	436	947	0	26	3663
1997	0	1804	187	722	0	36	2749
1998	0	2253	169	921	0	28	3371
1999	0	2442	319	887	0	32	3680
2000	0	3670	476	1186	0	70	5402
2001	0	4355	757	1633	0	29	6774
2002	0	4298	657	1521	0	12	6488
2003	0	4985	0	1776	0	14	6775
2004	0	7676	67	2000	0	1	9745
2005	0	11789	326	2368	0	1	14484
2006	0	9487	601	1896	0	1	11984
2007	0	9875	159	1854	0	1	11890
2008	0	12615	0	2164	0	2	14781
2009	0	15380	27	2185	0	3	17595
2010	0	13439	661	2476	0	2	16578
2011	0	9552	113	1566	0	1	11232
2012	0	4172	29	832	0	1	5034
2013	0	4307	42	272	0	1	4621
2014	0	12628	79	228	0	1	12936
2015	0	13981	367	282	0	1	14631
2016	0	11838	0	96	0	1	11935
2017	0	13323	0	53	0	1	13377
2018	0	11970	212	34	0	0	12216

[1]Catches in 1988 of 26t, 776t, 1091t and 2t for side otter trawlers and stern otter trawlers tonnage classes 2, 3 and 5 respectively were excluded because of suspected area misreporting.
[2]Miscellaneous gears include gillnet, handline and other unknown gears.

Table 4. Monthly landings (mt) of haddock by Canada from eastern Georges Bank during 1969-2018.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1969	105	74	6	291	588	691	559	580	551	360	102	34	3941
1970	2	105	0	1	574	345	103	456	242	103	26	12	1970
1971	0	9	1	0	400	132	283	278	97	246	141	21	1610
1972	0	119	2	0	2	111	84	116	98	68	7	2	609
1973	4	10	0	0	0	184	198	572	339	232	22	4	1565
1974	19	0	1	0	0	58	63	53	96	61	92	19	462
1975	4	14	0	0	0	166	256	482	100	166	118	45	1353
1976	0	7	62	68	60	587	152	190	186	26	9	7	1355
1977	102	177	7	0	23	519	1059	835	13	59	56	22	2871
1978	104	932	44	22	21	319	405	85	642	5433	1962	0	9968
1979	123	898	400	175	69	1393	885	396	406	261	53	22	5080
1980	38	134	14	29	223	2956	2300	965	1411	1668	104	176	10017
1981	38	481	568	4	254	1357	1241	726	292	82	378	239	5658
1982	129	309	1	11	46	1060	769	682	585	837	398	44	4872
1983	32	67	29	47	60	1288	387	483	526	195	88	6	3208
1984	3	5	81	88	73	433	219	254	211	71	25	0	1463
1985	1	11	33	99	26	354	392	1103	718	594	61	93	3484
1986	11	28	79	99	40	1339	1059	369	233	139	12	8	3415
1987	24	26	138	70	12	1762	1383	665	405	107	97	14	4703
1988[1]	39	123	67	79	15	1816	1360	315	130	65	13	24	4046
1989	33	94	48	7	20	1398	356	566	141	272	108	18	3060
1990	35	14	50	0	7	1178	668	678	469	199	18	22	3340
1991	144	166	49	26	21	1938	1004	705	566	576	123	137	5456
1992	118	205	97	152	36	1381	619	414	398	401	209	28	4058
1993	468	690	96	78	25	723	505	329	202	198	230	183	3727
1994	3	3	1	2	0	398	693	373	375	220	211	133	2411
1995	5	1	1	1	0	762	327	290	281	109	197	93	2065
1996	0	0	0	0	0	1067	672	706	359	278	191	391	3663
1997	0	0	0	0	0	328	751	772	426	190	116	166	2749
1998	0	0	0	0	0	687	420	580	707	542	164	271	3371
1999	37	0	0	0	0	898	975	562	573	295	269	70	3681
2000	1	0	0	0	0	1368	1175	1026	848	658	175	150	5402
2001	0	0	0	0	0	971	1335	930	1267	1075	647	548	6774
2002	0	0	0	0	0	572	1703	983	1364	820	593	452	6488
2003	0	0	0	0	0	840	1767	1290	930	952	676	320	6775
2004	0	0	0	0	0	1547	2268	2109	1753	1275	556	236	9745
2005	1025	1182	0	0	13	1423	3004	3820	2199	1198	357	266	14484
2006	1176	381	0	0	0	1093	2433	2668	2211	1149	558	316	11984
2007	1100	454	0	0	0	1432	3034	2510	1916	991	231	222	11890
2008	1867	1604	0	0	0	1640	2539	2446	2382	1314	645	343	14781
2009	2977	947	0	0	0	2217	1996	2889	2479	2191	1239	659	17595
2010	2391	574	0	0	0	1861	2893	3809	2257	1572	692	530	16578
2011	1954	466	0	0	0	941	2074	2554	1751	931	299	262	11232
2012	692	634	0	0	0	583	949	1077	490	419	61	128	5034
2013	843	185	0	0	0	193	50	350	939	1004	488	569	4621
2014	1555	578	0	0	0	1250	1640	1820	1814	1741	1060	1477	12936
2015	1731	346	0	0	0	1417	2267	2762	2018	1764	1349	976	14631
2016	1816	1067	0	0	0	806	1913	1904	1111	1906	590	821	11935
2017	2623	720	0	0	0	1191	1854	1748	1581	1292	1143	1224	13377
2018	1605	646	0	0	338	1319	1557	1359	1221	801	849	2520	12216

[1] Catches in 1988 of 3t, 1846t and 46t for Jan., Feb., and Mar., respectively for otter trawlers were excluded because of suspected area misreporting.

Table 5. Haddock discards from the Canadian scallop fishery on Georges Bank for 2018 calculated using a 3-month moving window to estimate discard rates. The discard rates for January and December are calculated by including observed trips from Dec. 2018 and Jan. 2019, respectively. Effort hours are in hours x meters.

Year	Month	Prorated Discards	Observed Effort (hrs x m)	Discard Rate (kg/hr x m)	Fleet Effort (hrs x m)	Discards (mt)	Cumulative Annual Discards (mt)
2018	Jan	182	930	0.084	2767	0.231	0.231
	Feb	182	930	0.082	10190	0.833	1.064
	Mar	290	6137	0.053	14923	0.795	1.859
	Apr	42	2583	0.033	16688	0.556	2.415
	May	29	2123	0.017	23607	0.401	2.816
	Jun	25	970	0.031	24819	0.771	3.587
	Jul	149	3444	0.026	23648	0.618	4.205
	Aug	60	4540	0.021	16695	0.344	4.549
	Sep	67	5440	0.017	12454	0.206	4.755
	Oct	74	2215	0.021	6795	0.141	4.896
	Nov	48	1453	0.033	4354	0.144	5.040
	Dec	48	1453	0.033	1127	0.037	5.077

Table 6. Monthly landings (mt) of haddock by the United States from eastern Georges Bank during 1969-2018. An allocation algorithm was applied to landings from 1994 to 2018 to determine area fished (Wigley et al. 2008a).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1969	525	559	976	1826	670	810	204	219	249	226	203	157	6624
1970	169	219	242	375	608	374	324	333	179	219	61	50	3154
1971	155	361	436	483	668	503	338	152	147	165	58	68	3533
1972	150	196	91	90	239	261	97	164	84	63	52	64	1551
1973	90	111	77	85	139	365	217	196	37	3	22	55	1397
1974	135	70	47	70	122	160	165	43	27	6	19	91	955
1975	152	123	32	116	388	489	138	95	57	24	52	39	1705
1976	116	147	84	106	323	162	7	6	5	2	3	13	974
1977	75	211	121	154	374	372	434	191	73	52	146	226	2428
1978	336	437	263	584	752	750	467	221	245	426	194	49	4725
1979	274	329	352	548	766	816	588	659	224	202	282	172	5213
1980	632	1063	742	784	711	461	324	254	221	91	110	222	5615
1981	551	1852	634	628	882	1327	1233	873	321	284	242	255	9081
1982	425	755	502	348	719	1805	757	145	201	216	276	138	6286
1983	492	931	272	181	310	1145	231	178	187	110	227	190	4453
1984	540	961	366	281	627	1047	370	303	250	196	92	89	5121
1985	165	190	254	300	352	206	60	47	1	24	41	43	1683
1986	184	396	334	479	496	221	31	6	12	6	6	29	2201
1987	225	52	43	307	233	342	67	30	24	4	23	68	1418
1988	196	152	207	245	366	316	30	19	6	1	45	110	1694
1989	114	56	47	164	161	145	15	8	1	5	25	46	785
1990	148	21	155	274	214	306	23	3	5	5	16	19	1189
1991	105	28	76	133	89	434	1	20	6	0	19	19	931
1992	253	81	51	149	353	669	20	20	17	3	2	12	1629
1993	15	12	16	55	88	209	6	3	3	7	2	8	424
1994	0	1	1	3	1	1	12	1	0	1	1	2	24
1995	1	1	3	4	2	3	1	0	0	0	1	0	15
1996	2	1	2	3	7	3	3	2	1	1	1	1	26
1997	5	4	3	4	11	6	2	1	9	4	2	6	55
1998	5	19	23	29	31	50	21	17	39	22	1	15	271
1999	35	15	30	52	71	62	23	18	28	0	0	22	359
2000	6	13	89	48	42	22	21	15	24	2	17	42	340
2001	42	9	228	146	81	97	51	12	8	38	21	31	762
2002	92	105	91	150	272	175	66	46	17	42	11	24	1090
2003	94	24	86	506	310	319	57	17	4	51	40	169	1677
2004	97	21	174	725	101	349	256	26	57	5	5	31	1847
2005[1]	2	0	45	34	210	158	103	93	0	0	1	2	649
2006[1]	1	0	0	23	192	87	0	7	0	0	1	3	313
2007[1]	1	0	5	71	43	60	3	0	0	25	47	0	256
2008[1]	0	0	6	26	31	80	47	92	65	153	98	539	1138
2009	13	4	41	677	30	109	38	458	140	31	195	418	2152
2010	130	13	281	503	100	76	16	367	193	118	224	147	2167
2011	75	70	110	341	165	150	76	123	40	34	43	93	1322
2012	50	10	30	112	113	48	17	4	20	18	5	17	443
2013	23	4	9	28	11	9	29	40	29	34	43	84	344
2014	21	25	169	104	110	300	20	28	70	59	66	208	1182
2015	105	91	366	92	115	147	273	114	98	17	14	74	1506
2016	28	37	18	59	37	90	32	10	14	4	4	7	340
2017	7	28	35	29	13	9	11	1	27	20	11	22	214
2018	7	63	11	13	14	16	12	4	25	4	2	83	253

[1]Restrictions placed on USA fishery in eastern Georges Bank due to bycatch limitations.

Table 7. United States landings (mt) of haddock from eastern Georges Bank during 1969-2018 by gear category and tonnage class. An allocation algorithm was applied to landings from 1994 to 2018 to determine area fished (Wigley et al. 2008a).

Year	Otter Trawl		Other	Total
	3	4		
1969	3013	3610	0	6624
1970	1602	1551	0	3154
1971	1760	1768	0	3533
1972	861	690	0	1551
1973	638	759	0	1397
1974	443	512	0	955
1975	1025	679	0	1705
1976	671	303	0	974
1977	1724	703	0	2428
1978	3140	1582	3	4725
1979	3285	1927	1	5213
1980	2654	2955	4	5615
1981	3601	5433	15	9081
1982	2589	3660	37	6286
1983	1162	3276	15	4453
1984	1855	3261	5	5121
1985	857	823	4	1683
1986	993	1207	1	2201
1987	766	651	1	1418
1988	920	768	6	1694
1989	359	419	6	785
1990	488	697	4	1189
1991	404	527	0	931
1992	650	979	0	1629
1993	153	272	0	424
1994	13	11	0	24
1995	4	11	0	15
1996	12	14	0	26
1997	39	15	1	55
1998	123	147	1	271
1999	126	229	4	359
2000	107	233	0	340
2001	248	513	1	762
2002	462	626	2	1090
2003	798	879	0	1677
2004	676	1169	2	1847
2005	255	359	35	649
2006	159	110	44	313
2007	139	101	16	256
2008	284	745	108	1138
2009	632	1395	125	2152
2010	472	1532	162	2167
2011	314	954	53	1322
2012	88	350	5	443
2013	50	281	13	344
2014	278	908	1	1182
2015	277	1229	0.2	1507
2016	54	285	0.7	341
2017	50	164	0.9	214
2018	19	231.8	2.2	253

Table 8. Inter- and intra-reader testing for Georges Bank haddock ageing for the 2016 Canadian and USA fisheries and 2016/2017 DFO/NMFS surveys. (SJS=S. Sutherland (National Marine Fisheries Service, NMFS) and DK=D. Knox (Canadian Department of Fisheries and Oceans, DFO), CV=coefficient of variation).

Sample Source	Test Type	Date Completed	Age Reader	Sample Size	CV (%)	Agreement (%)
DFO/NMFS Exchange:						
2018 Can. Commercial (Q1,2,3,4)	Exchange	Spring 2019	SJS vs DK	172	0.83	94.8
2019 DFO Survey	Exchange	Spring 2019	SJS vs DK	61	1.17	91.8
2018 NMFS Autumn Survey	Exchange	Spring 2019	SJS vs DK	154	2.42	89.0
2018 US Commercial (Q1-2)	Exchange	Spring 2019	SJS vs DK	117	1.53	90.6
2018 US Commercial (Q1-2) and Fall 2018 survey	Exchange	Spring 2019	SJS vs DK	245	1.28	91.4
NMFS testing:						
2018 NMFS Autumn Survey	Precision	Feb 2019	SJS	100	1.13	99.0
2018 US Commercial (Q4)	Precision	May 2019	SJS	97	0.00	100.0
2018 US Commercial (Q3)	Precision	Mar 2019	SJS	100	0.08	99.0
2018 US Commercial (Q2)	Precision	Nov 2018	SJS	99	0.38	97.0
2018 US Commercial (Q1)	Precision	Sep 2018	SJS	100	0.11	99.0
Haddock Reference Collection	Accuracy	Jul 2018	SJS	57	2.82	89.5
DFO testing:						
2018 Canadian Commercial (Q3)	Precision	Feb 2019	DK	87	2.06	88.5
2018 Canadian Commercial (Q2)	Precision	Feb 2019	DK	84	0.31	97.6
2018 Canadian Commercial (Q1)	Precision	Feb 2019	DK	88	1.05	93.2
2018 Canadian Commercial (Q4)	Precision	Feb 2019	DK	95	0.96	91.6

Table 9. Haddock age and length samples for landings from the Canadian groundfish fishery and for discards from the scallop dredge fishery in 2018 from eastern Georges Bank. (OTB= Otter Trawl Bottom, LL= Long Line, GN= Gill Net, DR =Scallop Dredge).

Qtr.	Gear	Month	Landings (kg)	Length Frequency Samples				Ages[3]
				At Sea		Port		
				Trips	Measured	Samples	Measured	
1	OTB	Jan	1,604,915	27	24,209	12	2,824	DFO Survey = 62 Port = 241
		Feb	646,055	8	8,633	4	930	At Sea = 0
	DR[1]		1,859	4	249			Total =303[4]
2	OTB[8]	June	1,656,794	61	82,158	14	3,279	Port = 210 At Sea = 2
	GN[2]	June	26.129			1	12	Total = 212[5]
	LL	June	2					
	DR[1]		1,727	5	60			
3	OTB	July	1,553,866	68	107,193			Port = 201
		Aug	1,346,659	39	58,783	6	1,457	At Sea = 6
		Sept	1,215,928	29	37,933	18	4,313	Total = 206[6]
	LL	July	3,504	1	703			
		Aug	12,593	2	1,866	1	238	
		Sept	5,128	2	1,101	2	460	
	GN[2]	July	27.215					
		Aug	144.788			1	25	
		Sept	232.422					
	DR[1]		1,168	7	115			
4	OTB	Oct	790,828	22	23,976	9	2,205	
		Nov	846,407	18	24,074	6	1,477	Port = 323
		Dec	2,520,341	30	36,467	14	3,390	At Sea = 0
	LL	Oct	10,318	2	637	5	1222	Total =323[7]
		Nov	2,364			2	397	
	GN2	Oct	45					
	DR[1]		380	6	89			
Totals			12,221,312	331	408,246	95	22,229	1,044

[1]Scallop fishery samples were combined by quarter.

[2]Gillnet added in at quarter level.

[3]When otoliths were not available for a length grouping, ages were inferred.

[4]Ages for 9 length groupings were inferred and are not included in the total.

[5]Ages for 10 length groupings were inferred and are not included in the total.

[6]Ages for 10 length groupings were inferred and are not included in the total.

[7]Ages for10 length groupings were inferred and are not included in the total.

[8]May OTB data was combined with June.

Table 10. Components of the 2018 catch at age in numbers of haddock from eastern Georges Bank by nation and quarter or half year for landings and discards.

	Age Group								
	0	1	2	3	4	5	6	7	8
Canadian Landings									
2018 Q1	0	0	3978	8284	10585	2071925	75300	15239	235514
2018 Q2	0	10186	74806	74981	43609	1698422	29923	23083	77276
2018 Q3	2916	95920	434731	343508	454483	3850216	43010	142379	25752
2018 Q4	875	18645	315897	204700	139967	3830505	92857	20434	199385
Year total	3792	124751	829411	631473	648644	11451068	241089	201135	537928
United States Landings1									
2018 H1									
2018 H2									
Year total	0	0	401	1643	2817	254571	6310	4016	13277
Canadian Discards									
2018 Q1	0	34	72	19	24	2164	35	6	100
2018 Q2	0	234	703	353	68	1388	43	19	102
2018 Q3	241	704	308	102	115	958	6	31	0
2018 Q4	750	97	168	34	5	303	3	0	9
Year total	990	1069	1251	508	212	4813	86	56	211
United States Discards1									
2018 H1									
2018 H2									
Year total	0	1172.65	18199.96	4300.47	710.67	23391.69	58.76	218.41	173.68
Total Catch									
2018	4782	126993	849263	637925	652383	11733844	247544	205425	551590

[1]United States landings and discards at age were calculated by half year, however, landings and discards occurred in other quarters.

Table 11. United States landings and discards of Eastern Georges Bank haddock in 2018 by quarter and market category and National Marine Fisheries Service sampling for lengths and ages. Note that summaries by market category are not possible for discards as the fish are discarded at sea and are not given a market category. Numbers in parentheses are additional lengths and ages from US commercial statistical areas 522 and 525 used to augment samples from statistical areas 561 and 562.

Market Category	Large	Scrod	Snapper	Unclassified	Total
			Landings (mt)		
Quarter 1	5	40	32	3	80
Quarter 2	1	17	24	2	43
Quarter 3	1	30	10	0.0	41
Quarter 4	1	43	45	0.1	89
Total	7	129	112	5	253
			Number Lengths measured		
Quarter 1	604	463	506		1573
Quarter 2	247	351	302		900
Quarter 3	100	403	301		804
Quarter 4		250	250		500
Total	951	1467	1359	0	3777
			Number aged		
Quarter 1	197	123	159		479
Quarter 2	120	173	150		443
Quarter 3		138	124		262
Quarter 4		93	98		191
Total	317	527	531	0	1375
			Discards (mt)		
Quarter 1	N/A	N/A		N/A	
Quarter 2	N/A	N/A		N/A	6
Quarter 3	N/A	N/A		N/A	
Quarter 4	N/A	N/A		N/A	16
Total	N/A	N/A		N/A	21

Table 12. Total annual commercial catch at age numbers (000's) of haddock from eastern Georges Bank during 1969-2018. Estimates of discards are included.

Year	Age Group										
	0	1	2	3	4	5	6	7	8	9+	0+
1969	6	0	18	1451	262	334	2909	831	91	283	6184
1970	0	66	84	7	351	151	130	1153	372	193	2508
1971	43	0	1201	251	31	252	159	161	774	412	3284
1972	118	346	1	390	72	21	94	39	16	451	1547
1973	7	1119	1758	6	364	38	10	39	8	169	3517
1974	9	37	2257	276	0	32	3	0	29	63	2706
1975	553	18	279	1504	216	5	36	2	2	31	2645
1976	1	402	157	173	834	135	0	19	0	18	1739
1977	0	1	8028	66	182	307	164	0	15	15	8778
1978	110	6	291	9956	164	173	306	80	10	9	11105
1979	12	212	17	208	4307	364	201	217	43	14	5597
1980	31	32	17701	343	302	2425	193	130	52	12	21220
1981	6	55	693	6773	400	497	1243	119	33	7	9826
1982	1	2	731	1057	2848	205	379	730	62	65	6080
1983	75	11	149	663	554	1653	208	104	409	35	3860
1984	1	72	100	259	350	270	1131	186	166	318	2854
1985	353	9	2147	386	182	199	128	381	53	117	3954
1986	0	89	39	2586	175	143	124	119	174	42	3492
1987	19	0	2081	131	1536	100	58	83	70	111	4190
1988	1	53	53	2199	124	894	111	39	46	100	3619
1989	8	2	1274	86	776	143	347	34	23	47	2740
1990	18	31	8	1346	133	770	73	168	43	43	2633
1991	35	22	466	91	2076	89	391	72	146	61	3450
1992	151	49	249	324	129	1466	90	320	26	91	2895
1993	4	80	283	357	291	91	667	41	157	76	2049
1994	13	36	423	870	186	73	101	190	89	48	2028
1995	4	8	79	534	414	53	25	3	52	16	1188
1996	6	4	32	489	864	419	60	18	3	72	1967
1997	1	29	94	73	535	484	195	13	8	34	1466
1998	19	18	195	292	260	541	448	114	12	35	1932
1999	2	27	44	752	319	249	347	256	99	25	2119
2000	1	6	320	449	1268	264	213	217	186	67	2991
2001	0	22	65	1733	533	847	263	204	232	204	4105
2002	0	1	333	218	1891	379	671	115	110	289	4008
2003	486	7	10	1831	288	1487	426	479	110	234	5358
2004	4	332	26	75	3646	605	1498	519	421	263	7388
2005	0	14	241	29	224	6891	526	823	128	157	9034
2006	1	20	16	2515	44	289	4544	234	551	154	8367
2007	0	2	39	181	7345	148	168	1431	136	187	9637
2008	0	4	30	273	268	9721	102	85	708	95	11288
2009	3	17	125	192	741	261	11222	73	58	379	13074
2010	15	31	56	391	314	844	382	9849	50	210	12142
2011	1	243	107	181	515	228	676	108	6233	75	8366
2012	3	75	638	174	126	351	174	379	138	2055	4112
2013	162	24	197	3458	233	108	233	72	106	613	5206
2014	5	939	340	1096	12514	468	95	71	60	255	15843
2015	8	27	2311	809	2658	10129	191	51	23	202	16408
2016	3	8	108	4121	558	868	5439	337	9	97	11547
2017	1	20	131	314	12554	270	334	2275	32	21	15953
2018	5	127	849	638	652	11734	248	205	552	13	15023

Table 13. Average weight at age (kg) of haddock from the combined Canadian and USA commercial groundfish fishery landings on eastern Georges Bank during 1969-2018. For 1969-1973 only USA fishery sampling for lengths and ages was available; for 1974-1984 a mix of USA and Canadian samples were used. For missing age 1 weights (**bold),** an average of 0.600 kg was used. Missing weights for older haddock were extrapolated within year class.

Year	Age Group								
	1	2	3	4	5	6	7	8	9+
1969	**0.600**	0.763	1.282	1.531	1.649	1.836	2.298	2.879	3.354
1970	0.721	1.067	0.812	1.653	1.886	2.124	2.199	2.841	3.150
1971	**0.600**	0.928	1.059	1.272	2.011	2.255	2.262	2.613	3.047
1972	0.759	**0.983**	1.562	1.750	2.147	2.505	2.411	2.514	2.989
1973	0.683	1.002	1.367	1.804	2.202	1.631	2.885	3.295	3.192
1974	**0.600**	1.052	1.491	**1.683**	2.017	3.760	**2.583**	3.145	3.735
1975	**0.600**	0.877	1.557	2.085	1.999	2.429	4.107	3.534	3.429
1976	0.610	0.984	1.292	1.853	2.417	**2.247**	2.774	**4.484**	3.807
1977	**0.600**	0.970	1.442	1.810	2.336	2.807	**2.494**	3.094	4.150
1978	0.619	1.158	1.432	2.067	2.602	2.926	2.971	2.741	4.334
1979	**0.600**	0.966	1.288	1.823	2.214	2.791	3.214	3.206	4.041
1980	0.405	0.889	1.035	1.703	2.094	2.606	3.535	3.584	3.109
1981	**0.600**	0.888	1.270	1.650	2.310	2.627	3.545	4.086	4.455
1982	**0.600**	0.964	1.370	1.787	2.332	2.550	2.957	3.528	3.426
1983	**0.600**	1.028	1.327	1.755	2.132	2.475	2.895	3.125	4.010
1984	**0.600**	0.872	1.338	1.798	2.151	2.577	2.842	3.119	3.411
1985	**0.600**	0.950	1.230	1.915	2.227	2.702	2.872	3.180	3.696
1986	0.452	0.981	1.352	1.866	2.367	2.712	2.969	3.570	3.908
1987	**0.600**	0.833	1.431	1.984	2.148	2.594	2.953	3.646	3.880
1988	0.421	0.974	1.305	1.708	2.042	2.350	3.011	3.305	3.693
1989	**0.600**	0.868	1.450	1.777	2.183	2.522	3.012	3.411	3.751
1990	0.639	0.999	1.419	1.787	2.141	2.509	2.807	3.002	3.668
1991	0.581	1.197	1.241	1.802	2.086	2.597	2.913	3.010	3.362
1992	0.538	1.163	1.622	1.654	2.171	2.491	2.988	3.388	3.524
1993	0.659	1.160	1.724	2.181	2.047	2.623	2.386	3.112	3.486
1994	0.405	1.141	1.669	2.244	2.662	2.454	2.837	3.253	3.449
1995	0.797	1.055	1.511	2.032	2.549	2.762	2.978	3.012	3.535
1996	0.576	1.026	1.441	1.796	2.296	2.490	3.331	2.220	3.620
1997	0.685	1.216	1.336	1.747	2.121	2.476	3.034	3.367	3.927
1998	0.568	1.131	1.573	1.697	1.983	2.312	2.864	3.395	3.657
1999	0.678	1.094	1.568	1.907	1.893	2.216	2.577	2.816	3.743
2000	0.664	1.104	1.470	1.917	2.242	2.132	2.518	2.829	3.170
2001	0.394	1.102	1.461	1.742	2.100	2.364	2.187	2.554	3.114
2002	0.405	1.010	1.400	1.739	1.905	2.352	2.742	2.550	2.895
2003	0.475	0.758	1.377	1.577	1.845	1.913	2.389	2.859	2.909
2004	0.482	0.589	1.100	1.502	1.610	1.872	1.993	2.307	2.558
2005	0.454	0.697	0.988	1.429	1.678	1.842	2.005	2.055	2.419
2006	0.335	0.514	0.977	0.977	1.598	1.776	1.861	2.021	2.216
2007	0.464	0.584	0.990	1.187	1.385	1.658	1.833	1.671	2.122
2008	0.458	0.791	1.003	1.230	1.390	1.610	1.572	1.912	2.434
2009	0.551	0.864	0.987	1.255	1.422	1.531	1.740	2.245	2.248
2010	0.436	0.739	1.063	1.231	1.338	1.503	1.594	1.728	2.220
2011	0.346	1.027	1.024	1.217	1.319	1.360	1.556	1.630	2.125
2012	0.256	0.646	1.027	1.222	1.310	1.437	1.477	1.559	1.705
2013	0.323	0.660	0.848	1.205	1.254	1.301	1.469	1.547	1.692
2014	0.272	0.546	0.760	0.942	1.165	1.267	1.514	1.443	1.692
2015	0.161	0.513	0.790	1.062	1.138	1.295	1.520	1.842	1.850
2016	0.314	0.742	0.754	1.073	1.209	1.282	1.494	1.959	1.781
2017	0.297	0.483	0.766	0.757	1.177	1.424	1.327	1.229	2.079
2018	0.298	0.453	0.665	0.769	0.840	1.085	1.234	1.386	1.446
Low	0.161	0.453	0.665	0.757	0.840	1.085	1.234	1.229	1.446
High	0.797	1.216	1.724	2.244	2.662	3.760	4.107	4.086	4.455
Median	0.464	0.964	1.316	1.739	2.044	2.352	2.660	2.859	3.358
Average	0.491	0.898	1.245	1.601	1.907	2.178	2.468	2.700	3.104
2016-18 Avg	0.303	0.559	0.728	0.866	1.075	1.264	1.351	1.525	1.769

Table 14. Average lengths at age (cm) of haddock from the combined Canadian and USA commercial groundfish fishery landings on eastern Georges Bank during 1969-2018. Highlighted cells follow the large year classes.

Year	Age Group									
	0	1	2	3	4	5	6	7	8	9+
1969			42.5	50.2	53.4	54.9	56.6	61.2	66.7	70.6
1970		40.1	47.0	43.4	54.9	57.4	60.0	60.4	66.4	68.6
1971			44.7	46.6	50.0	58.4	61.3	61.9	64.2	68.1
1972		40.6		53.3	55.4	59.4	63.3	63.5	62.0	67.3
1973		39.2	45.2	52.5	55.4	60.3	54.7	65.8	69.2	69.0
1974			45.6	52.1		59.6	72.5		69.2	73.3
1975			42.5	52.8	59.7	59.8	63.7	75.8	72.7	71.7
1976		37.4	44.6	49.5	57.1	62.3		65.8		72.6
1977			44.1	51.2	55.9	61.1	65.4		68.8	76.7
1978		37.6	46.4	50.5	57.3	63.5	65.8	65.9	66.1	76.1
1979			44.3	49.0	55.3	59.3	64.7	68.4	67.8	74.0
1980		32.5	42.5	44.9	54.3	58.6	63.1	71.6	71.0	67.0
1981			42.9	48.8	53.2	60.4	63.4	70.7	75.5	76.3
1982			44.4	50.1	55.1	60.6	63.1	66.3	71.5	70.9
1983			45.0	49.2	54.4	58.8	62.0	65.4	67.6	73.4
1984			44.1	50.5	55.8	59.8	63.6	66.5	68.2	70.3
1985			43.3	47.5	55.8	59.2	63.6	65.9	67.9	70.8
1986		33.7	43.8	49.6	55.1	60.1	63.7	66.3	70.8	72.0
1987			41.4	50.3	56.5	58.0	62.2	66.3	71.3	71.9
1988		32.8	43.7	48.6	53.7	58.0	60.6	67.1	68.5	69.3
1989			41.9	50.0	54.1	59.2	61.9	66.6	70.3	70.0
1990		37.9	44.2	50.0	55.4	58.2	63.4	63.7	64.9	69.4
1991		36.2	47.0	48.3	54.2	58.3	62.2	66.7	64.9	66.6
1992		35.7	46.4	52.7	53.9	58.2	63.2	65.5	71.6	67.8
1993		38.3	46.4	53.3	58.0	57.0	61.7	62.4	65.2	67.9
1994		32.5	46.1	52.6	58.1	61.6	59.7	62.9	65.6	67.4
1995		40.2	45.0	50.9	56.3	60.8	62.5	64.1	64.2	67.9
1996		36.4	44.6	50.0	53.9	58.6	60.1	66.7	58.1	68.4
1997		38.7	47.2	48.8	53.4	57.0	60.2	64.4	66.9	70.5
1998		36.5	46.1	51.6	52.8	55.7	58.7	63.3	67.2	68.8
1999		38.7	45.6	51.5	55.1	54.9	57.9	61.0	63.0	69.3
2000		38.5	45.7	50.4	55.2	58.3	57.1	60.4	62.9	65.3
2001		32.1	45.5	50.4	53.5	56.9	59.2	57.6	60.3	64.5
2002		32.5	44.3	49.6	53.5	55.2	59.2	62.6	60.7	63.5
2003		34.2	40.2	49.3	51.8	54.7	55.3	59.7	63.8	64.0
2004		34.5	36.9	45.6	50.8	52.3	54.7	55.9	58.3	60.1
2005		33.7	38.8	44.1	49.9	52.8	54.5	56.1	56.5	59.2
2006		30.4	35.2	43.7	43.9	51.9	53.8	54.7	56.1	57.8
2007		34.0	36.7	43.9	46.8	49.3	52.5	54.3	52.3	57.1
2008		33.3	40.7	44.3	47.6	49.6	52.0	51.3	55.0	59.6
2009		36.0	42.0	44.4	47.9	49.7	51.4	52.9	57.7	57.8
2010		33.1	39.9	45.1	47.6	49.1	50.9	52.1	53.3	58.4
2011		30.7	44.0	44.7	47.4	48.9	49.5	51.8	52.5	57.8
2012		27.7	37.9	44.8	47.4	48.6	50.2	50.7	51.5	53.2
2013	22.8	30.0	38.2	41.8	47.2	47.8	48.4	50.5	51.4	53.0
2014	20.5	28.1	36.1	40.3	43.3	46.7	48.1	51.2	50.3	53.3
2015		23.6	35.0	41.0	45.1	46.4	48.0	51.0	54.5	54.7
2016	22.4	29.7	39.7	40.0	45.3	47.2	48.1	50.6	55.7	53.6
2017		29.1	34.2	40.1	40.0	46.9	49.9	48.6	47.2	56.7
2018	21.4	29.1	33.6	38.1	40.3	41.5	45.4	47.0	49.3	49.9
Low		23.6	33.6	38.1	40.0	41.5	45.4	47.0	47.2	49.9
High		40.6	47.2	53.3	59.7	63.5	72.5	75.8	75.5	76.7
Median		34.2	44.1	49.4	53.9	58.1	60.1	63.1	64.9	67.9
Average		34.2	42.5	47.8	52.2	55.7	58.2	60.9	62.8	65.7
2016-18 Avg		29.3	35.8	39.4	41.9	45.2	47.8	48.8	50.7	53.4

Table 15. Total swept area estimates of abundance at age (numbers in 000's) of eastern Georges Bank haddock from the Canadian Department of Fisheries and Oceans (DFO) surveys during 1986-2019.

Year	Age Group									
	1	2	3	4	5	6	7	8	9+	Total
1986	5057	306	8176	997	189	348	305	425	401	16205
1987	46	4286	929	3450	653	81	387	135	1132	11099
1988	971	49	12714	257	4345	274	244	130	686	19670
1989	48	6664	991	2910	245	526	40	34	265	11724
1990	726	108	12300	168	4466	299	1370	144	389	19968
1991	383	2163	134	10819	114	1909	117	505	225	16368
1992	1914	3879	1423	221	4810	18	1277	52	656	14249
1993	3448	1759	545	431	34	1186	19	281	147	7849
1994	4197	15163	5332	549	314	20	915	18	356	26864
1995	1231	3224	6236	3034	720	398	0	729	849	16422
1996	1455	2290	4784	5305	3113	303	274	38	684	18247
1997	1033	1550	1222	2742	2559	1397	150	65	372	11090
1998	2379	10626	5348	3190	5312	5028	2248	348	601	35080
1999	24593	4787	10067	3104	1963	1880	1764	448	174	48780
2000	3177	15865	7679	12108	2900	2074	2726	1591	813	48932
2001	23026	3519	14633	4255	5608	1808	1426	1963	2299	58536
2002	732	28174	5977	12660	2981	2646	648	529	2423	56769
2003	1682	1503	82161	5533	15105	3675	2355	1106	1986	115107
2004	91843	539	2682	54882	5001	9695	1654	954	634	167883
2005	1669	20958	531	1557	25559	3403	4815	1087	548	60125
2006	9130	5817	178604	2521	2251	15695	764	1633	261	216675
2007	3051	9541	3289	67311	984	154	3584	251	652	88816
2008	3832	1219	4647	5025	103874	1006	191	8553	724	129071
2009	2001	3977	2668	5989	652	43838	637	125	1568	61456
2010	868	606	3005	2335	4855	1433	42302	314	1071	56788
2011	209508	1892	1649	3079	1329	2974	741	29157	535	250864
2012	20047	353084	4108	746	1061	410	684	401	4454	384995
2013	2988	33059	320949	5319	786	1390	588	969	5442	371491
2014	474896	8419	17468	51849	654	88	28	183	548	554132
2015	6200	892569	20633	8311	60473	0	281	53	1092	989612
2016	9685	10517	544958	2169	2238	30113	346	0	329	600364
2017	27077	13235	7231	237788	2111	1295	5586	26	139	294488
2018	4843	16067	12221	1267	177984	458	138	6136	50	219162
2019	4811	2606	17553	9178	1850	108310	4170	92	203	148775

Table 16. Total swept area estimated abundance at age (numbers in 000's) of eastern Georges Bank haddock from the National Marine Fisheries Service spring surveys during 1968-2019. From 1973-1981, a 41 Yankee trawl was used while a 36 Yankee trawl was used in other years up to and including 2008. Since 2009 a new net, vessel and protocols were used and conversion factors to equate to *Albatross IV* catches were applied.

Year	Age Group									
	1	2	3	4	5	6	7	8	9+	Total
1968	0	3254	68	679	4853	2045	240	123	234	11496
1969	17	35	614	235	523	3232	1220	358	489	6724
1970	478	190	0	560	998	441	3165	2491	769	9092
1971	0	655	261	0	144	102	58	1159	271	2650
1972	2594	0	771	132	25	47	211	27	1214	5020
1973	2455	5639	0	1032	154	0	276	0	1208	10763
1974	1323	20596	4084	0	354	0	43	72	322	26795
1975	528	567	6016	1063	0	218	127	45	208	8773
1976	8228	402	424	1127	532	0	0	0	22	10735
1977	126	26003	262	912	732	568	0	22	102	28727
1978	0	743	20859	641	880	1163	89	23	116	24516
1979	10496	441	1313	9764	475	72	445	42	9	23056
1980	4355	66450	1108	1086	5761	613	371	693	360	80797
1981	3281	2823	27085	2906	751	2455	347	56	21	39725
1982	584	3703	1658	7802	767	455	697	0	0	15666
1983	238	770	686	359	2591	30	0	798	58	5529
1984	1366	1414	1046	910	847	1189	133	73	490	7469
1985	40	8911	1396	674	1496	588	1995	127	483	15709
1986	3334	280	3597	246	210	333	235	560	159	8953
1987	122	5480	144	1394	157	231	116	370	0	8013
1988	305	61	1868	235	611	203	218	178	0	3678
1989	84	6665	619	1343	267	791	58	92	47	9966
1990	1654	70	10338	598	1042	110	182	0	0	13995
1991	740	2071	432	3381	192	203	66	87	25	7198
1992	529	287	205	158	602	32	46	46	0	1905
1993	1870	1116	197	232	195	717	77	35	43	4480
1994	1025	4272	1487	269	184	118	278	28	84	7745
1995	921	2312	4184	1727	265	152	51	272	214	10099
1996	912	1365	3789	3190	1905	237	36	0	496	11931
1997	1635	1226	380	595	470	343	24	44	20	4736
1998	549	6046	2005	1281	1184	303	58	15	122	11562
1999	6286	1914	3655	661	1128	1062	468	476	46	15696
2000	2675	2131	3399	1624	636	564	438	305	165	11938
2001	10503	1186	3304	1232	374	294	113	20	20	17047
2002	231	40432	10938	4044	1492	473	287	229	236	58362
2003	125	1105	16915	2245	3773	476	200	82	286	25206
2004	195013	4724	2644	45872	3544	5261	960	1245	842	260104
2005	540	32911	257	614	5818	671	1196	240	67	42313
2006	2961	1247	48882	213	949	6650	325	574	187	61988
2007	1468	11383	2055	95882	180	441	2168	222	312	114110
2008	3402	1671	4332	240	38569	836	371	1739	480	51639
2009	2896	2758	1589	5126	801	23985	563	483	1259	39462
2010	481	644	3326	1461	3785	517	20735	0	600	31548
2011	16812	1319	834	707	551	1052	303	6751	155	28484
2012	19701	99410	1372	362	725	657	908	43	3532	126709
2013	2583	9575	60096	1197	506	411	349	292	1101	76111
2014	91436	4429	8306	28732	291	65	78	49	153	133540
2015	2158	203399	3264	2837	16150	376	0	64	111	228359
2016	13974	1285	86616	904	912	6866	29	0	88	110673
2017	9948	3841	925	89283	705	607	4233	37	19	109598
2018	1869	8316	6085	164	32066	82	279	604	6	49471
2019	732	1379	10143	2901	817	38361	449	209	720	55709

Table 17. Total swept area estimated abundance at age (numbers in 000's) of eastern Georges Bank haddock from National Marine Fisheries Service fall surveys during 1963-2018. Since 2009 a new net, vessel and protocols were used and conversion factors to equate to *Albatross IV* catches were applied.

Year	Age Group									
	0	1	2	3	4	5	6	7	8+	Total
1963	105993	40995	10314	3378	5040	4136	1477	451	276	172061
1964	1178	123976	46705	4358	807	1865	477	211	167	179742
1965	259	1503	51338	8538	479	302	142	148	208	62918
1966	9325	751	1742	20323	3631	671	138	133	84	36798
1967	0	3998	73	327	1844	675	141	88	88	7233
1968	55	113	800	28	37	2223	547	177	313	4293
1969	356	0	0	509	62	30	739	453	108	2257
1970	0	6400	336	16	415	337	500	902	578	9483
1971	2626	0	788	97	0	265	27	73	594	4471
1972	4747	2396	0	232	0	0	53	0	275	7702
1973	1223	16797	1598	0	168	0	0	8	16	19809
1974	151	234	961	169	0	6	0	0	70	1589
1975	30365	664	192	1042	239	0	0	0	28	32530
1976	738	121717	431	25	484	71	0	17	37	123521
1977	47	238	26323	445	125	211	84	4	4	27480
1978	14642	547	530	7706	56	42	94	0	0	23617
1979	1598	21605	14	335	1489	45	12	0	0	25098
1980	3556	2788	5829	0	101	1081	108	25	4	13492
1981	596	4617	2585	2748	89	136	318	0	15	11103
1982	62	0	673	465	2508	153	97	528	42	4527
1983	3609	444	236	501	289	402	17	12	86	5598
1984	45	3775	856	233	194	45	262	0	41	5451
1985	12148	381	1646	199	70	68	46	30	21	14611
1986	30	7471	109	961	52	50	72	24	23	8793
1987	508	0	843	28	152	38	22	0	0	1592
1988	122	3983	184	2348	155	400	142	140	38	7513
1989	167	83	2645	112	509	68	73	0	0	3656
1990	1217	1041	36	1456	65	196	24	5	0	4040
1991	705	331	267	52	289	25	10	0	0	1679
1992	3484	1052	172	110	0	95	0	18	18	4948
1993	687	6656	3601	585	0	87	96	30	0	11742
1994	625	782	927	419	96	32	0	24	0	2905
1995	892	1436	5993	3683	550	30	0	0	53	12637
1996	1742	453	570	2302	963	167	0	0	0	6196
1997	217	5738	3368	592	690	385	0	0	13	11004
1998	2566	2966	4214	1085	705	526	722	0	0	12784
1999	3268	1236	5364	5060	837	2825	148	1150	991	20879
2000	1368	5284	6226	3712	622	229	0	146	97	17684
2001	659	16626	1382	6939	3000	1586	306	127	58	30684
2002	172	1864	44602	6040	5120	1660	863	457	354	61131
2003	196182	60	285	3415	655	739	20	99	158	201613
2004	2864	116289	322	775	17200	1034	2410	416	528	141837
2005	4981	3114	95159	340	532	3631	347	242	155	108502
2006	930	8752	1040	65817	1083	82	796	0	16	78517
2007	1264	1922	11764	965	52456	955	562	244	0	70132
2008	1902	1865	1162	2564	477	21289	0	74	484	29818
2009	2010	862	1352	1082	2504	388	20906	88	237	29430
2010	172390	1154	585	1069	393	1166	589	9909	172	187428
2011	14019	106939	349	225	281	331	650	219	3673	126686
2012	3493	10311	72573	237	151	83	102	80	754	87784
2013	909714	3149	6643	52237	445	106	21	0	360	972675
2014	2039	245370	1715	1306	18618	419	174	16	8	269664
2015	42284	7314	363054	1910	3623	33858	67	14	32	452156
2016	81298	20564	2308	155369	597	683	6052	0	44	266916
2017	14485	55181	14541	927	56856	68	1015	1050	14	144136
2018	18148	5233	12068	3501	58	17681	145	548	588	57978

Table 18. Average weight at age (kg) of eastern Georges Bank haddock from DFO surveys for 1986-2019. These weights are used to represent beginning of year population weights. 9+ weights are population weighted averages. Highlighted cells indicated exceptionally strong year classes.

Year	Age Group								
	1	2	3	4	5	6	7	8	9+
1986	0.135	0.451	0.974	1.445	3.044	2.848	3.598	3.376	3.918
1987	0.150	0.500	0.716	1.672	2.012	2.550	3.148	3.151	3.629
1988	0.097	0.465	0.931	1.795	1.816	1.918	2.724	3.264	3.871
1989	0.062	0.474	0.650	1.392	1.995	2.527	2.158	2.859	3.141
1990	0.149	0.525	0.924	1.181	1.862	2.073	2.507	2.815	3.472
1991	0.120	0.685	0.800	1.512	1.695	2.434	2.105	3.122	3.432
1992	0.122	0.602	1.118	1.061	2.078	2.165	2.709	2.284	3.440
1993	0.122	0.481	1.227	1.803	1.274	2.332	2.343	2.739	3.280
1994	0.107	0.469	1.047	1.621	1.927	2.154	3.154	2.688	3.084
1995	0.086	0.493	0.963	1.556	2.222	2.445	2.4[1]	2.991	3.184
1996	0.139	0.495	0.919	1.320	1.932	2.555	2.902	2.611	3.588
1997	0.132	0.506	0.782	1.205	1.664	2.176	2.454	2.577	3.158
1998	0.107	0.535	1.035	1.161	1.570	1.954	2.609	3.559	3.462
1999	0.130	0.474	0.911	1.290	1.259	1.869	2.131	2.722	2.992
2000	0.116	0.543	0.949	1.478	1.871	1.789	2.298	2.508	2.901
2001	0.093	0.524	1.005	1.371	1.798	2.165	2.250	2.593	2.928
2002	0.096	0.332	0.778	1.138	1.494	1.965	2.177	2.206	2.708
2003	0.080	0.369	0.846	1.063	1.477	1.645	2.208	2.229	2.487
2004	0.064	0.310	0.781	1.151	1.306	1.558	1.622	1.956	2.216
2005	0.028	0.218	0.493	0.696	1.226	1.321	1.531	1.600	2.444
2006	0.059	0.171	0.389	0.657	0.870	1.366	1.591	1.742	2.355
2007	0.077	0.246	0.405	0.709	0.992	1.745	1.559	1.671	1.862
2008	0.107	0.329	0.573	0.795	0.927	1.254	1.729	1.476	1.897
2009	0.114	0.387	0.775	0.999	0.987	1.258	1.482	2.680	2.228
2010	0.072	0.385	0.749	0.960	1.120	1.207	1.333	1.772	2.066
2011	0.038	0.322	0.612	0.900	0.953	1.018	1.120	1.371	1.721
2012	0.070	0.186	0.457	0.506	0.997	1.104	1.084	1.190	1.346
2013	0.070	0.261	0.412	0.789	1.092	0.972	1.100	1.142	1.457
2014	0.042	0.323	0.537	0.648	0.911	1.214	1.214	0.953	1.432
2015	0.102	0.189	0.407	0.706	0.807	1.097	1.199	1.358	1.242
2016	0.041	0.178	0.342	0.699	1.121	1.020	1.238	1.151	2.106
2017	0.043	0.168	0.421	0.437	0.729	0.888	0.981	1.340	1.409
2018	0.059	0.210	0.392	0.413	0.544	1.017	1.509	0.846	1.734
2019	0.070	0.227	0.431	0.557	0.717	0.697	0.684	1.456	1.185
Low	0.028	0.168	0.342	0.413	0.544	0.697	0.684	0.846	1.185
High	0.150	0.685	1.227	1.803	3.044	2.848	3.598	3.559	3.918
Median	0.094	0.386	0.777	1.100	1.290	1.767	2.105	2.257	2.597
Average	0.091	0.383	0.728	1.076	1.420	1.715	1.953	2.176	2.570
Avg 2017-19	0.057	0.202	0.415	0.469	0.663	0.868	1.058	1.214	1.442

[1]The weight midway between the age 6 and 8 weight for that cohort was used as data were not available for this age group.

Table 19. Average lengths at age (cm) of eastern Georges Bank haddock from DFO surveys for 1986-2019. Highlighted cells indicated exceptionally strong year classes.

Year	Age Group								
	1	2	3	4	5	6	7	8	9+
1986	22.9	36.2	45.4	51.0	63.7	61.9	67.8	66.0	70.7
1987	24.2	36.3	39.7	53.4	57.1	61.1	65.1	65.8	69.6
1988	22.3	36.4	45.1	55.7	55.9	58.0	62.4	65.8	71.5
1989	19.5	35.9	39.1	50.4	56.8	61.3	58.0	64.6	66.3
1990	24.7	35.8	44.4	48.0	55.9	58.7	61.6	63.1	67.5
1991	23.1	40.7	42.7	51.7	52.9	60.2	58.3	65.1	67.8
1992	23.2	39.2	47.7	46.8	57.7	62.5	63.9	60.3	68.1
1993	23.6	36.6	49.7	55.5	50.0	60.4	59.3	63.7	67.3
1994	22.3	35.8	45.8	53.8	57.6	58.5	65.9	66.5	65.4
1995	20.2	36.3	45.1	52.7	59.0	62.5		65.0	66.0
1996	24.2	36.2	44.4	50.1	56.9	62.7	66.2	61.8	68.4
1997	23.6	37.1	42.1	48.9	54.2	59.5	62.4	63.5	66.8
1998	21.8	37.6	46.4	47.3	52.9	57.2	62.5	69.3	68.7
1999	23.7	35.9	44.8	49.8	48.9	56.1	58.9	63.6	66.6
2000	22.7	37.6	44.3	52.1	56.4	54.7	59.6	61.7	64.7
2001	21.7	37.5	46.1	51.1	56.2	60.0	59.0	62.5	65.5
2002	21.5	31.8	42.1	47.5	52.0	58.1	60.3	59.2	64.4
2003	20.2	34.0	43.3	46.8	52.0	53.8	61.2	61.3	63.3
2004	19.1	31.8	42.0	47.9	50.6	53.3	55.3	59.1	60.2
2005	15.1	29.1	37.2	41.1	49.7	51.6	53.8	54.3	62.7
2006	18.7	27.0	34.0	40.2	42.6	51.8	52.8	55.7	62.2
2007	20.6	29.6	34.2	41.0	46.7	55.0	53.5	54.1	55.4
2008	23.1	33.1	39.4	43.0	45.7	50.5	56.3	52.9	57.9
2009	23.2	34.7	42.6	45.8	44.9	49.3	51.9	61.7	59.4
2010	20.3	34.8	43.0	46.3	48.3	50.5	51.4	55.7	59.8
2011	16.6	32.5	40.1	45.8	47.5	47.6	49.3	52.3	56.9
2012	19.9	26.7	36.2	37.1	47.0	48.7	48.6	50.1	52.0
2013	19.8	30.0	35.0	43.9	48.3	48.2	49.4	50.4	53.5
2014	16.4	32.4	37.9	40.5	46.8	49.2	50.5	47.8	54.0
2015	21.8	27.2	35.1	42.8	44.5		51.6	52.5	51.5
2016	17.2	27.3	33.1	43.1	48.8	47.4	51.8		59.1
2017	17.5	26.2	35.9	36.3	43.8	47.2	48.1	54.5	54.6
2018	18.8	28.7	34.3	34.8	39.3	49.8	55.1	45.1	54.5
2019	19.9	29.1	35.9	38.6	42.1	41.9	42.1	54.8	52.3
Low	15.1	26.2	33.1	34.8	39.3	41.9	42.1	45.1	51.5
High	24.7	40.7	49.7	55.7	63.7	62.7	67.8	69.3	71.5
Median	21.6	34.7	42.1	47.1	50.3	55.0	58.0	61.3	63.9
Average	21.0	33.4	41.0	46.5	51.0	54.8	56.8	59.1	62.2
Avg 2017-2019	18.7	28.0	35.4	36.6	41.8	46.3	48.4	51.4	53.8

Table 20. Statistical properties of estimates of population abundance (numbers in 000's) at beginning of year 2019 and survey calibration constants (unitless, survey:population) for eastern Georges Bank haddock obtained from a bootstrap with 1000 replications.

Age	Estimate	Standard Error	Relative Error	Bias	Relative Bias
		Population Abundance (000's)			
1	15773	9737	0.617	2403	0.152
2	9593	4099	0.427	738	0.077
3	38146	12149	0.318	1431	0.038
4	16090	4492	0.279	482	0.030
5	1545	501	0.324	59	0.038
6	195543	44207	0.226	2593	0.013
7	1023	327	0.320	53	0.051
8	567	215	0.379	30	0.053
		Survey Calibration Constants			
DFO Survey, 1986-2019					
1	0.380	0.061	0.160	0.007	1.876
2	0.644	0.103	0.160	0.011	0.018
3	1.146	0.192	0.168	0.020	0.017
4	1.040	0.168	0.162	0.020	0.019
5	1.099	0.177	0.161	0.018	0.016
6	0.938	0.154	0.164	0.007	0.007
7	1.058	0.177	0.167	0.018	0.017
8	0.984	0.150	0.152	0.007	0.007
NMFS Spring Survey, Yankee 36,1969-72/1982-2019					
1	0.228	0.078	0.344	0.016	0.068
2	0.534	0.165	0.309	0.016	0.029
3	0.652	0.229	0.351	0.036	0.055
4	0.806	0.283	0.352	0.050	0.062
5	0.895	0.300	0.335	0.053	0.059
6	0.811	0.332	0.410	0.057	0.070
7	1.488	0.534	0.359	0.088	0.059
8	0.724	0.262	0.363	0.047	0.064
NMFS Spring Survey, Yankee 41, 1973-81					
1	0.185	0.026	0.143	0.001	0.004
2	0.399	0.058	0.145	0.004	0.009
3	0.510	0.078	0.152	0.009	0.018
4	0.443	0.064	0.145	0.005	0.012
5	0.519	0.074	0.143	0.008	0.015
6	0.456	0.068	0.149	0.003	0.006
7	0.474	0.070	0.147	0.008	0.016
8	0.478	0.075	0.158	0.004	0.009
NMFS Fall Survey, 1969-2018					
0	0.222	0.031	0.138	0.003	0.014
1	0.413	0.056	0.135	0.003	0.008
2	0.313	0.043	0.136	0.004	0.012
3	0.282	0.037	0.131	0.003	0.011
4	0.235	0.031	0.131	0.000	0.001
5	0.202	0.027	0.135	0.002	0.011

Table 21. Calculation of rho and percent adjustment for retrospective analysis.

Peel	Age 1 Recruits	Age 3-8 Biomass	Age 5-8 F
1	0.61	0.25	-0.637
2	0.95	0.78	-0.791
3	1.52	1.14	-0.753
4	1.45	2.42	-0.480
5	1.65	2.59	-0.715
6	0.97	3.44	-0.721
7	5.71	1.64	-0.641
Mohn's Rho	**1.84**	**1.75**	**-0.677**
% Adjustment	**0.352**	**0.363**	**3.094**
calculated as 1/(1+ rho value)			

Table 22. Estimated and rho adjusted values for fishing mortality for ages 5 to 8 (F_{5-8}) and 3+ biomass (B_{3+}), and confidence intervals (CI) for the original estimated values of F_{5-8} and B_{3+}. (Note: The % rho adjustment value of 0.363 for Age 3-8 biomass was used to adjust the age 3+ biomass estimate at the beginning of 2019).

Parameter	Original Estimate	Rho Adjusted Estimate	80% CI	95% CI
B_{3+} (mt)	167476	60,794	134,600 to 214,892	117,652 to 245,303
F_{5-8}	0.05	0.17	0.04 to 0.07	0.04 to 0.09

Table 23. Beginning of year population abundance (numbers in 000's) for eastern Georges Bank haddock during 1969-2019 from a virtual population analysis using the bootstrap bias adjusted population abundance at the beginning of 2019. Highlighted cells follow recent large year classes, 2000, 2003, 2010 and 2013.

Year	Age Group											
	1	2	3	4	5	6	7	8	9+	1+	2+	3+
1969	804	193	3639	872	911	7650	2497	250	776	17592	16788	16596
1970	3592	658	141	1681	479	447	3659	1299	506	12462	8870	8212
1971	235	2881	463	109	1061	256	249	1961	971	8187	7952	5071
1972	5302	192	1285	155	62	642	69	61	1340	9108	3806	3614
1973	11637	4029	157	702	63	32	441	21	728	17811	6173	2144
1974	3081	8519	1728	123	251	18	17	327	454	14517	11436	2917
1975	3448	2489	4947	1166	100	176	12	14	557	12910	9462	6972
1976	54072	2807	1787	2701	761	78	112	8	437	62762	8690	5883
1977	6037	43907	2157	1307	1463	501	64	74	348	55858	49821	5914
1978	4056	4941	28723	1706	906	922	263	52	319	41889	37833	32891
1979	52339	3316	3783	14594	1249	587	480	144	287	76777	24438	21122
1980	6236	42659	2699	2909	8082	695	300	199	301	64082	57846	15186
1981	4614	5077	19095	1901	2110	4442	396	130	352	38116	33501	28425
1982	2094	3729	3532	9566	1196	1281	2521	217	358	24493	22399	18670
1983	2549	1713	2395	1943	5276	795	708	1408	356	17143	14595	12882
1984	16085	2077	1268	1366	1093	2836	464	486	1046	26722	10637	8560
1985	1637	13105	1611	805	804	652	1310	213	821	20956	19320	6215
1986	13881	1332	8796	972	496	479	419	730	693	27799	13918	12586
1987	2162	11284	1055	4881	638	278	281	236	971	21786	19624	8340
1988	15974	1770	7366	745	2619	432	175	156	826	30063	14089	12319
1989	1017	13031	1401	4057	499	1342	254	109	672	22383	21366	8335
1990	2364	831	9521	1069	2623	280	788	177	576	18229	15865	15034
1991	2040	1907	673	6582	756	1457	164	494	540	14613	12572	10665
1992	7864	1651	1143	469	3527	538	841	70	660	16763	8899	7248
1993	11626	6394	1127	645	269	1576	360	402	491	22891	11265	4871
1994	10836	9446	4979	603	268	138	695	258	522	27744	16908	7463
1995	5501	8839	7352	3294	327	154	24	398	516	26405	20904	12065
1996	5218	4497	7165	5538	2324	220	103	17	687	25769	20551	16054
1997	15192	4269	3653	5425	3756	1526	126	68	509	34523	19331	15063
1998	7816	12412	3410	2925	3959	2639	1073	92	435	34760	26944	14532
1999	26149	6383	9987	2529	2160	2754	1757	776	389	52883	26734	20352
2000	7396	21385	5186	7498	1783	1544	1943	1209	842	48785	41389	20004
2001	62027	6050	17219	3841	4997	1222	1073	1395	1450	99275	37248	31198
2002	3234	50764	4894	12535	2665	3329	764	694	1937	80816	77582	26819
2003	1770	2646	41261	3811	8560	1840	2122	523	1794	64326	62557	59910
2004	196823	1443	2158	32129	2860	5670	1123	1307	1587	245099	48276	46833
2005	4371	160845	1158	1699	23019	1798	3297	456	1754	198397	194026	33181
2006	8542	3566	131471	922	1189	12662	999	1960	1553	162864	154323	150756
2007	2885	6976	2906	105368	715	714	6296	608	2242	128710	125825	118849
2008	3856	2360	5676	2215	79642	452	434	3868	2043	100547	96691	94331
2009	1453	3153	1905	4401	1572	56445	278	278	4116	73602	72149	68997
2010	4415	1174	2468	1386	2936	1052	36118	162	3203	52915	48500	47326
2011	96191	3586	910	1669	853	1646	519	20726	2521	128622	32431	28845
2012	13476	78535	2840	583	904	494	744	328	13372	111275	97799	19264
2013	7554	10965	63722	2168	364	427	249	271	9243	94963	87409	76444
2014	589435	6163	8800	49051	1565	201	142	138	7141	662636	73202	67039
2015	5304	481740	4739	6217	28917	862	80	53	5677	533588	528283	46544
2016	29674	4319	392328	3151	2714	14598	534	20	4488	451826	422152	417833
2017	55939	24288	3438	317489	2078	1443	7080	138	3595	415490	359551	335263
2018	10955	45781	19767	2532	248606	1457	881	3756	3009	336744	325789	280008
2019	13370	8854	36715	15608	1486	192951	970	537	5030	275522	262152	253297

Table 24. Fishing mortality rates for eastern Georges Bank haddock during 1969-2018 from a virtual population analysis using the bootstrap bias adjusted population abundance at the beginning of 2019. The aggregated rates are weighted by population numbers. The rates for ages 4 to 8 and 5 to 8 are also shown as exploitation rate (%). Highlighted cells follow recent large year classes, 2000, 2003, 2010 and 2013.

	Age Group												
Year	1	2	3	4	5	6	7	8	9+	4-8	4-8(%)	5-8	5-8(%)
1969	0.000	0.111	0.572	0.399	0.512	0.538	0.453	0.508	0.508	0.508	36.4	0.516	36.9
1970	0.021	0.152	0.057	0.261	0.425	0.383	0.424	0.377	0.538	0.377	28.7	0.410	30.7
1971	0.000	0.608	0.892	0.369	0.302	1.114	1.202	0.564	0.623	0.564	39.5	0.570	39.8
1972	0.075	0.005	0.404	0.705	0.468	0.175	0.973	0.342	0.460	0.342	26.4	0.275	21.9
1973	0.112	0.647	0.045	0.830	1.056	0.410	0.101	0.571	0.294	0.571	39.8	0.245	19.7
1974	0.013	0.343	0.193	0.000	0.154	0.181	0.015	0.103	0.164	0.103	8.9	0.124	10.6
1975	0.006	0.132	0.405	0.227	0.051	0.255	0.218	0.218	0.063	0.218	17.8	0.184	15.3
1976	0.008	0.064	0.113	0.413	0.217	0.000	0.208	0.000	0.046	0.357	27.3	0.197	16.2
1977	0.000	0.224	0.035	0.166	0.262	0.444	0.000	0.247	0.048	0.247	19.9	0.297	23.4
1978	0.002	0.067	0.477	0.112	0.235	0.452	0.405	0.244	0.033	0.244	19.7	0.349	26.9
1979	0.004	0.006	0.062	0.391	0.386	0.471	0.679	0.401	0.056	0.401	30.2	0.464	33.9
1980	0.006	0.604	0.151	0.121	0.399	0.363	0.639	0.335	0.046	0.335	26.0	0.402	30.2
1981	0.013	0.163	0.491	0.263	0.299	0.367	0.401	0.330	0.024	0.330	25.6	0.348	26.8
1982	0.001	0.243	0.398	0.395	0.208	0.393	0.382	0.377	0.224	0.377	28.7	0.345	26.6
1983	0.005	0.101	0.362	0.375	0.421	0.338	0.176	0.383	0.114	0.383	29.0	0.385	29.1
1984	0.005	0.054	0.254	0.331	0.317	0.573	0.578	0.467	0.405	0.467	34.1	0.505	36.3
1985	0.006	0.199	0.305	0.285	0.316	0.242	0.384	0.321	0.170	0.321	25.0	0.330	25.6
1986	0.007	0.033	0.389	0.221	0.380	0.334	0.372	0.304	0.069	0.304	23.9	0.342	26.4
1987	0.000	0.227	0.147	0.423	0.189	0.260	0.392	0.389	0.135	0.389	29.4	0.276	21.9
1988	0.004	0.033	0.396	0.201	0.468	0.332	0.278	0.395	0.143	0.395	29.8	0.438	32.4
1989	0.002	0.114	0.070	0.236	0.379	0.333	0.159	0.266	0.080	0.266	21.2	0.320	25.0
1990	0.015	0.010	0.169	0.147	0.388	0.336	0.267	0.311	0.085	0.311	24.4	0.356	27.3
1991	0.012	0.312	0.162	0.424	0.139	0.349	0.651	0.392	0.133	0.392	29.6	0.318	24.8
1992	0.007	0.182	0.372	0.358	0.605	0.202	0.538	0.533	0.166	0.533	37.8	0.549	38.7
1993	0.008	0.050	0.426	0.678	0.465	0.620	0.135	0.557	0.187	0.557	39.1	0.527	37.5
1994	0.004	0.051	0.213	0.411	0.356	1.542	0.357	0.472	0.107	0.472	34.4	0.499	35.9
1995	0.002	0.010	0.083	0.149	0.197	0.199	0.125	0.155	0.036	0.155	13.0	0.177	14.7
1996	0.001	0.008	0.078	0.188	0.221	0.357	0.212	0.202	0.123	0.202	16.7	0.232	18.8
1997	0.002	0.025	0.022	0.115	0.153	0.152	0.118	0.133	0.076	0.133	11.3	0.152	12.8
1998	0.003	0.017	0.099	0.103	0.163	0.207	0.124	0.153	0.092	0.153	12.9	0.172	14.4
1999	0.001	0.008	0.087	0.150	0.136	0.149	0.174	0.151	0.075	0.151	12.7	0.151	12.8
2000	0.001	0.017	0.100	0.206	0.178	0.164	0.131	0.185	0.092	0.185	15.4	0.162	13.6
2001	0.000	0.012	0.117	0.166	0.206	0.269	0.235	0.202	0.168	0.202	16.6	0.218	17.8
2002	0.000	0.007	0.050	0.181	0.170	0.250	0.180	0.192	0.180	0.192	15.9	0.209	17.2
2003	0.004	0.004	0.050	0.087	0.212	0.294	0.285	0.263	0.155	0.203	16.7	0.237	19.2
2004	0.002	0.020	0.039	0.133	0.264	0.342	0.701	0.436	0.201	0.194	16.0	0.370	28.2
2005	0.003	0.002	0.028	0.157	0.398	0.387	0.320	0.368	0.104	0.375	28.5	0.388	29.3
2006	0.003	0.005	0.021	0.055	0.310	0.499	0.297	0.368	0.116	0.437	32.3	0.458	33.6
2007	0.001	0.006	0.071	0.080	0.257	0.299	0.287	0.281	0.096	0.095	8.2	0.285	22.6
2008	0.001	0.014	0.054	0.143	0.144	0.286	0.244	0.225	0.053	0.149	12.6	0.149	12.6
2009	0.013	0.045	0.118	0.205	0.202	0.246	0.339	0.263	0.107	0.243	19.6	0.246	19.8
2010	0.008	0.054	0.191	0.286	0.378	0.506	0.355	0.413	0.075	0.359	27.5	0.361	27.6
2011	0.003	0.033	0.246	0.412	0.347	0.595	0.258	0.400	0.034	0.409	30.6	0.408	30.6
2012	0.006	0.009	0.070	0.271	0.552	0.486	0.808	0.615	0.185	0.557	39.1	0.624	42.5
2013	0.003	0.020	0.062	0.126	0.392	0.900	0.385	0.559	0.076	0.301	23.7	0.591	40.8
2014	0.002	0.061	0.147	0.328	0.397	0.726	0.781	0.635	0.040	0.334	25.9	0.472	34.4
2015	0.005	0.005	0.202	0.622	0.482	0.278	1.167	0.642	0.040	0.503	36.1	0.478	34.7
2016	0.000	0.027	0.011	0.208	0.419	0.519	1.144	0.694	0.024	0.475	34.6	0.523	37.2
2017	0.000	0.006	0.101	0.043	0.146	0.276	0.424	0.282	0.007	0.053	4.7	0.348	26.8
2018	0.011	0.019	0.034	0.309	0.051	0.189	0.265	0.168	0.005	0.057	5.0	0.054	4.8

Table 25. Beginning of year biomass (mt) for eastern Georges Bank haddock during 1969-2019. Weights at age from the DFO survey were applied to the virtual population analysis bootstrap bias adjusted population numbers at age at the beginning of 2018 to determine biomass. Highlighted cells follow recent large year classes, 2000, 2003, 2010 and 2013.

Year	Age Group											
	1	2	3	4	5	6	7	8	9+	1+	2+	3+
1969	92	99	3402	1311	1816	17938	6702	733	2674	34768	34676	34576
1970	413	339	132	2528	954	1048	9823	3805	1743	20784	20371	20032
1971	27	1483	433	164	2113	600	670	5744	3346	14580	14553	13070
1972	610	99	1201	234	123	1506	185	180	4616	8752	8142	8044
1973	1338	2073	146	1056	125	74	1185	62	2509	8569	7231	5158
1974	354	4383	1615	184	499	42	46	956	1565	9646	9292	4908
1975	396	1281	4626	1754	200	412	33	41	1918	10660	10264	8983
1976	6216	1444	1670	4062	1516	183	299	24	1507	16921	10705	9261
1977	694	22591	2016	1965	2915	1175	171	217	1200	32946	32252	9660
1978	466	2542	26854	2565	1805	2162	706	153	1100	38355	37889	35346
1979	6016	1706	3537	21947	2488	1375	1289	421	987	39767	33751	32044
1980	717	21949	2523	4375	16104	1630	805	584	1036	49725	49008	27059
1981	530	2612	17853	2858	4204	10414	1063	380	1212	41127	40596	37984
1982	241	1918	3302	14386	2384	3003	6766	636	1232	33868	33627	31709
1983	293	881	2239	2922	10513	1865	1901	4125	1226	25964	25671	24790
1984	1849	1069	1185	2054	2178	6651	1247	1424	3604	21260	19411	18342
1985	188	6743	1506	1210	1601	1529	3517	625	2827	19745	19557	12815
1986	1869	601	8570	1404	1508	1366	1507	2465	2716	22007	20138	19537
1987	325	5637	756	8163	1283	708	885	745	3524	22025	21700	16063
1988	1553	822	6854	1338	4756	829	477	508	3197	20335	18782	17960
1989	63	6179	910	5650	996	3392	548	311	2110	20158	20095	13916
1990	352	436	8799	1263	4885	580	1974	499	2000	20789	20437	20001
1991	244	1306	539	9949	1281	3546	344	1541	1852	20602	20358	19052
1992	962	995	1277	498	7331	1165	2279	160	2270	16935	15974	14979
1993	1418	3076	1383	1163	342	3677	844	1102	1612	14617	13199	10123
1994	1156	4432	5212	977	516	297	2190	693	1611	17085	15929	11498
1995	474	4361	7081	5126	727	376	58	1190	1643	21035	20561	16200
1996	723	2225	6585	7311	4489	562	299	46	2464	24703	23980	21755
1997	2008	2162	2855	6539	6250	3320	309	176	1606	25226	23218	21056
1998	839	6645	3530	3397	6215	5157	2800	326	1505	30414	29575	22930
1999	3390	3023	9096	3261	2719	5148	3745	2111	1164	33657	30266	27243
2000	856	11619	4920	11085	3335	2763	4465	3030	2442	44517	43661	32042
2001	5791	3168	17311	5265	8983	2646	2414	3619	4247	53443	47652	44484
2002	309	16832	3808	14261	3981	6540	1664	1532	5244	54171	53862	37030
2003	142	978	34910	4050	12643	3026	4685	1165	4463	66063	65920	64943
2004	12576	447	1686	36988	3736	8835	1822	2555	3516	72161	59585	59138
2005	122	35024	571	1183	28223	2375	5047	730	4288	77563	77442	42417
2006	501	610	51124	606	1034	17297	1589	3414	3658	79834	79333	78723
2007	221	1713	1177	74711	709	1246	9818	1016	4174	94784	94563	92850
2008	413	777	3254	1761	73851	568	749	5708	3875	90955	90542	89766
2009	166	1220	1477	4396	1551	71015	412	745	9171	90153	89988	88768
2010	320	452	1848	1331	3289	1270	48134	288	6620	63551	63231	62779
2011	3698	1154	558	1501	813	1676	581	28411	4339	42731	39034	37879
2012	948	14595	1299	295	902	545	806	391	17993	37773	36825	22230
2013	529	2863	26274	1711	397	414	273	310	13468	46241	45712	42848
2014	24779	1991	4724	31794	1427	244	172	132	10228	75491	50712	48721
2015	540	91136	1928	4391	23347	945	96	72	7051	129507	128967	37831
2016	1219	769	134314	2203	3042	14884	661	23	9450	166565	165346	164577
2017	2389	4077	1448	138842	1514	1282	6943	185	5064	161744	159355	155278
2018	644	9617	7741	1046	135158	1483	1330	3176	5218	165411	164767	155150
2019	932	2010	15829	8701	1065	134545	664	782	5958	170486	169554	167544

Table 26. Partial recruitment, fishing mortality (F) per year divided by the maxium F at age per year, for 1969-2018 from the eastern Georges Bank fishery.

	Age Group								
Year	1	2	3	4	5	6	7	8	9
1969	0.00	0.19	1.00	0.70	0.89	0.94	0.79	0.89	0.89
1970	0.04	0.28	0.11	0.48	0.79	0.71	0.79	0.70	1.00
1971		0.51	0.74	0.31	0.25	0.93	1.00	0.47	0.52
1972	0.08	0.00	0.42	0.72	0.48	0.18	1.00	0.35	0.47
1973	0.11	0.61	0.04	0.79	1.00	0.39	0.10	0.54	0.28
1974	0.04	1.00	0.56		0.45	0.53	0.04	0.30	0.48
1975	0.01	0.33	1.00	0.56	0.13	0.63	0.54	0.54	0.15
1976	0.02	0.15	0.27	1.00	0.53		0.50		0.11
1977	0.00	0.51	0.08	0.37	0.59	1.00	0.00	0.56	0.11
1978	0.00	0.14	1.00	0.23	0.49	0.95	0.85	0.51	0.07
1979	0.01	0.01	0.09	0.58	0.57	0.69	1.00	0.59	0.08
1980	0.01	0.94	0.24	0.19	0.62	0.57	1.00	0.52	0.07
1981	0.03	0.33	1.00	0.53	0.61	0.75	0.82	0.67	0.05
1982	0.00	0.61	1.00	0.99	0.52	0.99	0.96	0.95	0.56
1983	0.01	0.24	0.86	0.89	1.00	0.80	0.42	0.91	0.27
1984	0.01	0.09	0.44	0.57	0.55	0.99	1.00	0.81	0.70
1985	0.02	0.52	0.79	0.74	0.82	0.63	1.00	0.83	0.44
1986	0.02	0.08	1.00	0.57	0.98	0.86	0.96	0.78	0.18
1987	0.00	0.54	0.35	1.00	0.45	0.61	0.93	0.92	0.32
1988	0.01	0.07	0.85	0.43	1.00	0.71	0.59	0.84	0.31
1989	0.01	0.30	0.19	0.62	1.00	0.88	0.42	0.70	0.21
1990	0.04	0.03	0.44	0.38	1.00	0.87	0.69	0.80	0.22
1991	0.02	0.48	0.25	0.65	0.21	0.54	1.00	0.60	0.20
1992	0.01	0.30	0.61	0.59	1.00	0.33	0.89	0.88	0.27
1993	0.01	0.07	0.63	1.00	0.69	0.91	0.20	0.82	0.28
1994	0.00	0.03	0.14	0.27	0.23	1.00	0.23	0.31	0.07
1995	0.01	0.05	0.42	0.75	0.99	1.00	0.63	0.78	0.18
1996	0.00	0.02	0.22	0.53	0.62	1.00	0.59	0.57	0.35
1997	0.01	0.16	0.15	0.75	1.00	0.99	0.77	0.87	0.50
1998	0.01	0.08	0.48	0.50	0.79	1.00	0.60	0.74	0.45
1999	0.01	0.04	0.50	0.86	0.78	0.85	1.00	0.86	0.43
2000	0.00	0.08	0.49	1.00	0.86	0.80	0.64	0.90	0.45
2001	0.00	0.04	0.44	0.62	0.77	1.00	0.87	0.75	0.63
2002	0.00	0.03	0.20	0.72	0.68	1.00	0.72	0.77	0.72
2003	0.01	0.01	0.17	0.30	0.72	1.00	0.97	0.90	0.53
2004	0.00	0.03	0.06	0.19	0.38	0.49	1.00	0.62	0.29
2005	0.01	0.00	0.07	0.39	1.00	0.97	0.80	0.93	0.26
2006	0.01	0.01	0.04	0.11	0.62	1.00	0.60	0.74	0.23
2007	0.00	0.02	0.24	0.27	0.86	1.00	0.96	0.94	0.32
2008	0.00	0.05	0.19	0.50	0.50	1.00	0.85	0.79	0.18
2009	0.04	0.13	0.35	0.60	0.60	0.73	1.00	0.77	0.32
2010	0.02	0.11	0.38	0.56	0.75	1.00	0.70	0.82	0.15
2011	0.00	0.06	0.41	0.69	0.58	1.00	0.43	0.67	0.06
2012	0.01	0.01	0.09	0.34	0.68	0.60	1.00	0.76	0.23
2013	0.00	0.02	0.07	0.14	0.44	1.00	0.43	0.62	0.08

2014	0.00	0.08	0.19	0.42	0.51	0.93	1.00	0.81	0.05
2015	0.00	0.00	0.17	0.53	0.41	0.24	1.00	0.55	0.03
2016	0.00	0.02	0.01	0.18	0.37	0.45	1.00	0.61	0.02
2017	0.00	0.01	0.24	0.10	0.34	0.65	1.00	0.67	0.02
2018	0.04	0.06	0.11	1.00	0.16	0.61	0.86	0.55	0.02
[1]Avg 2016-2018	0.01	0.03	0.17	0.28	0.41	0.63*	0.95	0.61	0.02

[1]Exluding large year classes, 2010 and 2013.

*A two year average

Table 27. Input for projections and risk analyses of eastern Georges Bank haddock for the 2019 fishery. A catch of 30,000 mt in 2019 and natural mortality = 0.2 were assumed. The 2013 year class weights are highlighted. Age 0 was included in the projection inputs but all values were 0s.

	Age group								
Year	1	2	3	4	5	6	7	8	9+
Population Numbers (000s)									
2019	13370	8854	36715	15608	1486	192951	970	537	5030
2020	10218	10899	7162	28207	11513	1049	133982	551	4137
2021	13423	8340	8847	5605	21445	8481	729	84580	3576
2022	13423	10956	6770	6923	4261	15798	5893	460	60935
Partial Recruitment to the Fishery[1]									
2019	0.01	0.03	0.17	0.28	0.41	0.45[3]	1.00	0.61	0.23
2020	0.01	0.03	0.17	0.28	0.41	0.63[2]	1.00[3]	0.61	0.23
2021	0.01	0.03	0.17	0.28	0.41	0.63[2]	1.00	0.67[3]	0.23
Weight at beginning of year for population (kg)[4]									
2019	0.070	0.227	0.431	0.557	0.717	0.697	0.684	1.456	1.185
2020	0.070	0.227	0.431	0.557	0.717	1.001	0.820[6]	1.316	1.185
2021	0.070	0.227	0.431	0.557	0.717	1.001	1.144[5]	0.820[6]	1.185
2022	0.070	0.227	0.431	0.557	0.717	1.001	1.144[5]	1.316[5]	1.185
Weight at age for catch (kg)[7]									
2019	0.297	0.453	0.665	0.769	1.165	0.987[8]	1.234	1.229	1.446
2020	0.297	0.453	0.665	0.769	1.165	1.085	1.022[8]	1.229	1.446
2021	0.297	0.453	0.665	0.769	1.165	1.085	1.234	1.070[8]	1.446
Maturity									
2019-2021	0	0	1	1	1	1	1	1	1

[1]Based on recent three year average, excluding the 2010 and 2013 yc; used for 2019, 2020, and 2021.
[2] Two year average, excluding the 2010 and 2013 yc
[3]2013 yc values.
[4]2019 average weights at age from DFO survey, unless indicated otherwise
[5] Based on recent three year average, excluding the 2010 and 2013 yc.
[6]2013 year class average weights at age from DFO survey based on regression of previous growth.
[7]Lowest values in the time series (1969-2019).
[8] 2013 year class values adjusted using the growth rate difference between ages of the 2010 year class.

Table 28. Bias adjusted deterministic projection results for eastern Georges Bank haddock for the 201 and 2019 fishery using 13.42 million age 1 recruits (2010 to 2019 median from 2019 VPA) for the 2020, 2021 and 2022 year classes, the input values detailed in Table 25 and assuming that the 2019 quota of 30,000 mt is caught and F=0.26 in 2020 and 2021. Natural mortality was assumed to be 0.2. Highlighted values represent the 2013 year class.

	Age group											
Year	1	2	3	4	5	6	7	8	9+	1+	2+	3+
Population Numbers (000s)												
2019	13370	8854	36715	15608	1486	192951	970	537	5030			
2020	10218	10899	7162	28207	11513	1049	133982	551	4137			
2021	13423	8340	8847	5605	21445	8481	729	84580	3576			
2022	13423	10956	6770	6923	4261	15798	5893	460	60935			
Population Biomass (mt)												
2019	936	2010	15824	8694	1066	134487	664	782	5960	170422	169486	167476
2020	715	2474	3087	15711	8255	1049	109865	725	4903	146784	146069	143595
2021	940	1893	3813	3122	15376	8487	833	69356	4237	108057	107118	105225
2022	940	2487	2918	3856	3055	15808	6739	605	72209	108617	107677	105190
Fishing Mortality												
2019	0.004	0.012	0.064	0.104	0.149	0.165	0.366	0.222	0.084	0.2255		
2020	0.003	0.009	0.045	0.074	0.106	0.164	0.26	0.158	0.06	0.172		
2021	0.003	0.009	0.045	0.074	0.106	0.164	0.26	0.174	0.06	0.176		
Projected Catch Numbers (000s)												
2019	53	97	2053	1404	187	26634	271	97	369			
2020	29	85	287	1828	1048	144	27922	73	218			
2021	37	65	354	363	1952	1167	152	12291	188			
Catch Biomass (mt)												

2019	16	44	1365	1079	217	26291	335	120	533	30000	29984	29941
2020	8	38	191	1406	1221	157	28531	90	315	31956	31948	31910
2021	11	29	236	279	2274	1266	187	13152	272	17707	17696	17666

Highlighted values indicate the 2013 year class.

Table 29. Bias adjusted sensitivity projection results for eastern Georges Bank haddock for the 2020 and 2021 fishery with a rho adjustment (=0.363) applied to the 2019 population numbers for ages 0-9+. The projections use 13.42million age 1 recruits (2010 to 2019 median from 2019 VPA results) for the 2020, 2021 and 2022 year classes, the input values detailed in Table 27; and assume that the 2019 quota of 30,000 mt is caught and F=0.26 in 2020 and 2021. Natural mortality was assumed to be 0.2. Highlighted values indicate the 2013.

	Age Group											
Year	1	2	3	4	5	6	7	8	9+	1+	2+	3+
Population Numbers (000s)												
2019	4853	3214	13328	5666	540	70041	352	195	1826			
2020	3709	3918	2530	8883	3310	273	33660	88	1216			
2021	13422	3027	3180	1980	6753	2439	190	21249	1000			
2022	13422	10955	2457	2489	1506	4975	1694	120	15387			
Population Biomass (mt)												
2019	340	730	5744	3156	387	48819	241	284	2164	61863	61523	60794
2020	260	889	1091	4948	2374	273	27601	116	1441	38992	38733	37843
2021	940	687	1371	1103	4842	2440	217	17424	1185	30208	29269	28582
2022	940	2487	1059	1386	1079	4978	1938	158	18233	32258	31318	28832
Fishing Mortality												
2019	0.014	0.039	0.206	0.337	0.481	0.533	1.184	0.719	0.272		0.72925	
2020	0.003	0.009	0.045	0.074	0.106	0.164	0.26	0.158	0.06			
2021	0.003	0.009	0.045	0.074	0.106	0.164	0.26	0.174	0.06			
Projected Catch Numbers (000s)												
2019	61	112	2254	1479	188	26452	226	92	396			
2020	10	30	101	576	301	38	7015	12	64			
2021	37	24	127	128	615	335	40	3088	53			
Catch Biomass (mt)												
2019	18	51	1499	1137	219	26111	279	113	573	30000	29982	29931
2020	3	14	67	443	351	41	7168	14	93	8193	8190	8177
2021	11	11	85	99	716	364	49	3304	76	4714	4703	4692

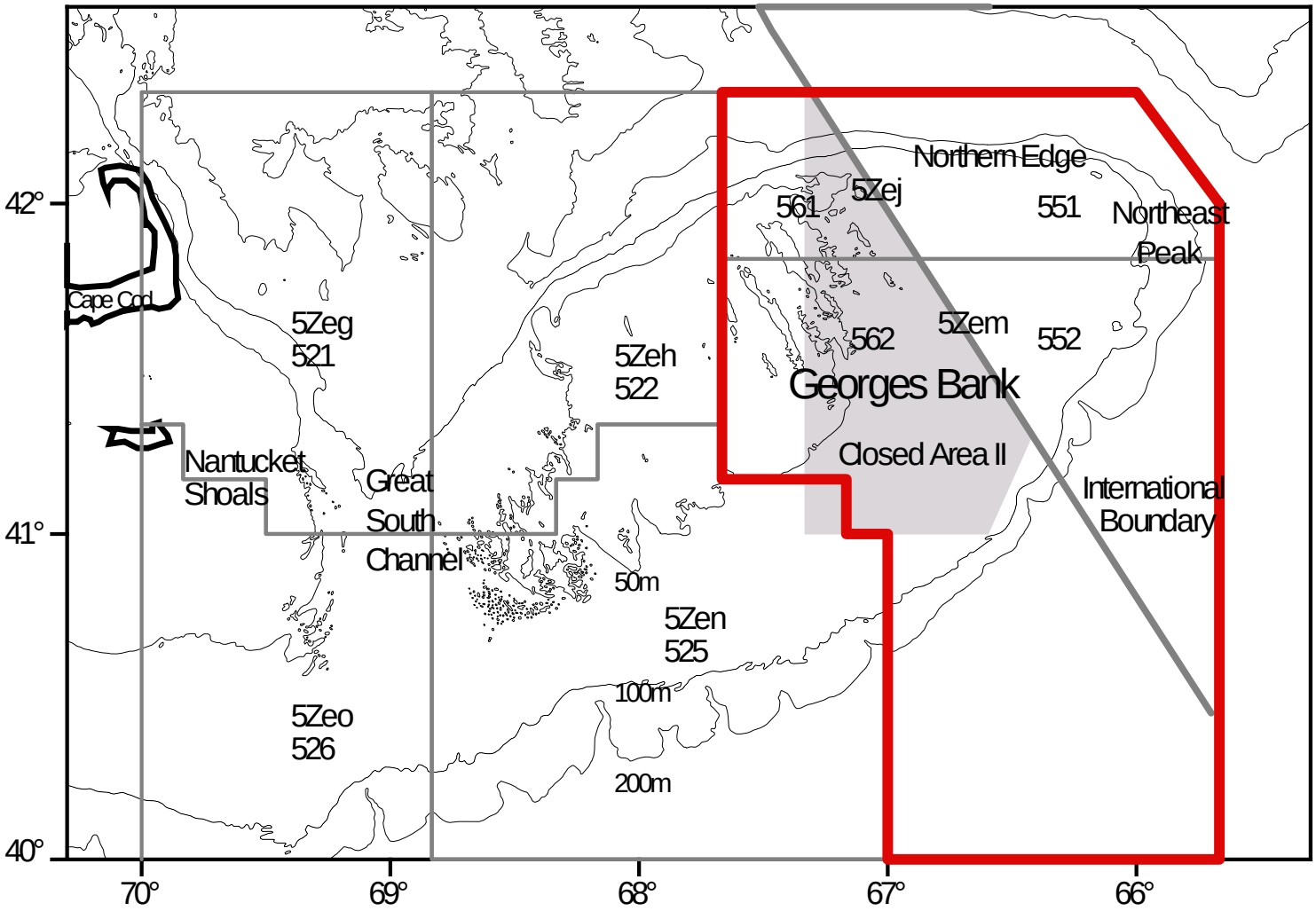

Figure 1. Fisheries statistical unit areas in North Atlantic Fisheries Organization Subdivision 5Ze. Alpha-numeric codes, e.g. 5Zej, are the Canadian Department of Fisheries and Oceans designations and numeric codes, e.g. 561, are National Marine Fisheries Service designations. The eastern Georges Bank management unit is outlined by a heavy red line.

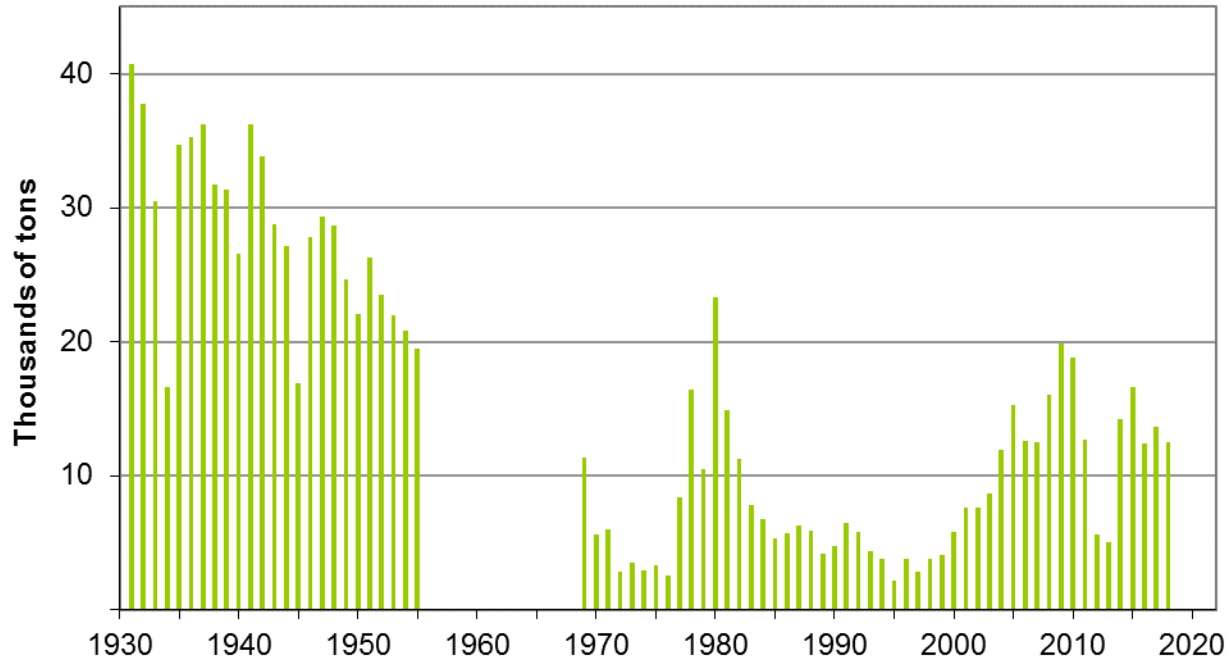

Figure 2. Historical catch of eastern Georges Bank haddock during 1931-1955 (Gavaris and Van Eeckhaute 1997) compared to recent catches during 1969-2018. Catch data for 1956 to 1968 were not available by unit area.

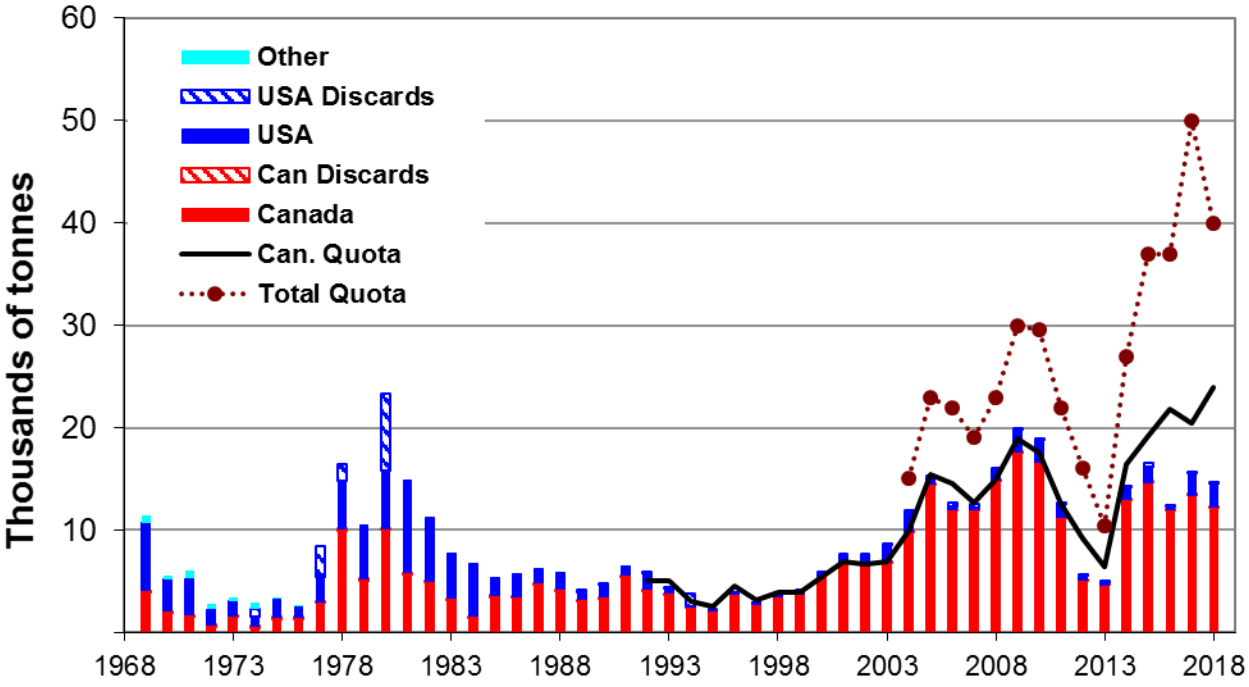

Figure 3. Nominal catches of eastern Georges Bank haddock during 1969-2018.

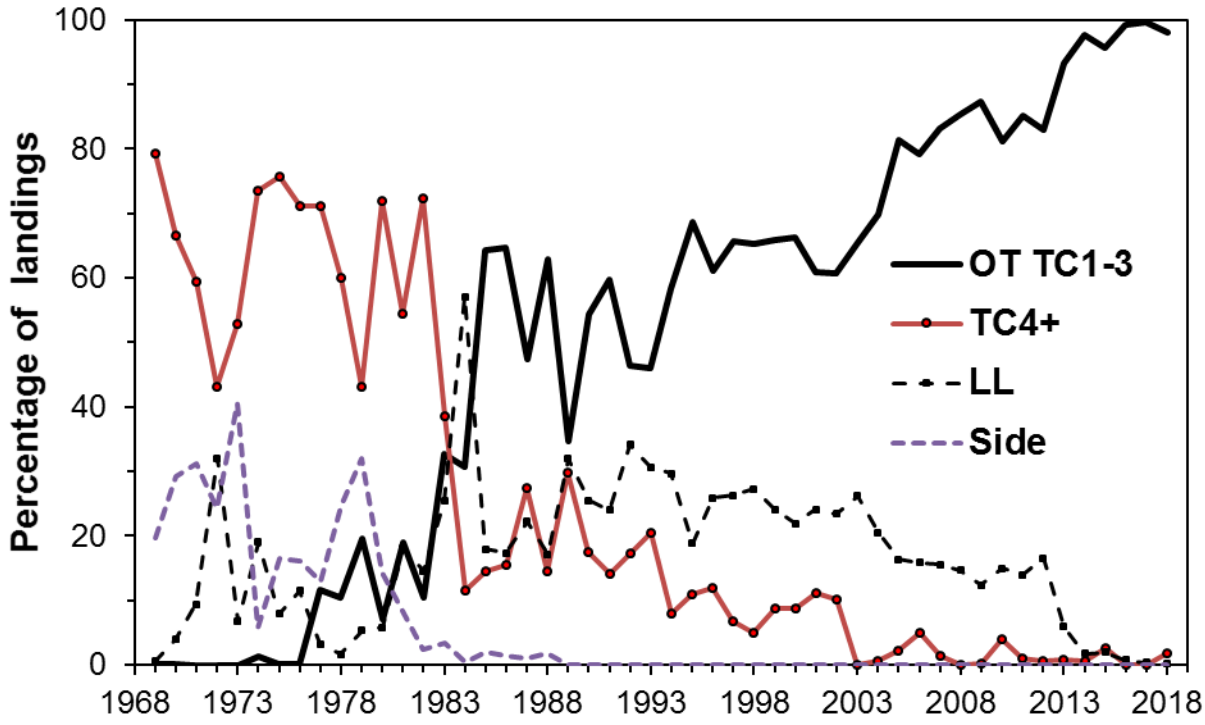

Figure 4. Percentage of annual landings (t) by gear type for the Canadian EGB haddock fishery, 1969-2018. TC 1-3 = otter trawl tonnage class 1-3; TC 4+ = otter trawl tonnage class 4+; LL = longline; Side = side otter trawl.

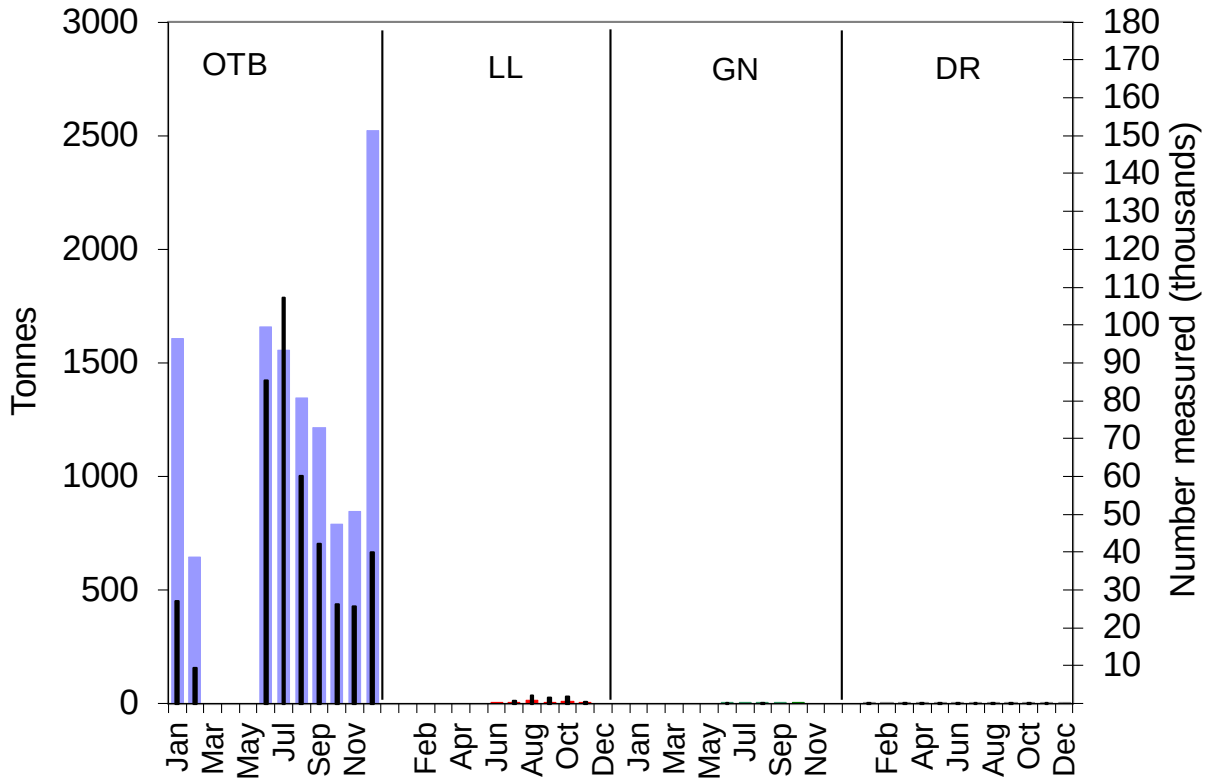

Figure 5. Haddock landings by the Canadian commercial groundfish fishery and discards from the scallop fishery from eastern Georges Bank by month and gear in 2018 (wide bars) with sampling levels (narrow bars). Landings from the gillnet fishery were very low and no samples were available. OTB= otter trawl bottom, LL= longline, GN= gill net, DR= scallop dredge.

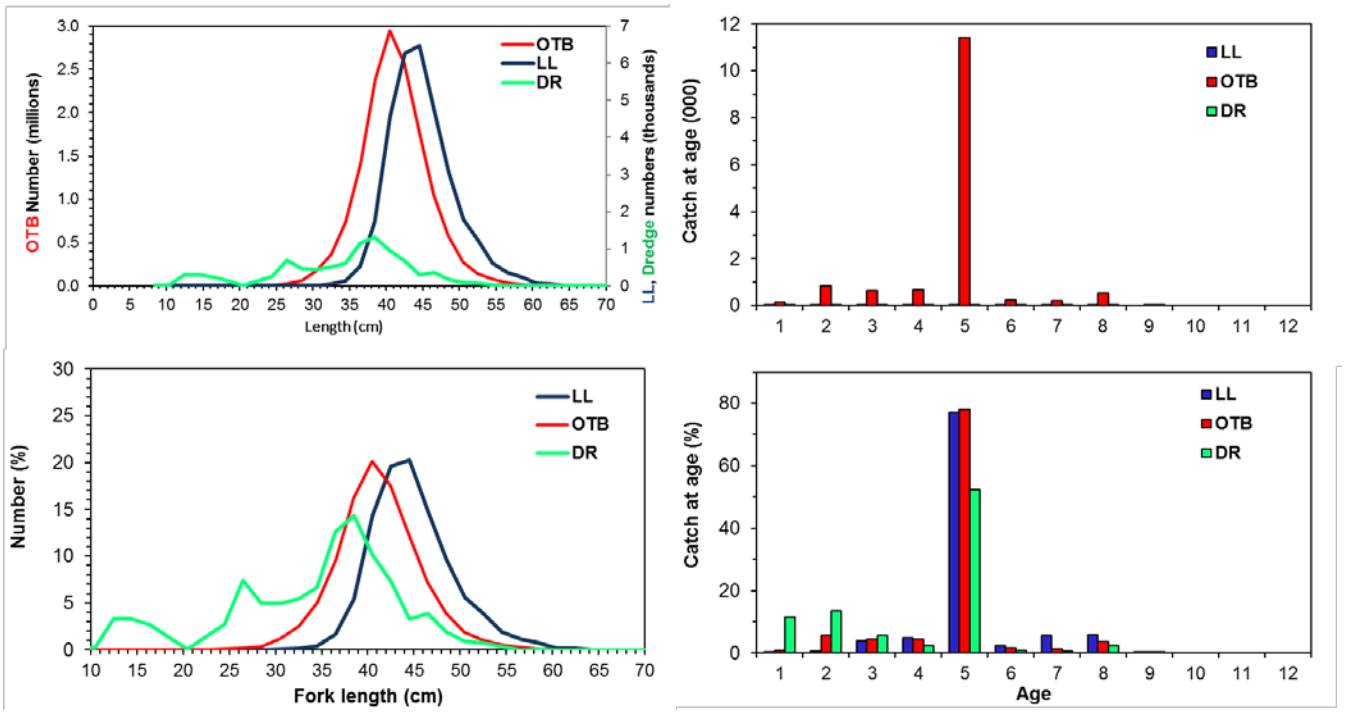

Figure 6. Canadian Eastern Georges Bank haddock fishery catch at size (left panels) and catch at age (right panels) in numbers and percentage by gear category for 2018. OTB= otter trawl bottom, LL= longline, DR= scallop dredge.

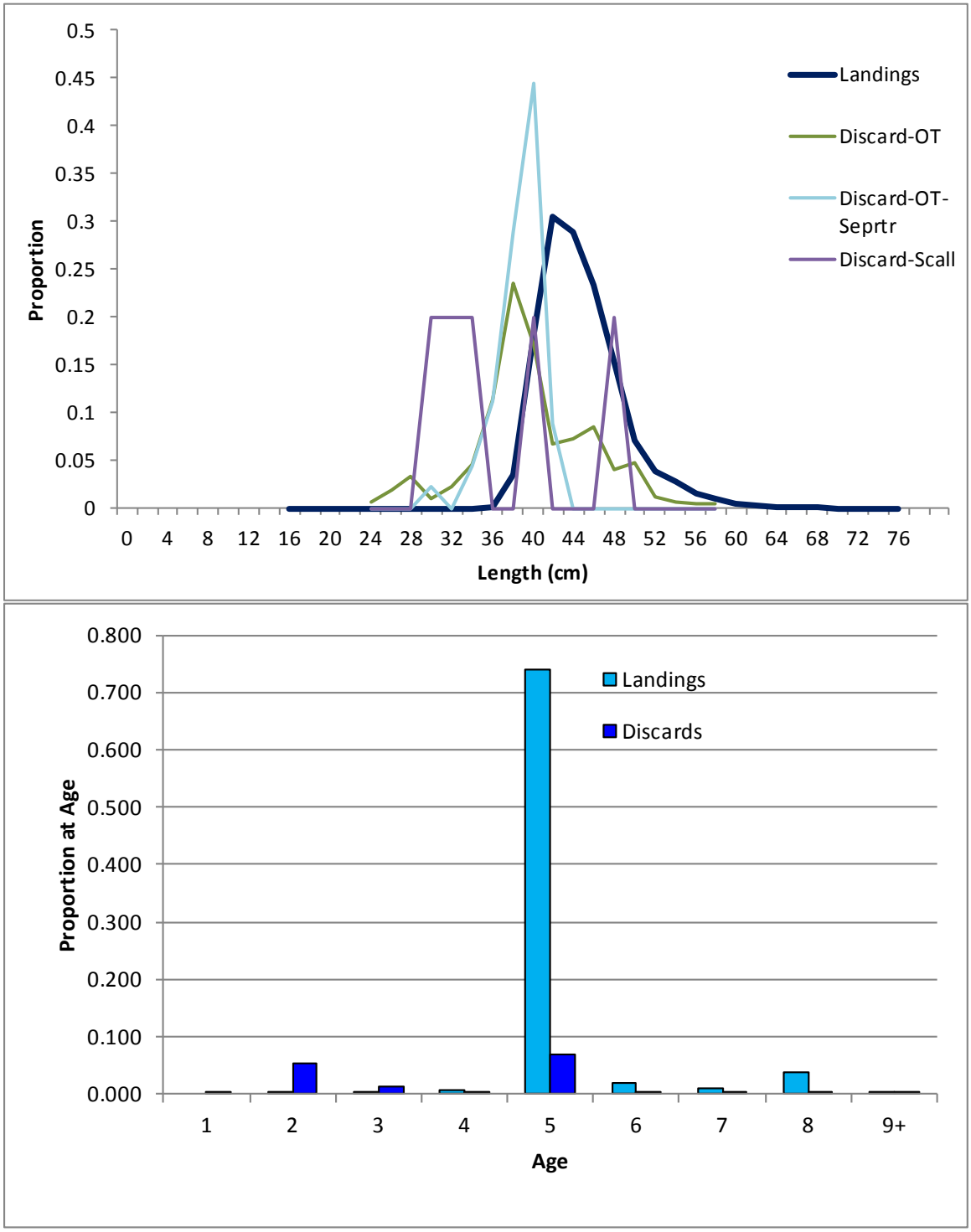

Figure 7. USA Eastern Georges Bank haddock fishery catch at size (top panel) and catch at age (bottom panel) as a proportion for landings and discards in 2018.

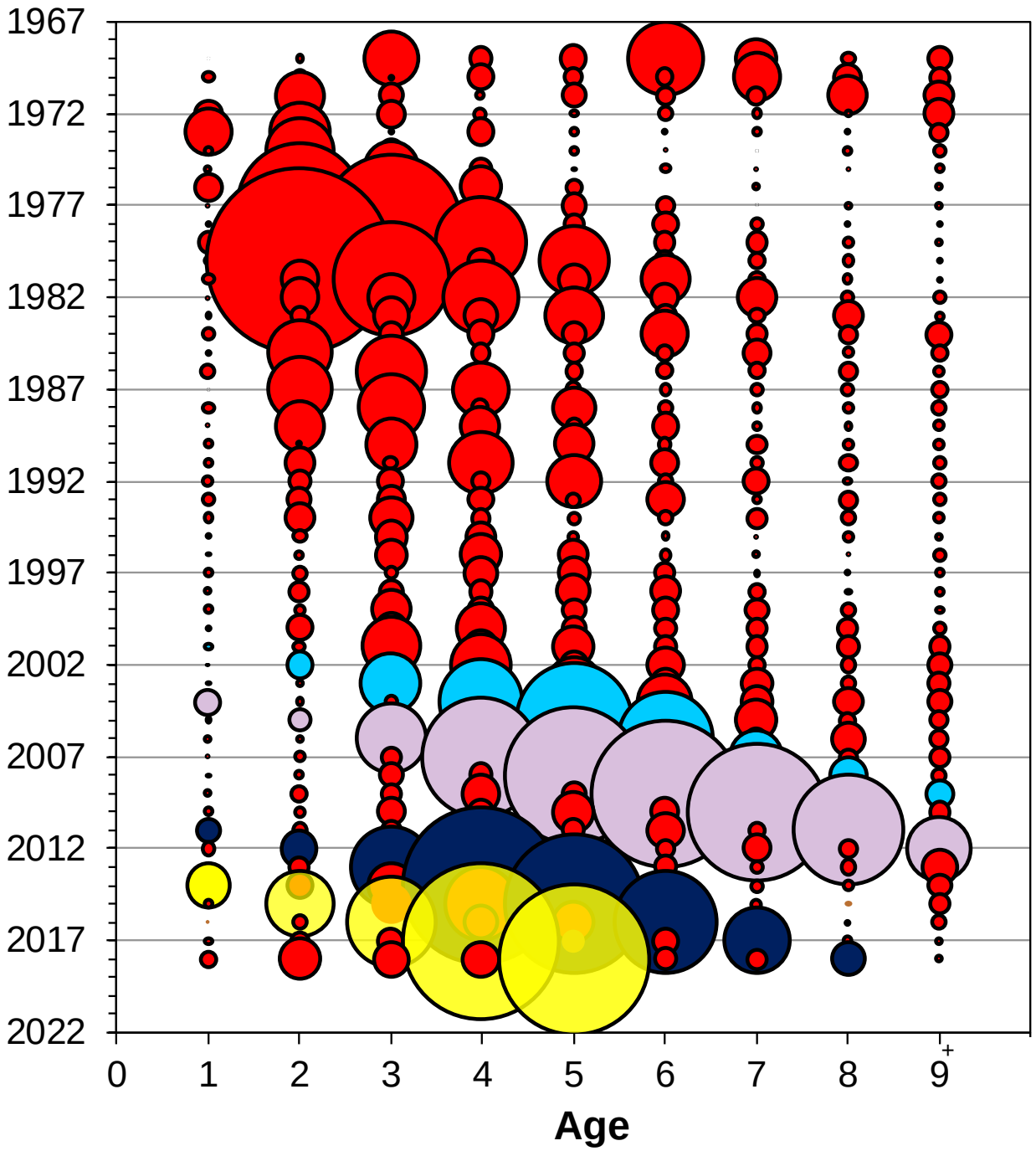

Figure 8. Total commercial catch at age (numbers) of eastern Georges Bank haddock during 1969-2018. The 2000, 2003, 2010 and 2013 year classes are indicated in blue, purple, dark blue, and yellow respectively. The bubble area is proportional to catch magnitude.

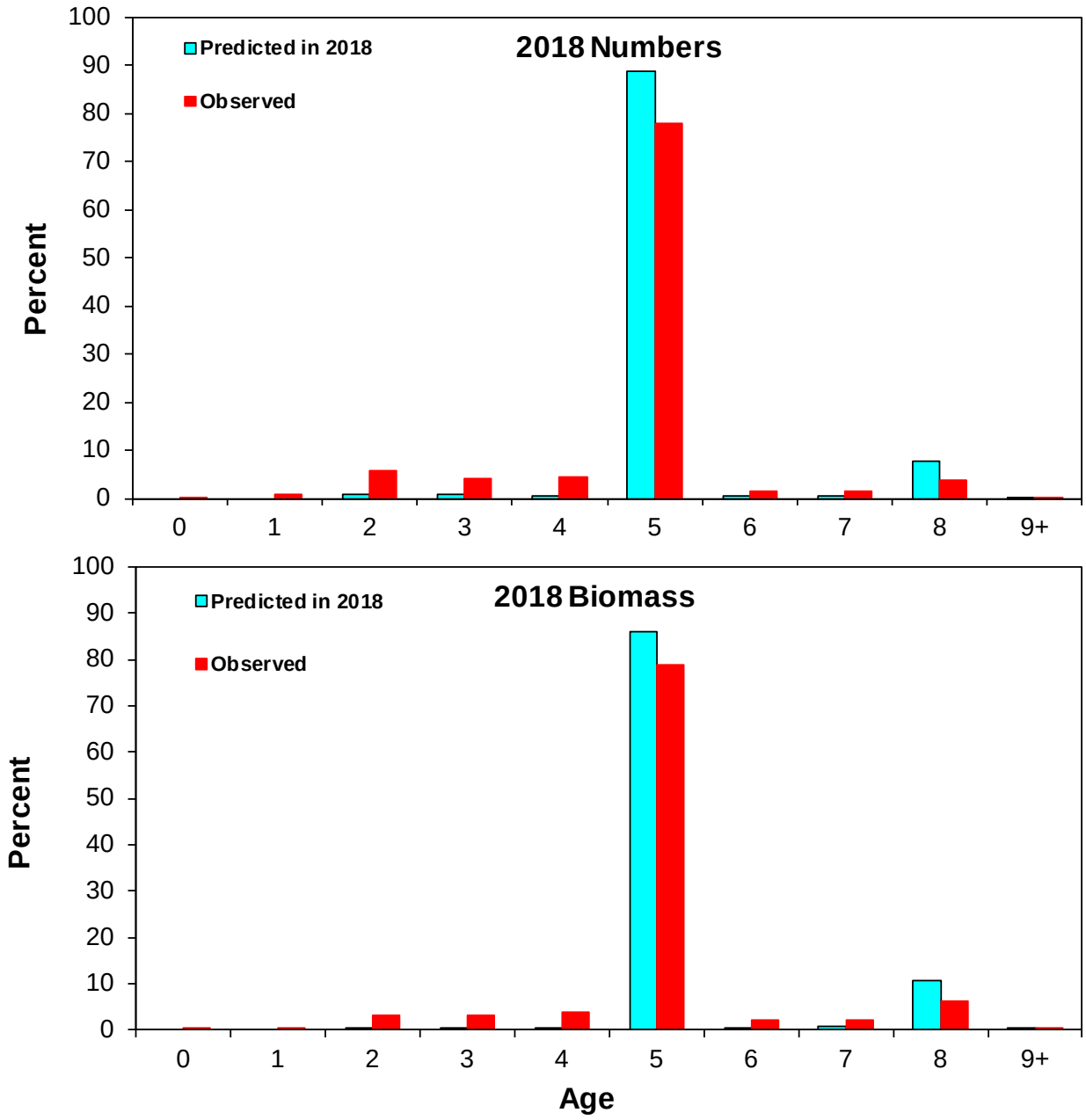

Figure 9. Percent composition in numbers and biomass of eastern Georges Bank haddock based on landings predicted to occur in 2018 and observed landings in 2018.

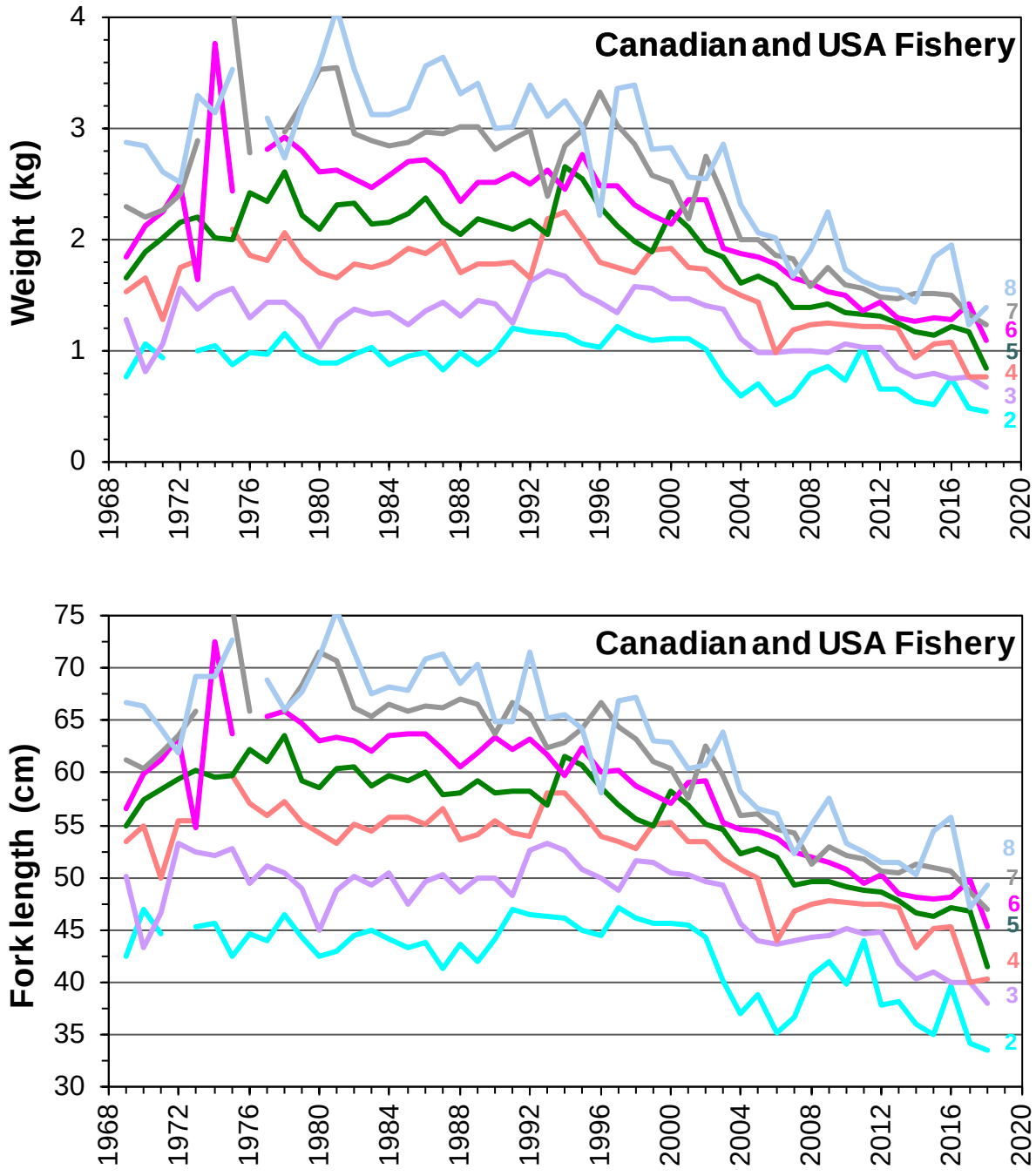

Figure 10. Average weights at age (Upper Panel) and lengths at age (Lower Panel) for eastern Georges Bank haddock from the combined Canadian and USA commercial groundfish fishery for 1969-2018.

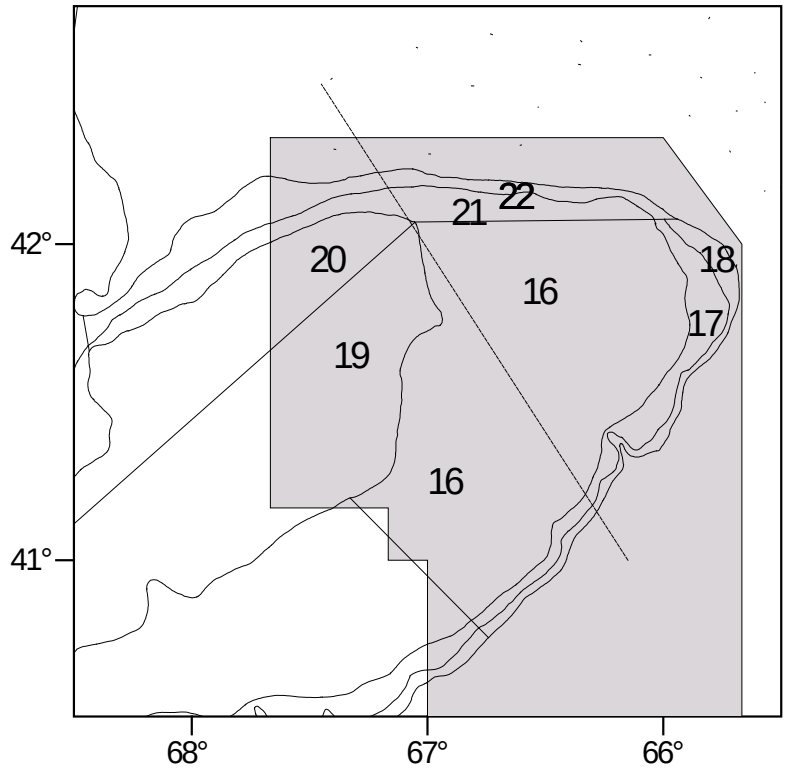

Figure 11. Stratification scheme used for National Marine Fisheries Service (NMFS) surveys. The eastern Georges Bank management area is indicated by shading.

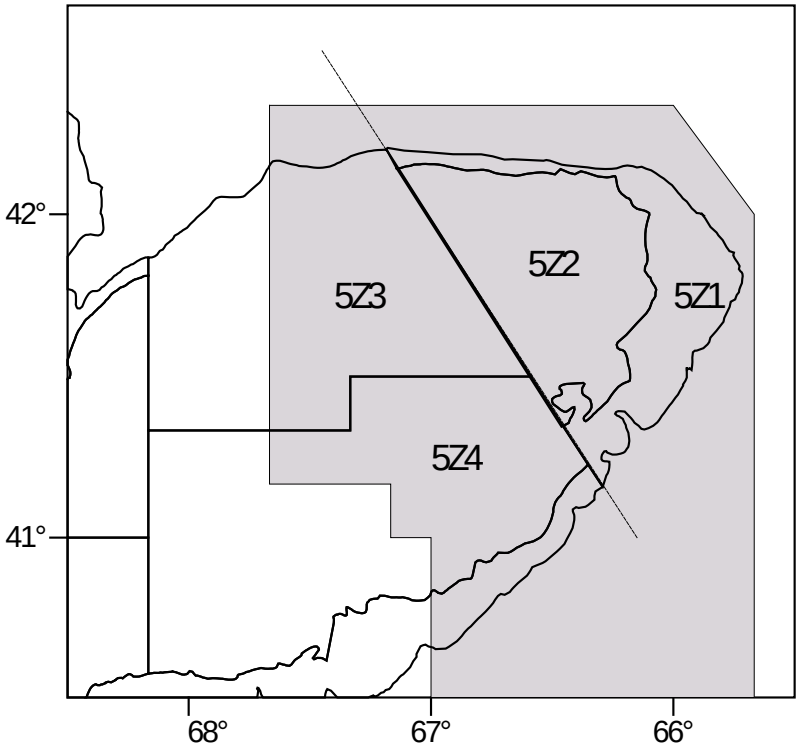

Figure 12. Stratification scheme used for the Canadian Department of Fisheries and Oceans (DFO) survey. The eastern Georges Bank management area is indicated by shading.

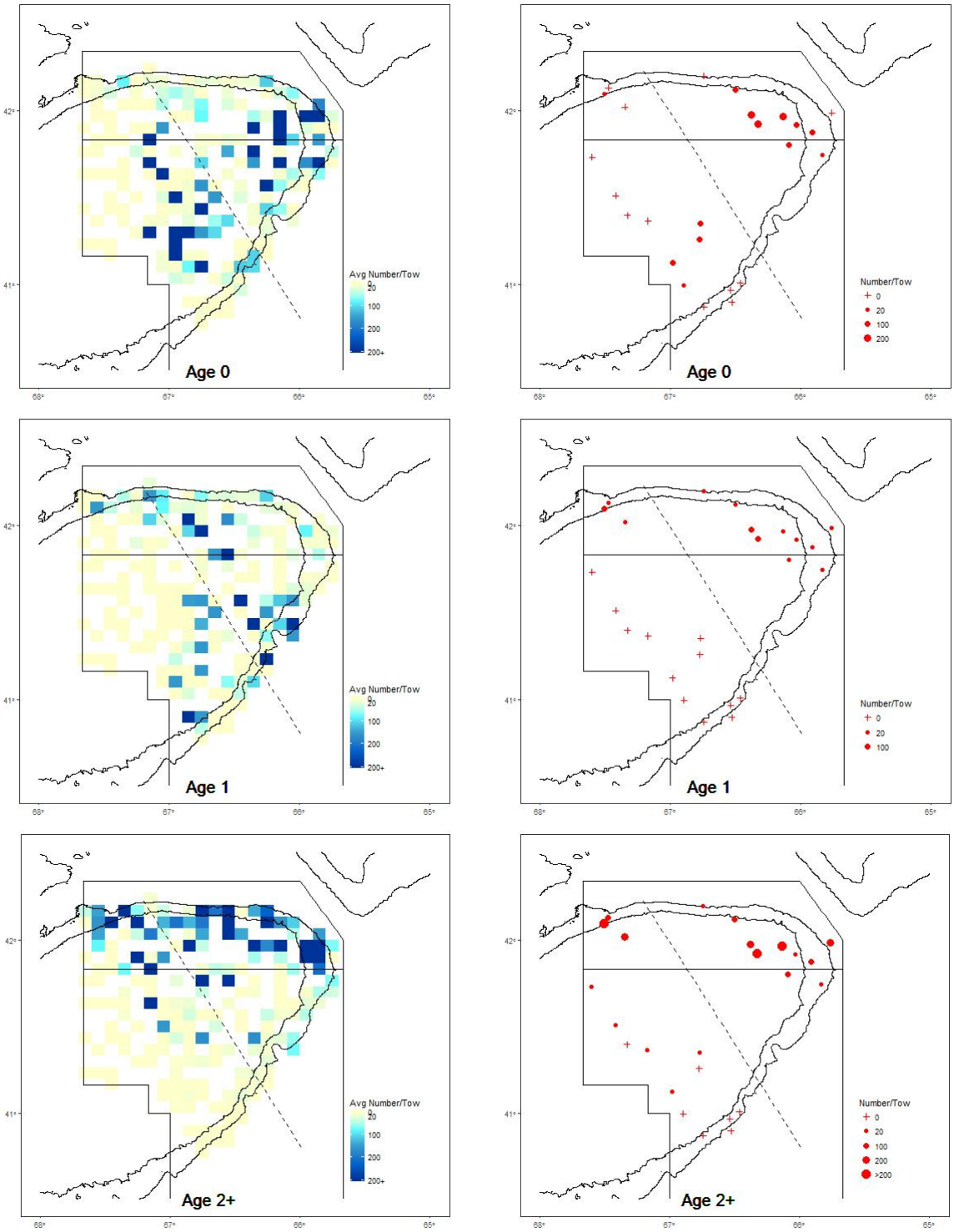

Figure 13. Distribution of eastern Georges Bank haddock abundance (number/tow) as observed from the NMFS **fall** survey for ages 0, 1 and 2+. The squares (left panels) are shaded relative to the average survey catch for 2008 to 2017. The expanding symbols (right panels) represent the **2018** survey catches. Length based conversion coefficients have been applied since the 2009 survey to make them comparable to surveys undertaken by the *Albatross IV*.

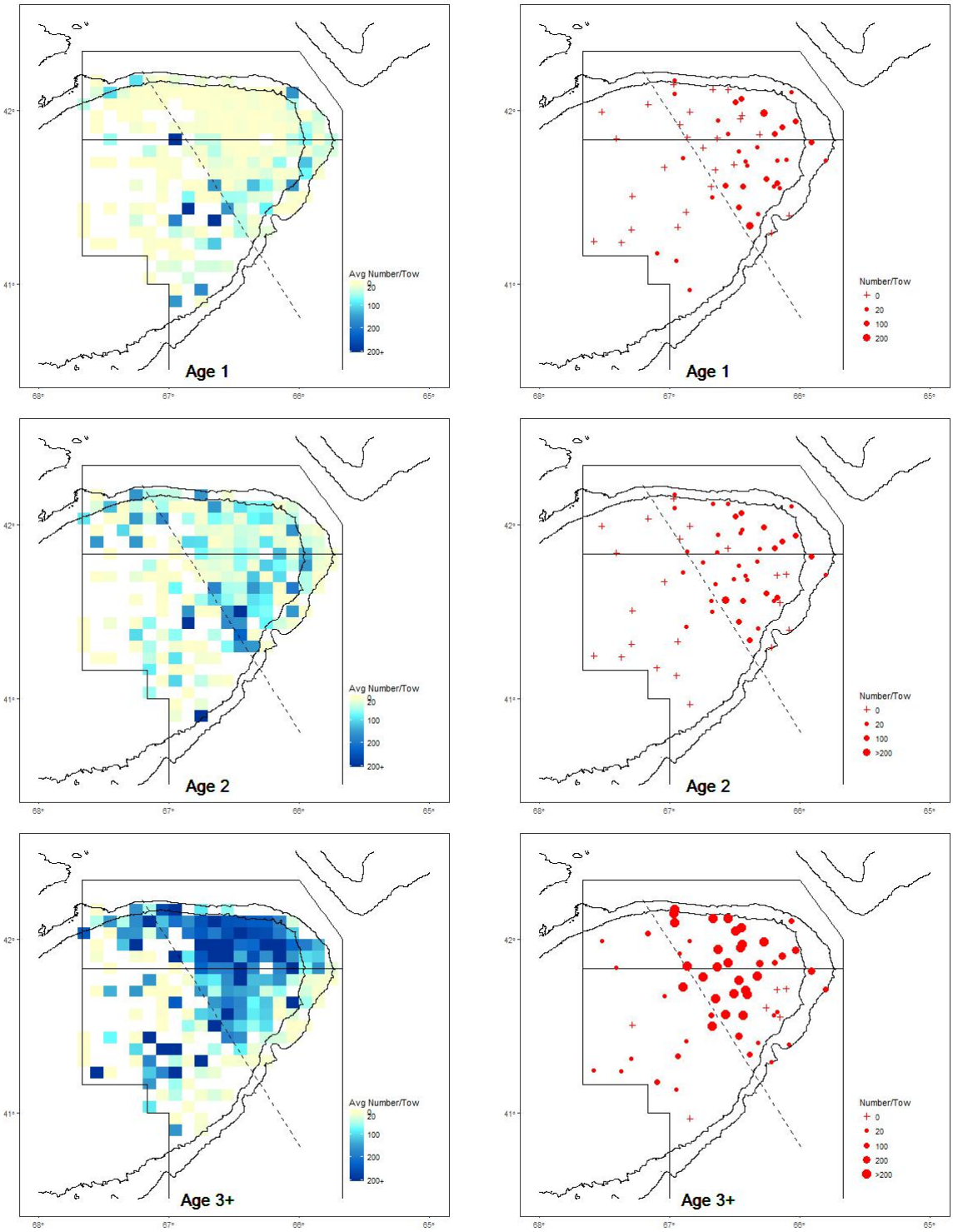

Figure 14. Distribution of eastern Georges Bank haddock abundance (number/tow) as observed from the DFO winter survey for ages 1, 2 and 3+. The squares (left panels) are shaded relative to the average survey catch for 2009 to 2018. The expanding symbols (right panels) represent the **2019** survey catches.

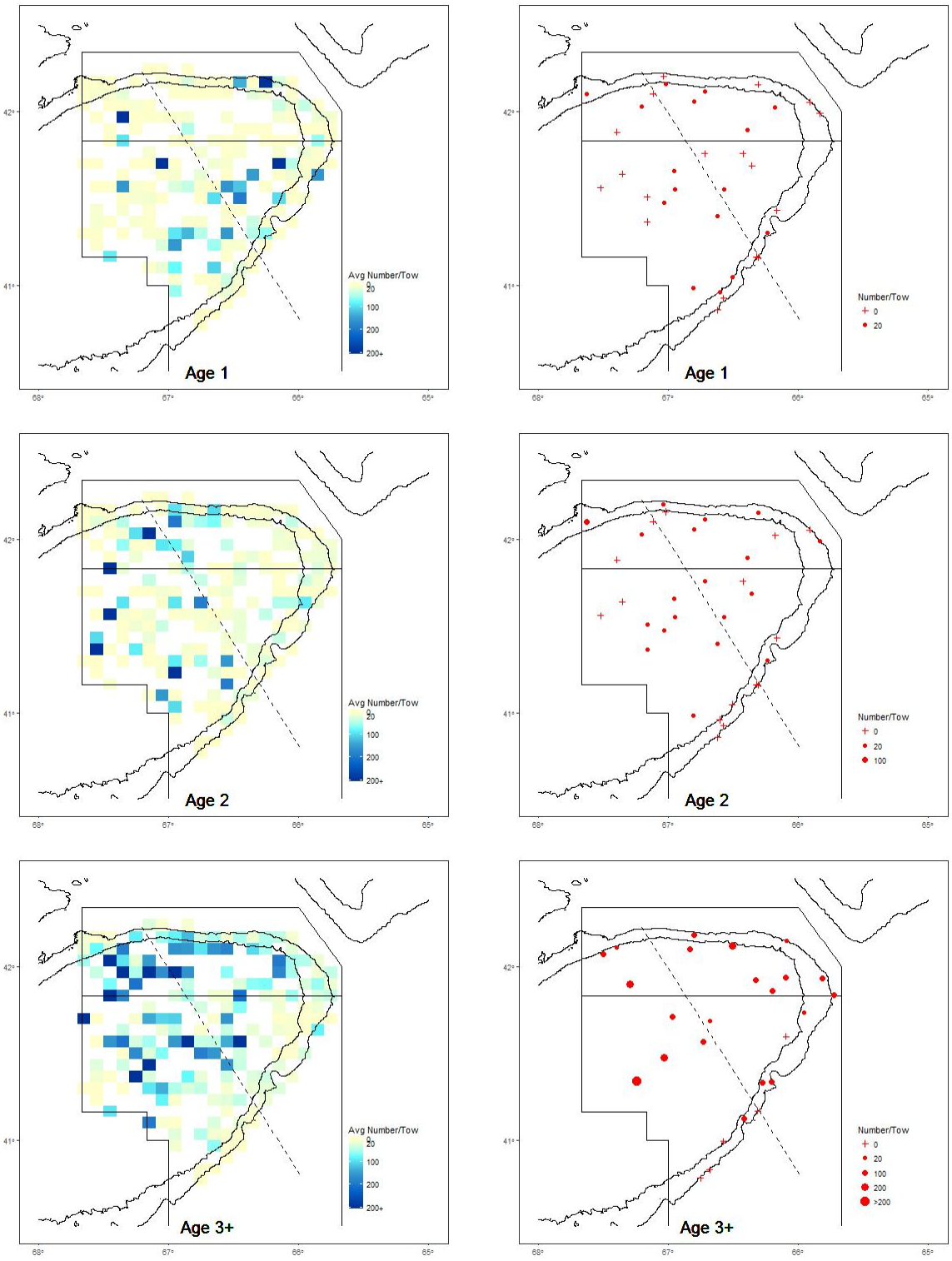

Figure 15. Distribution of eastern Georges Bank haddock abundance (number/tow) as observed from the National Marine Fisheries Service **spring** survey for ages 1, 2 and 3+. The squares (left panels) are shaded relative to the average survey catch for 2007 to 2018. The expanding symbols (right panels) represent the **2019** survey catches. Length based conversion coefficients have been applied since the 2009 survey to make them comparable to surveys undertaken by the *Albatross IV*.

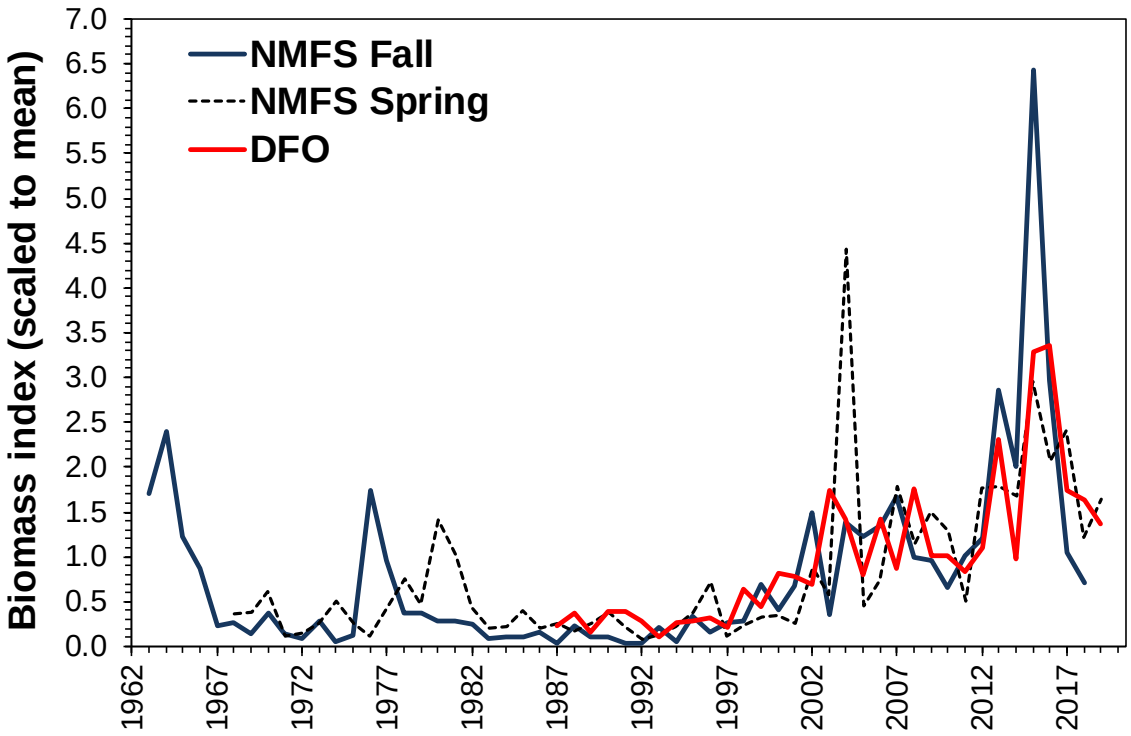

Figure 16. Scaled total biomass indices from NMFS fall (1963-2018), NMFS spring (1968-2019) and DFO (1987-2019) research surveys for eastern Georges Bank. Biomass conversion coefficients have been applied to the NMFS surveys to adjust for changes in door type (BMV *vs* Polyvalent; 1968-1984), vessel (*Delaware II vs Albatross IV;* 1968-2008) and vessel/net (*Albatross IV* vs *Henry B. Bigelow;* Yankee 36 *vs* 4 seam-3 bridle; 2009-2019).

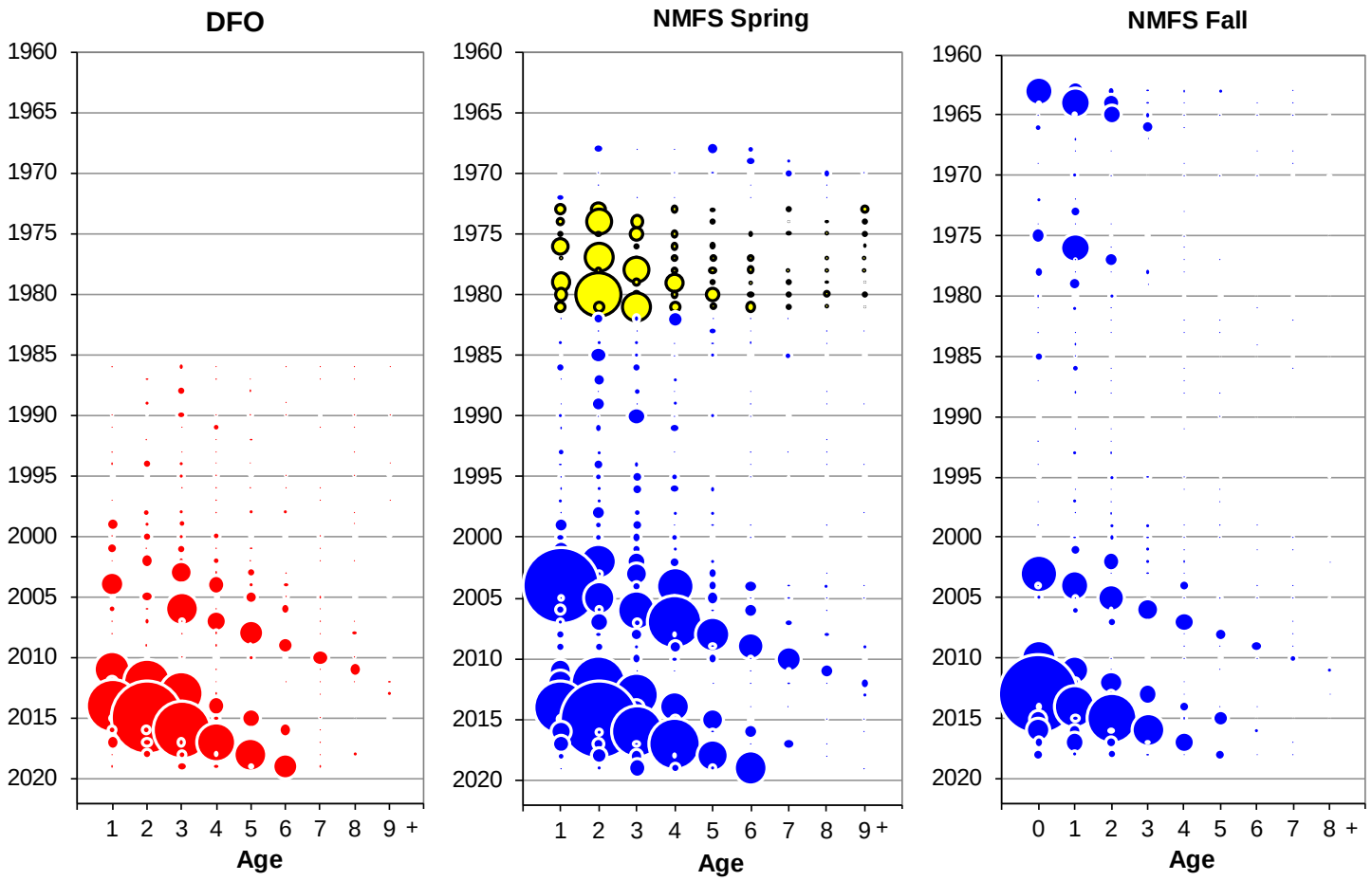

Figure 17. Estimated abundance at age (numbers in 000's) of eastern Georges Bank haddock for the Canadian Department of Fisheries and Oceans (DFO) for 1986 to 2019, the National Marine Fisheries Service (NMFS) spring survey for 1968 to 2019 and the NMFS fall survey for 1963 to 2018. Bubble area is proportional to magnitude (see Tables 18-20). Conversion factors to adjust for changes in door type and survey vessel were applied to the NMFS surveys. From 1973-81 (yellow circles), a 41 Yankee trawl was used for the NMFS spring survey while a 36 Yankee was used in the other years. Length based conversion coefficients have been applied to the NMFS surveys since the 2009 survey to make them comparable to surveys undertaken by the *Albatross IV*. Symbol size has not been adjusted between surveys for the catchability of the survey.

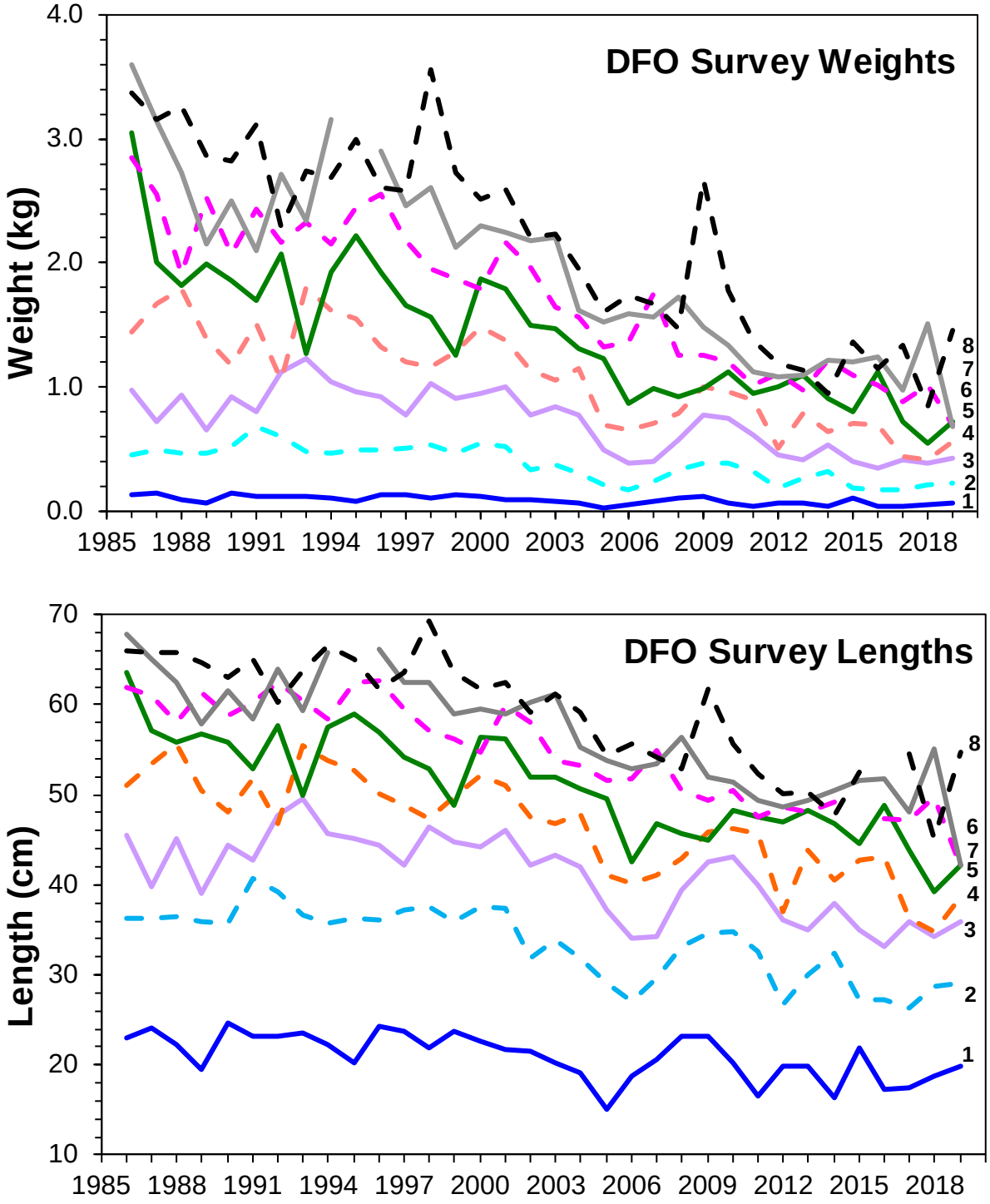

Figure 18. Average weights (upper panel) and lengths (lower panel) at age for eastern Georges Bank haddock derived from DFO winter surveys during 1986-2019.

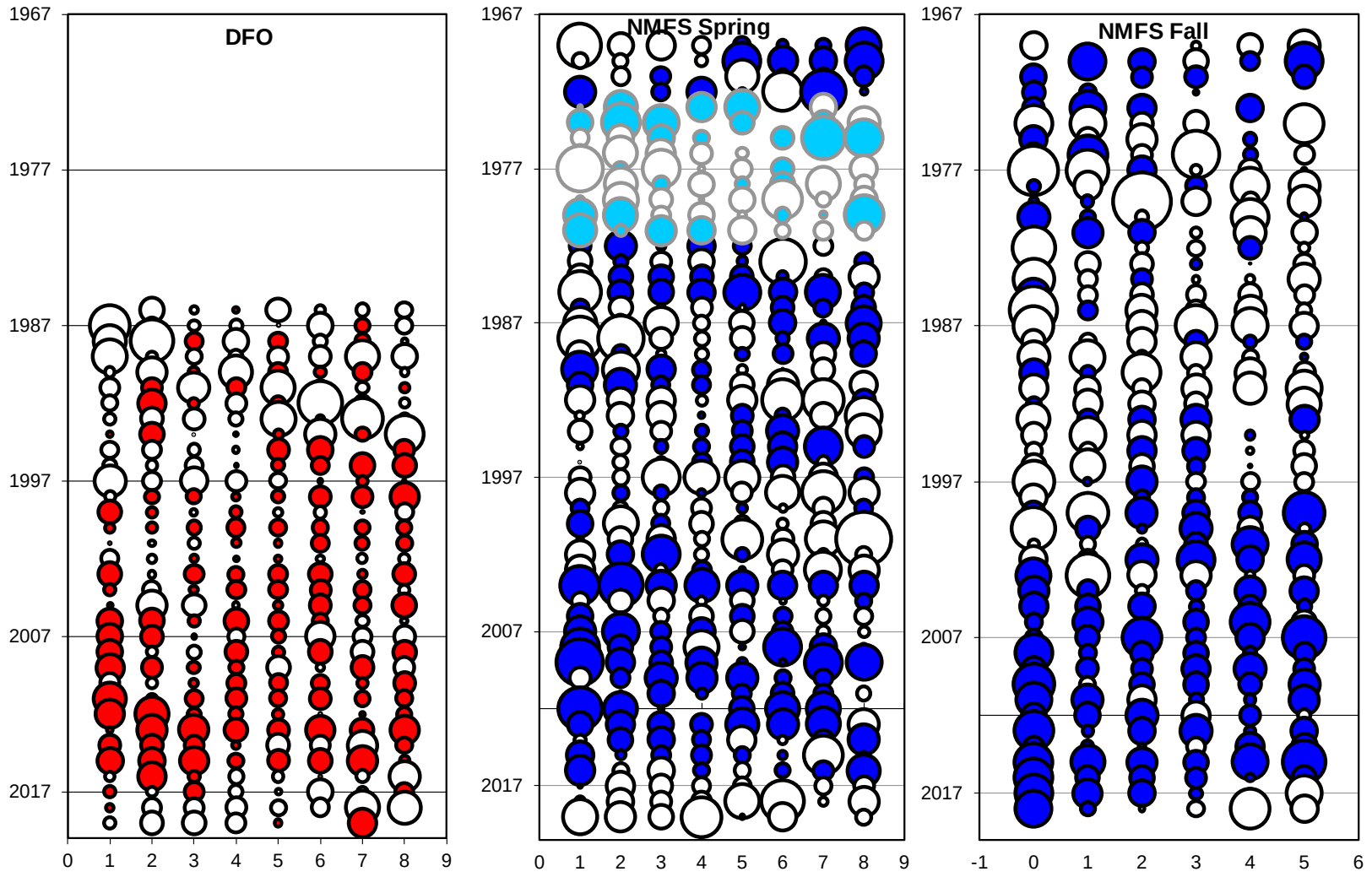

Figure 19. Residuals of survey abundance indices by year and age group from the DFO survey (1986-2019), the NMFS spring survey (1969-2019) and the NMFS fall survey (1969-2018) for eastern Georges Bank haddock. Solid symbols indicate positive values (i.e. model predicts lower abundance than surveys), open symbols indicate negative values (i.e. model predicts higher abundance than surveys). Bubble area is proportional to magnitude. From 1973-81 (light blue circles), a Yankee 41 trawl was used for the NMFS spring survey while a Yankee 36 trawl was used in the other years.

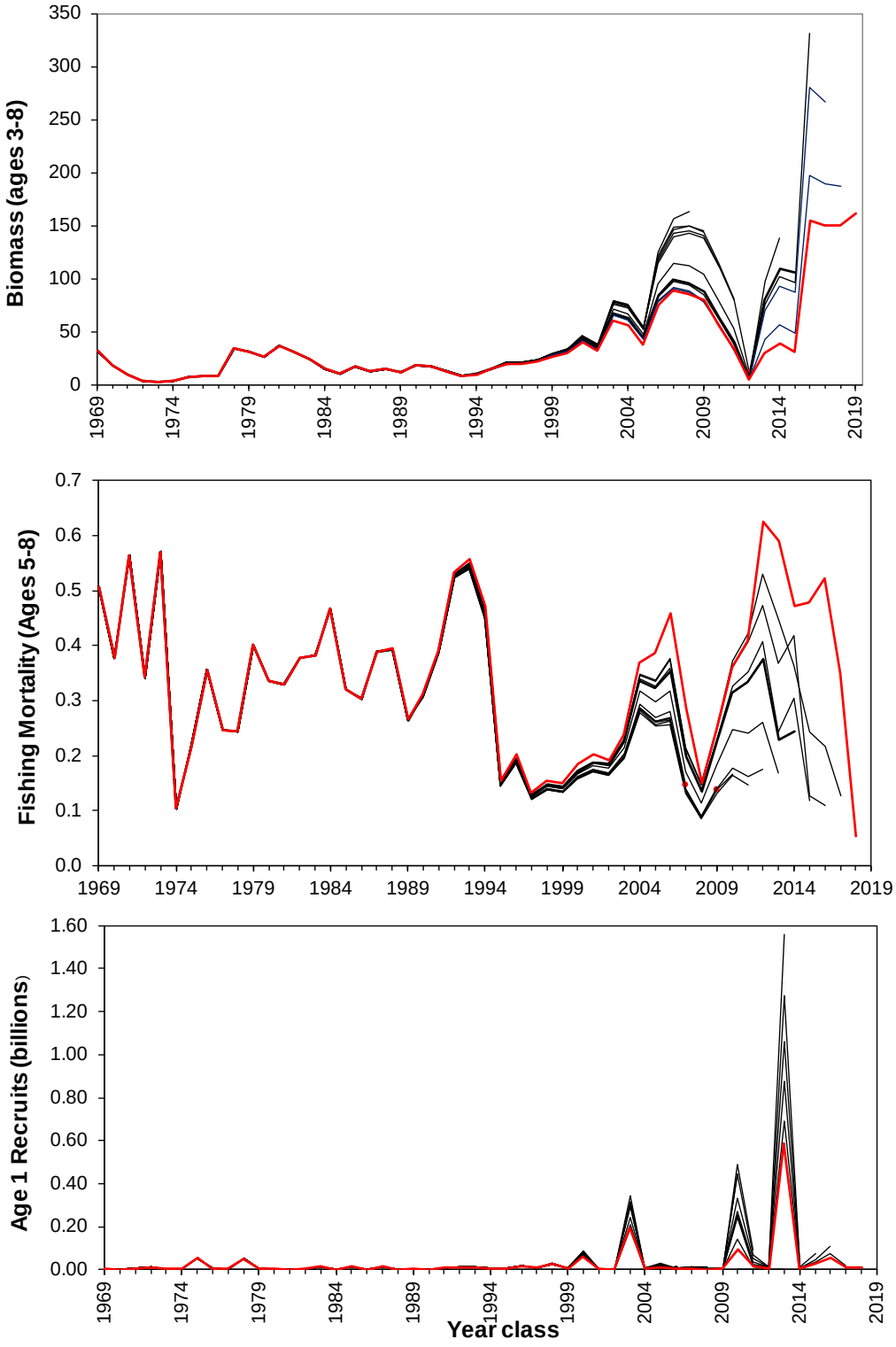

Figure 20. Retrospective results from virtual population analysis for eastern Georges Bank haddock for biomass (ages 3-8), fishing mortality (ages 5-8) and recruitment (age 1) as successive years of data are removed from the assessment. The most recent assessment results are indicated in red.

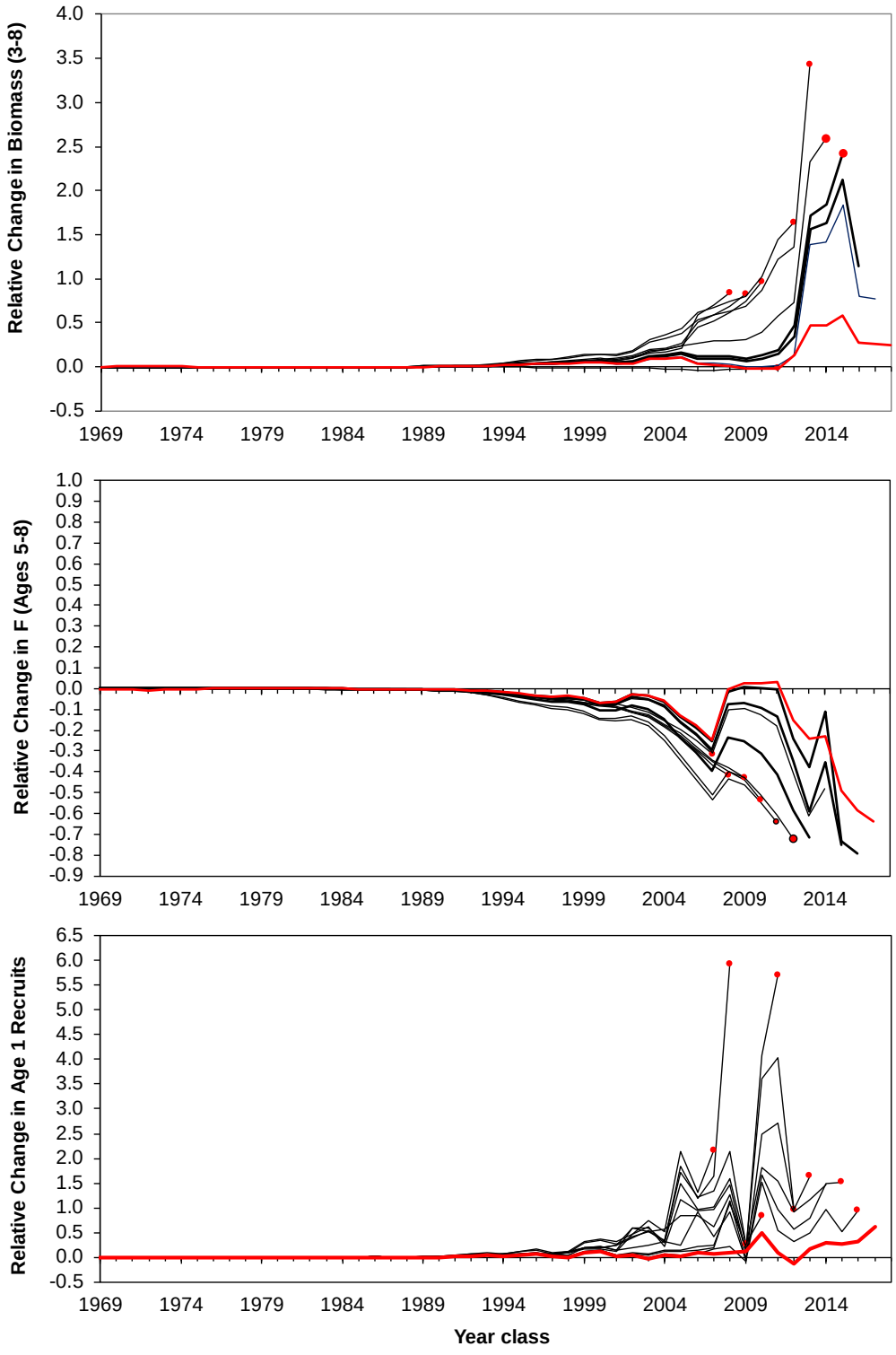

Figure 21. Relative retrospective results from virtual population analysis for eastern Georges Bank haddock for biomass (ages 3-8), fishing mortality (ages 5-8) and recruitment (age 1) as successive years of data are removed from the assessment. Changes are relative to the 2019 assessment.

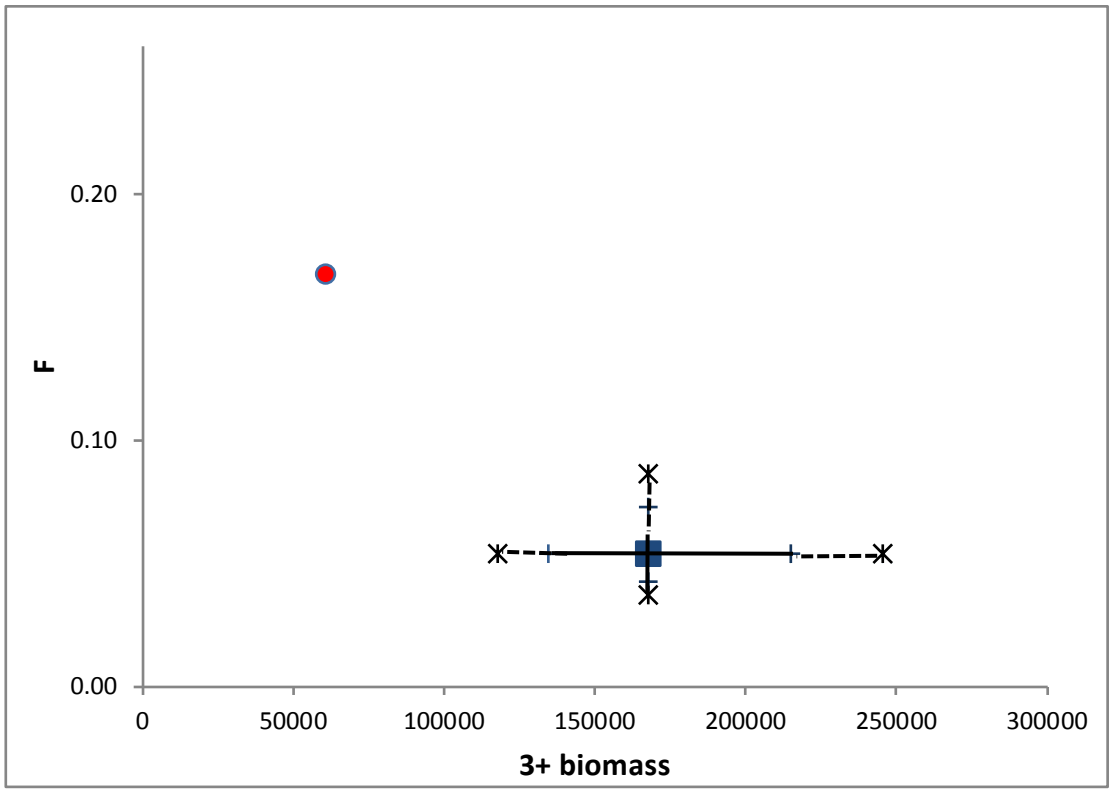

Figure 22. Estimate of fishing mortality on ages 5 to 8 and ages 3+ biomass estimated using the Benchmark VPA formulation (blue square) and the rho adjusted value (red circle). The solid lines show the 80% confidence interval around the benchmark estimate, while the dotted lines show the 95% confidence interval. (Note: The % rho adjustment value of 0.564 for Ages 3-8 biomass was used to adjust the age 3+ biomass estimate at the beginning of 2017).

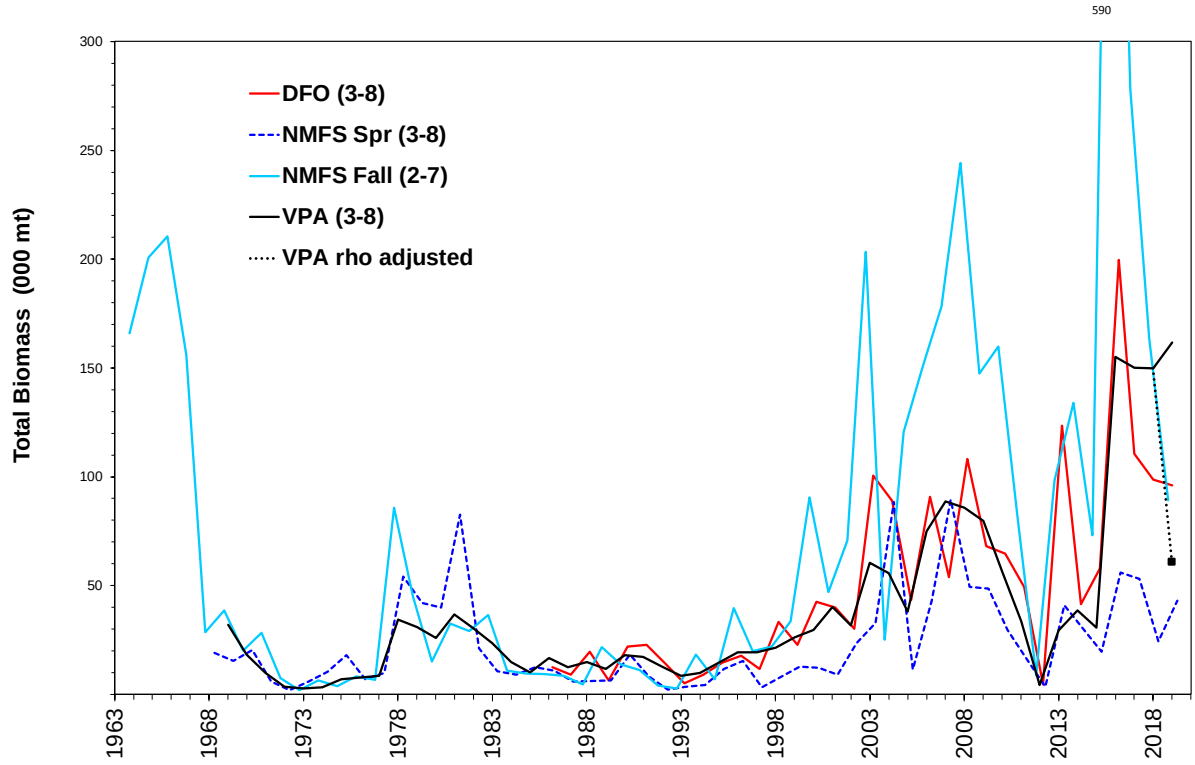

Figure 23. The 1969 to 2019 eastern Georges Bank adult haddock (ages 3-8) biomass from virtual population analysis compared with the survey adult biomass (scaled with catchabilities from 2019) for ages 3-8 (DFO and NMFS spring) and ages 2-7 (NMFS fall).

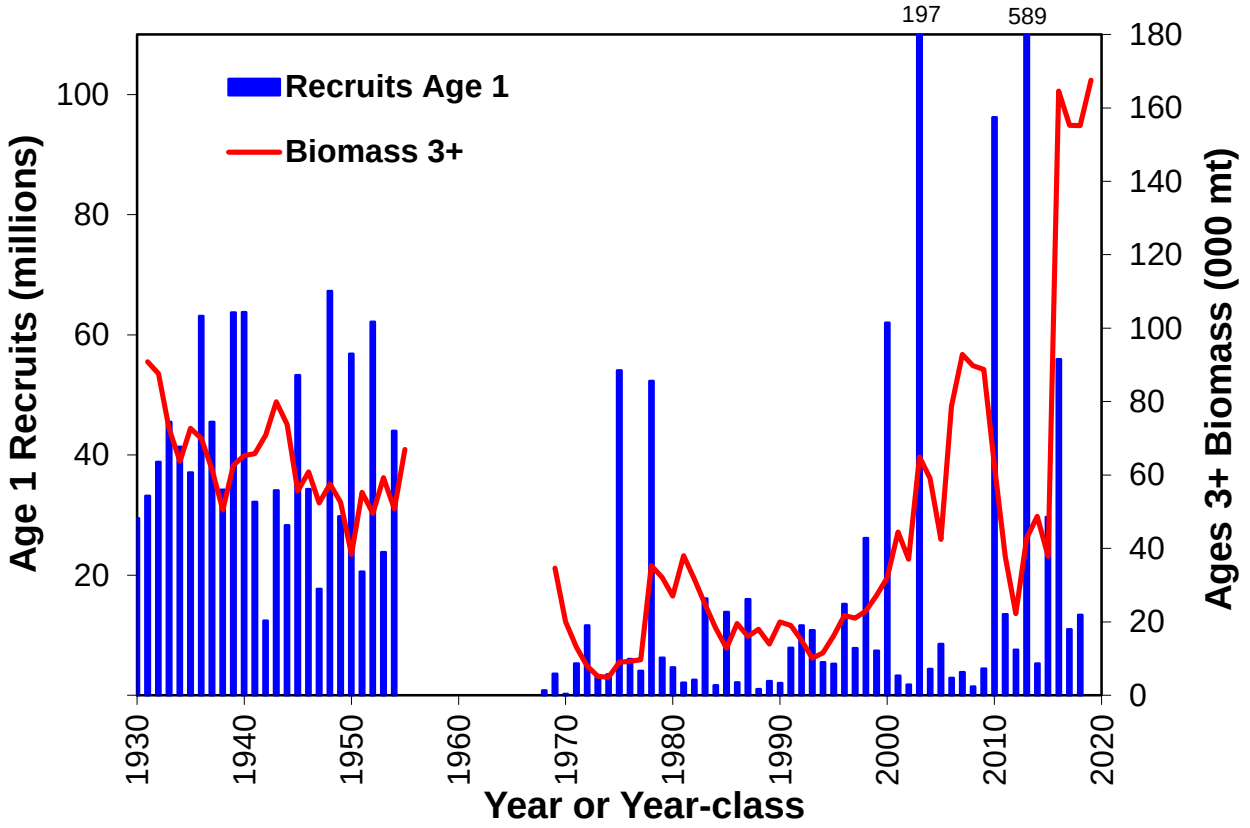

Figure 24. Beginning of year adult (3+) biomass and number of age 1 recruits for eastern Georges Bank haddock during 1931-1955 and 1969-2019.

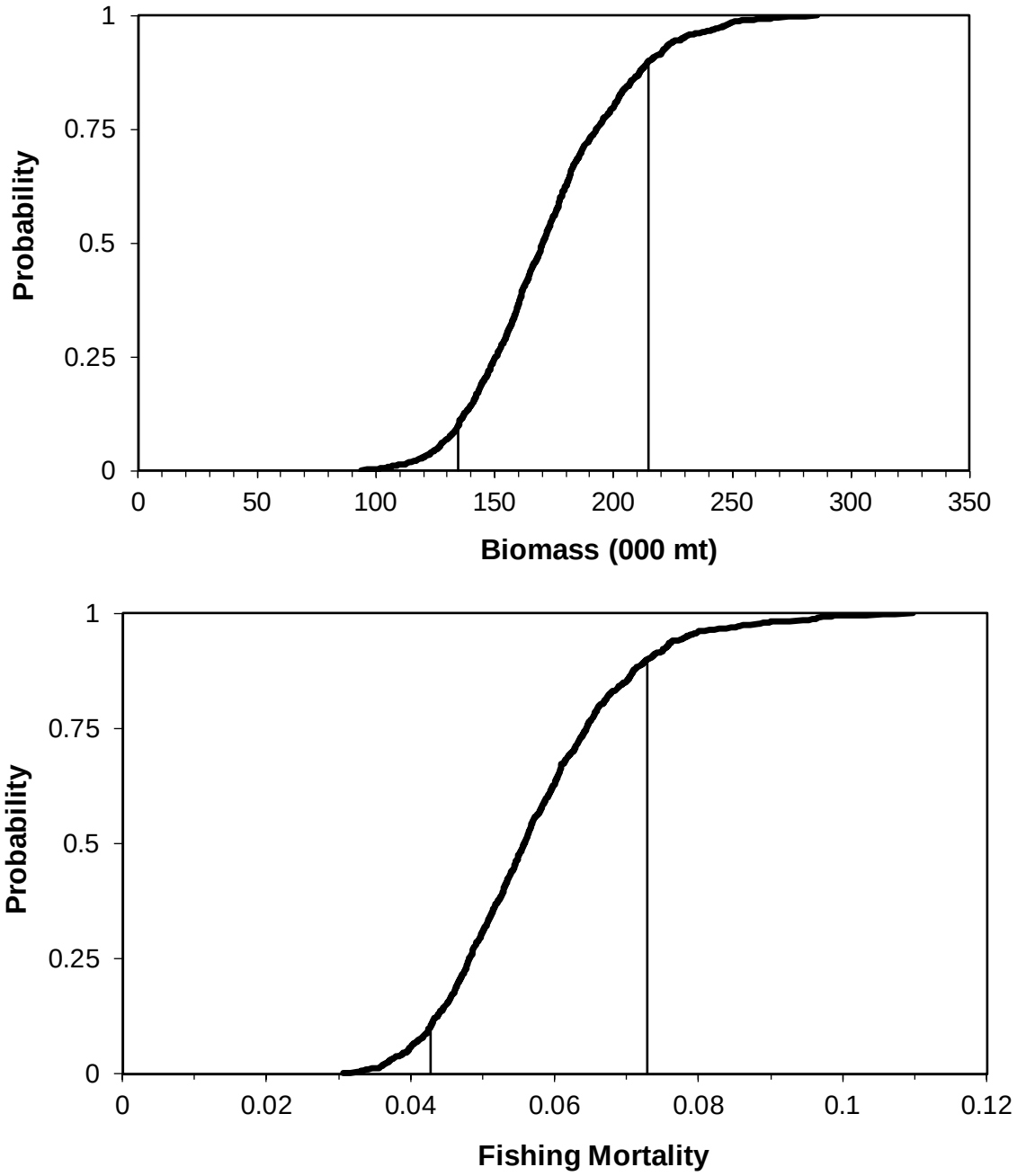

Figure 25. Cumulative probability distribution with 80% confidence intervals for 2019 age 3+ biomass (000 mt) and 2018 ages 5-8 fishing mortality for eastern Georges Bank haddock. CI for biomass = 134,600-214,892 mt; CI for F = 0.04-0.07.

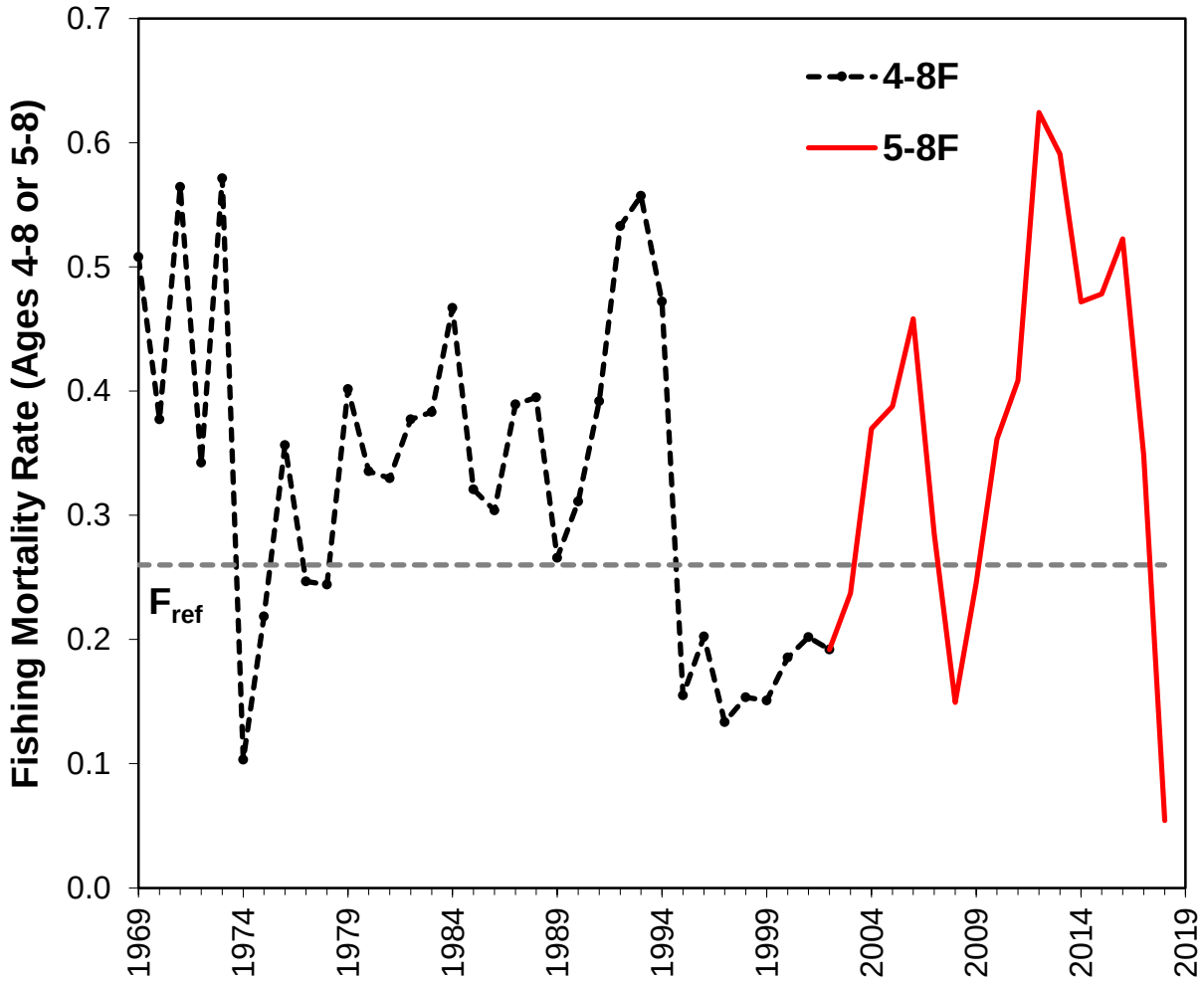

Figure 26. Fishing mortality rate (weighted by population) for eastern Georges Bank haddock ages 4+ and 5+ during 1969-2018 and the fishing mortality threshold reference established at F_{ref} = 0.26.

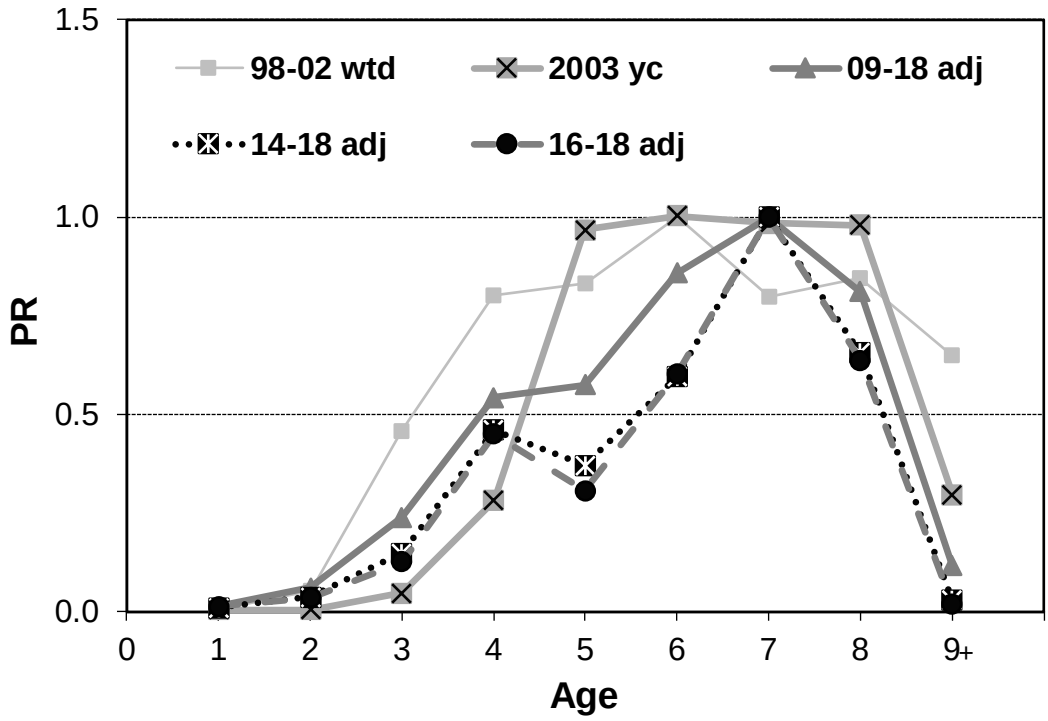

Figure 27. The average partial recruitment of eastern Georges Bank haddock for 1998-2002 (population weighted), 2009-2018, 2014-2018, 2016-2018 and for the 2003 year class. The partial recruitment is normalized to ages 4-8 for years before 2003 and to ages 5-8 for years after 2002.

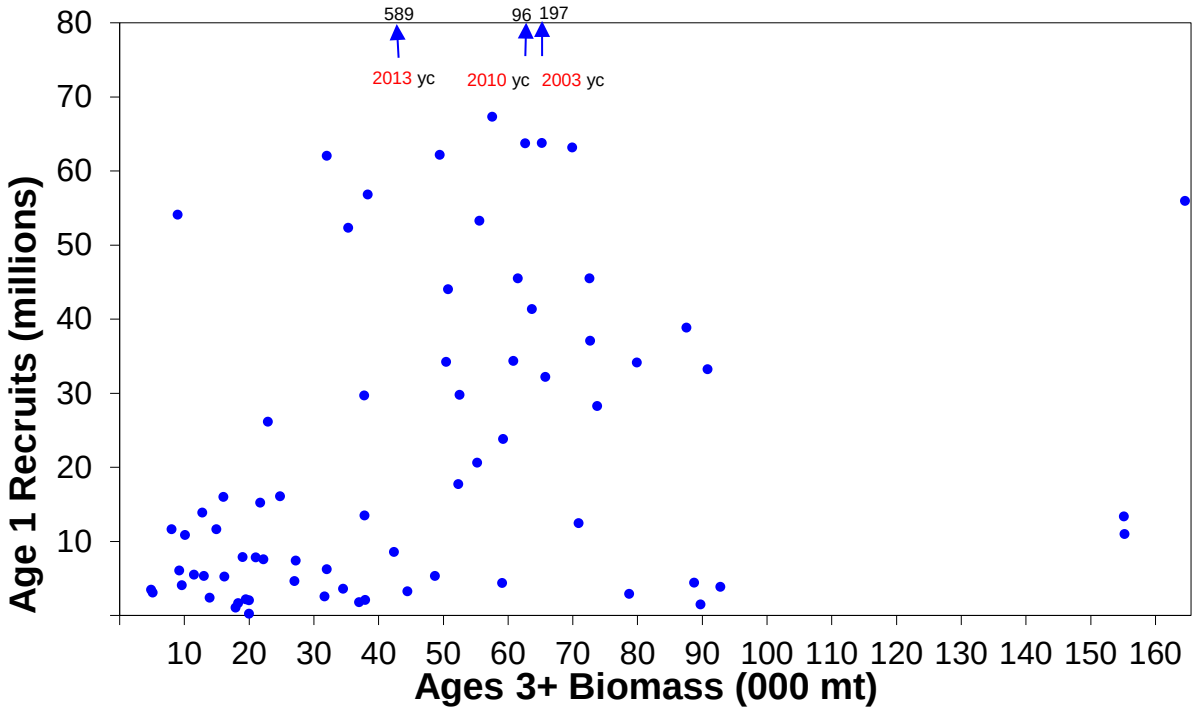

Figure 28. Relationship between eastern Georges Bank adult (ages 3+) haddock biomass during 1931-1955 and 1969-2018 and recruits at age 1. The large year classes since 2000 are labeled in red font.

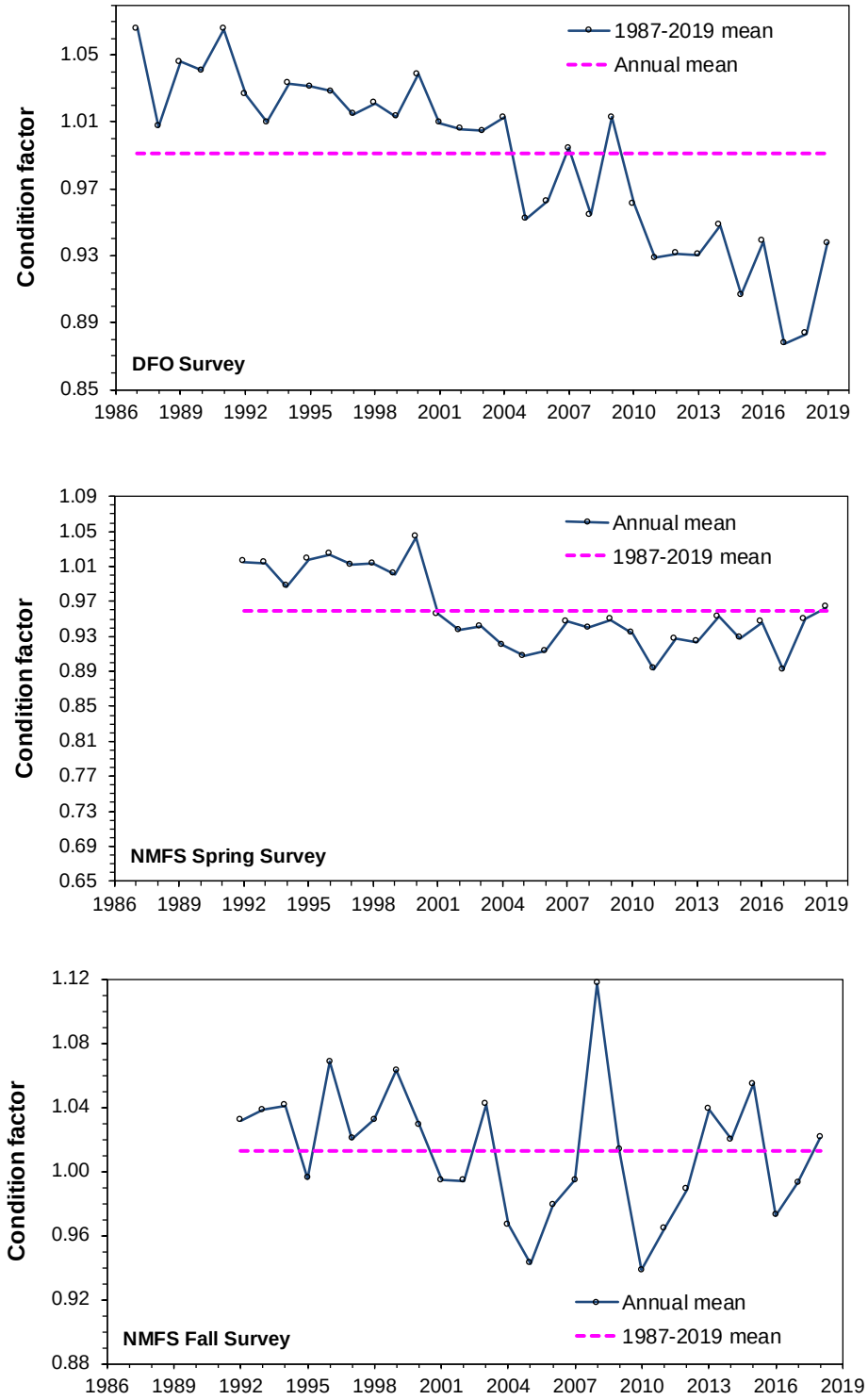

Figure 29. Annual mean condition as indicated by Fulton's K (W/L^3) for eastern Georges Bank haddock (30-70 cm FL) from the DFO survey (1986-2019; top panel), NMFS Spring Survey (1992-2019; middle panel) and NMFS fall survey (1992-2018; lower panel). The pink dashed line is the mean value for the survey time series.

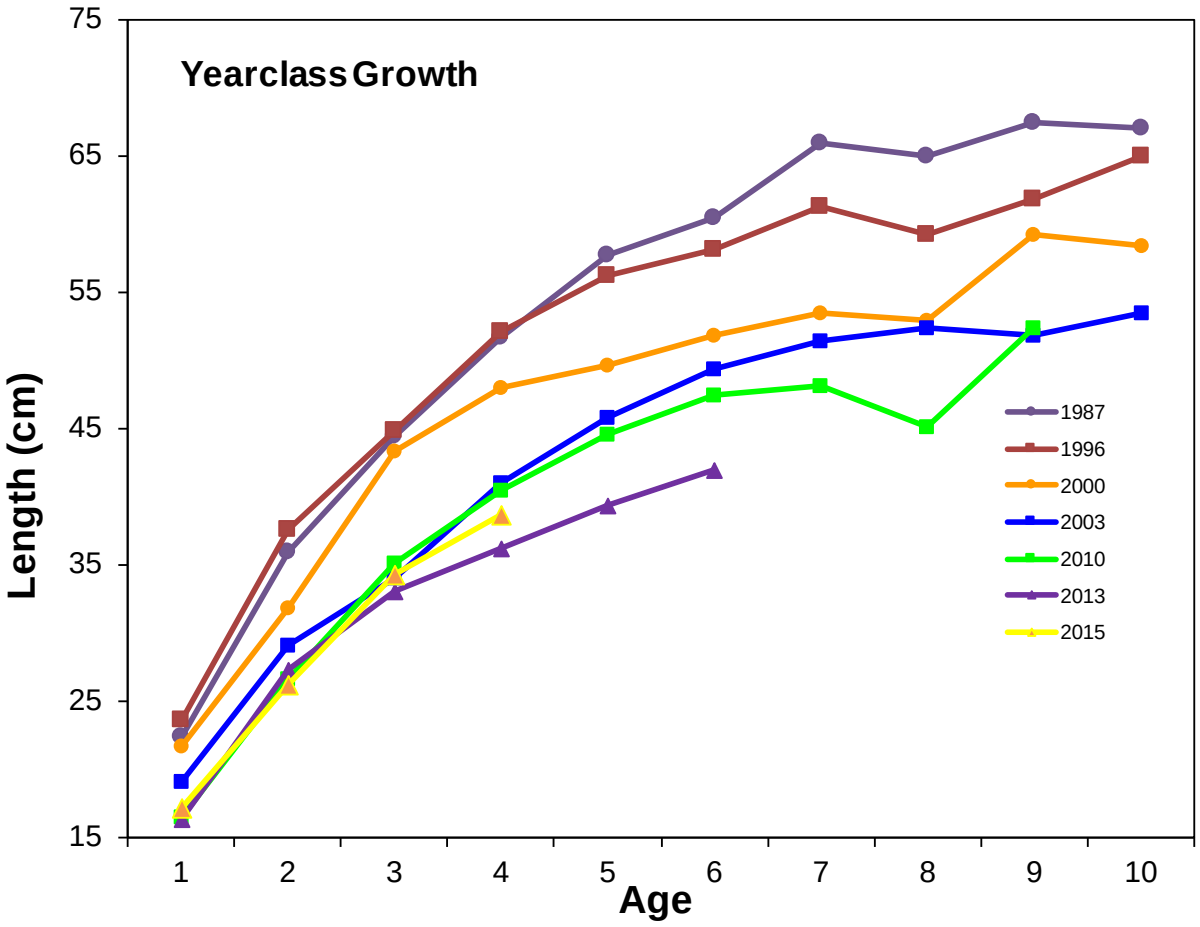

Figure 30. Mean length at age for selected year classes of eastern Georges Bank haddock sampled from the DFO survey.

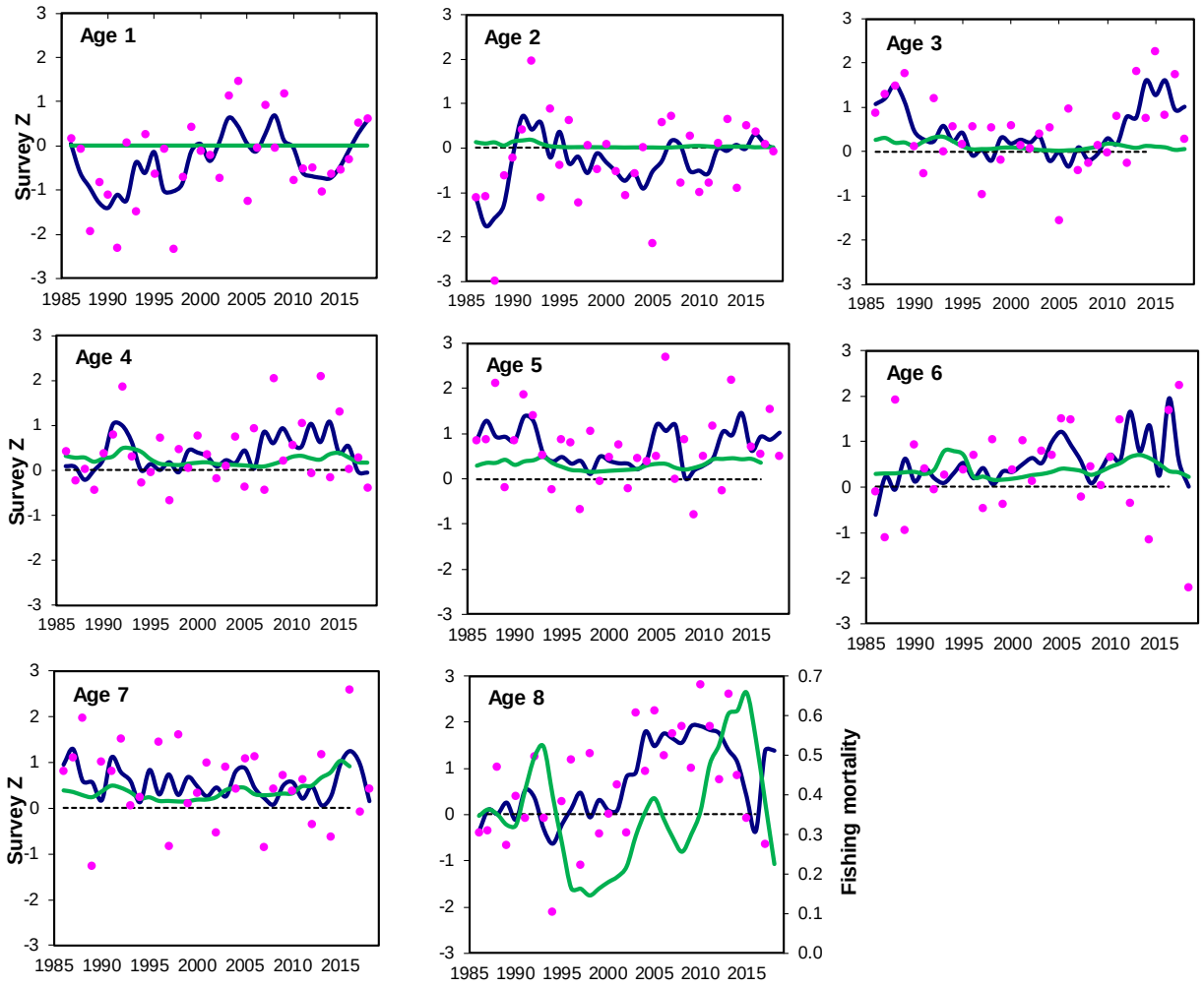

Figure 31. Eastern Georges Bank haddock total mortality (Z; 3-year smooth, navy blue line and pink circles are the annual z value) for ages 1-8 from DFO survey catch at age data, 1986-2018 compared to F for age 1-8 (F; 3-year smooth, green line) calculated from the 2019 VPA model output.

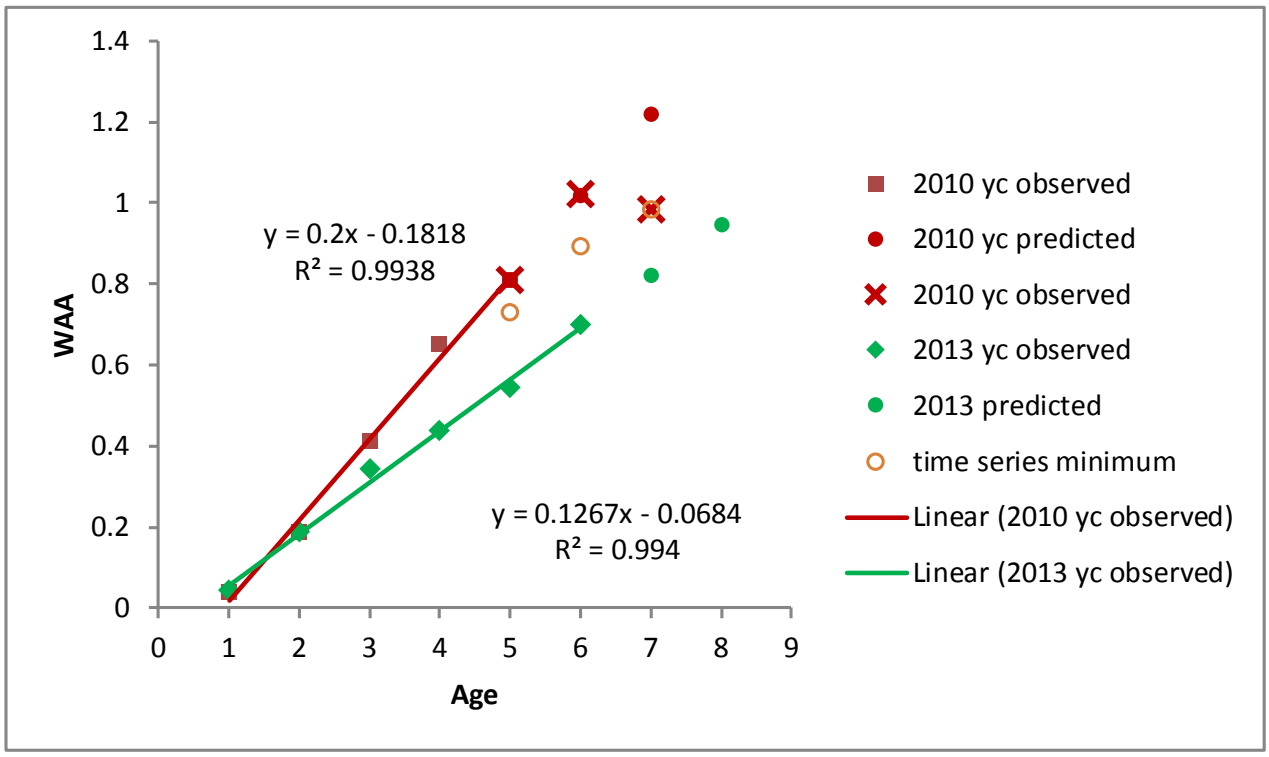

Figure 32. Linear regression model examining the relationship between survey weight and age of Eastern Georges Bank haddock. Solid squares (2010 yc) and diamonds (2013 yc) represent observed values for ages 1-5. Solid circles represent predicted values from the linear regression function. Open circles represent the minimum weight value in the time series (1969-2019). The X's represent the observed data for the 2010 year class based on the survey.

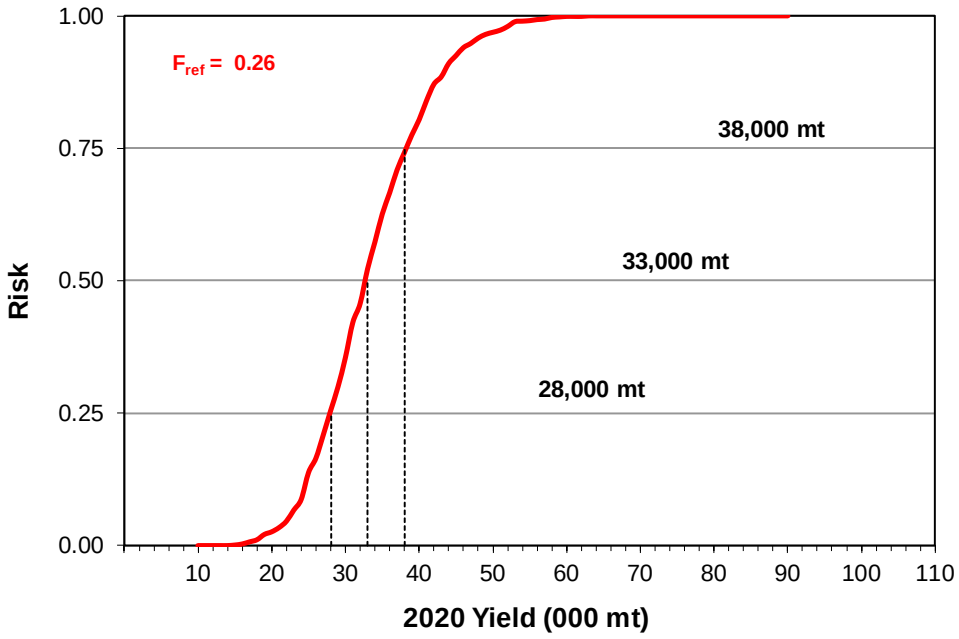

Figure 33. Risk of 2020 fishing mortality exceeding F_{ref} = 0.26 for eastern Georges Bank haddock for increasing catch quotas.

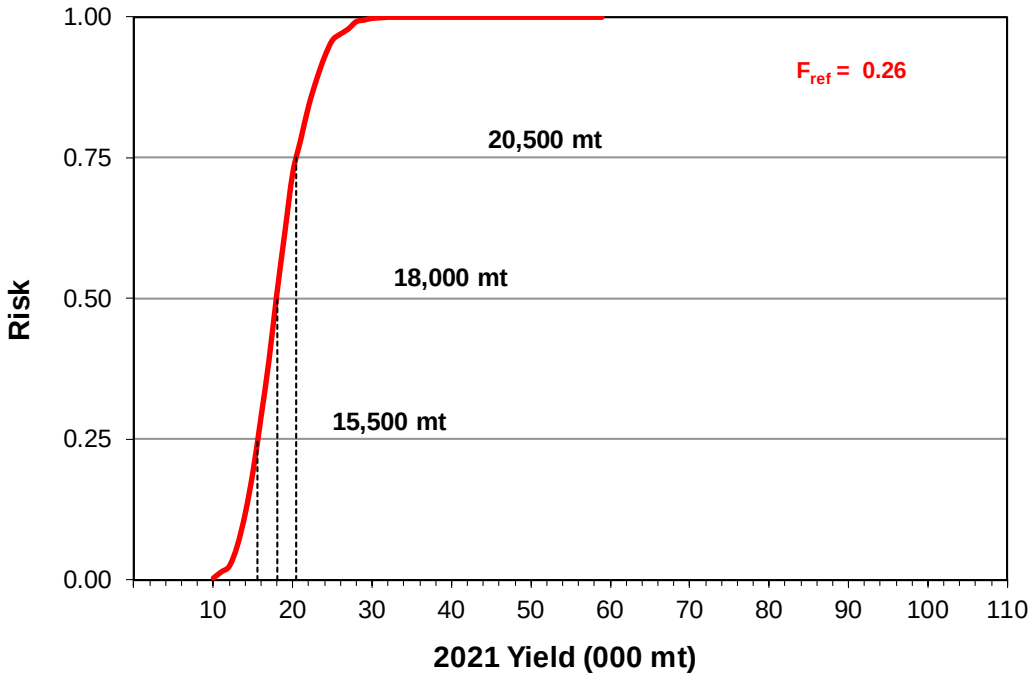

Figure 34. Risk of 2021 fishing mortality exceeding F_{ref} = 0.26 for eastern Georges Bank haddock for increasing catch quotas.

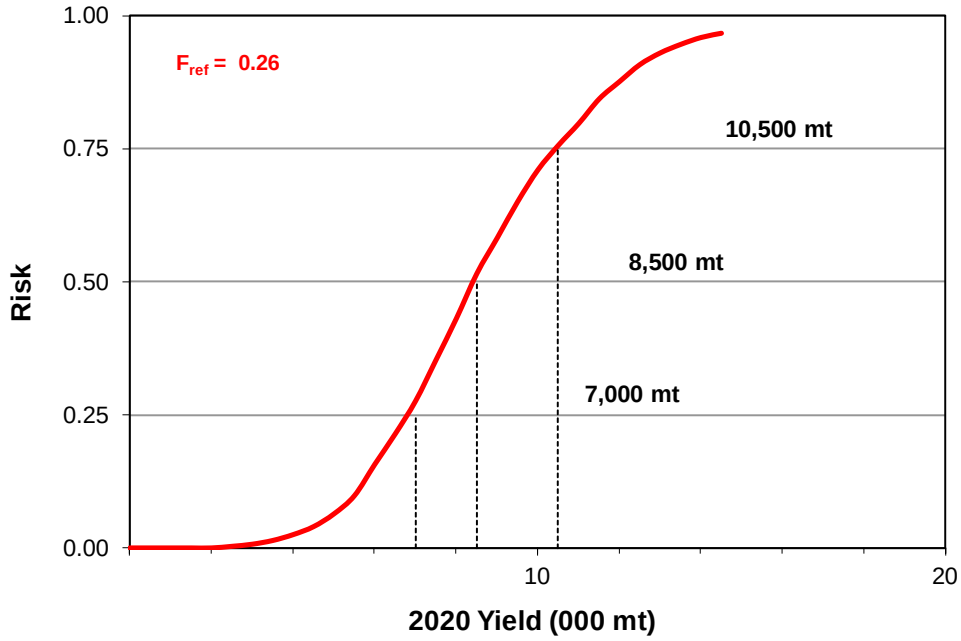

Figure 35. Sensitivity risk analysis of 2020 fishing mortality exceeding F_{ref} = 0.26 for eastern Georges Bank haddock for increasing catch quotas. A rho adjustment (0.363) was applied to down weight the 2019 population estimates prior to conducting risk calculations.

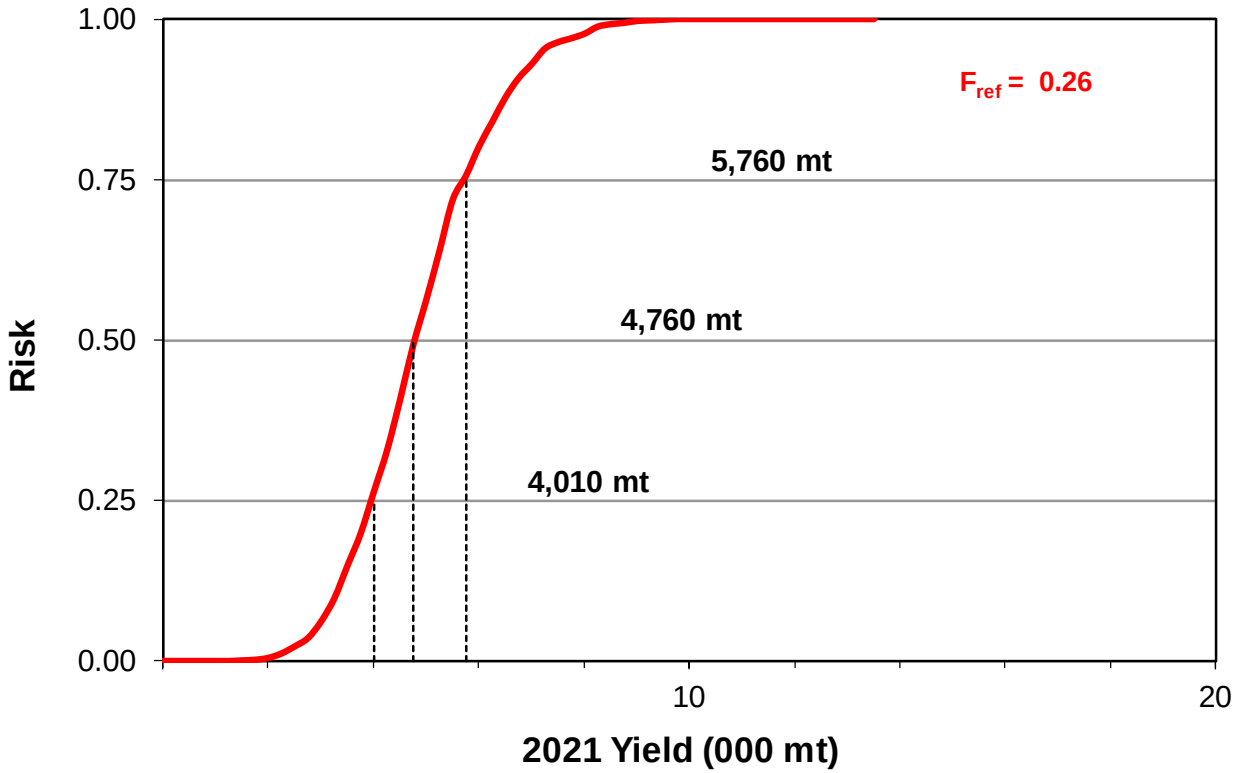

Figure 36. Sensitivity risk analysis of 2021 fishing mortality exceeding F_{ref} = 0.26 for eastern Georges Bank haddock for increasing catch quotas. A rho adjustment (0.363) was applied to down weight the 2019 population estimates prior to conducting risk calculations.

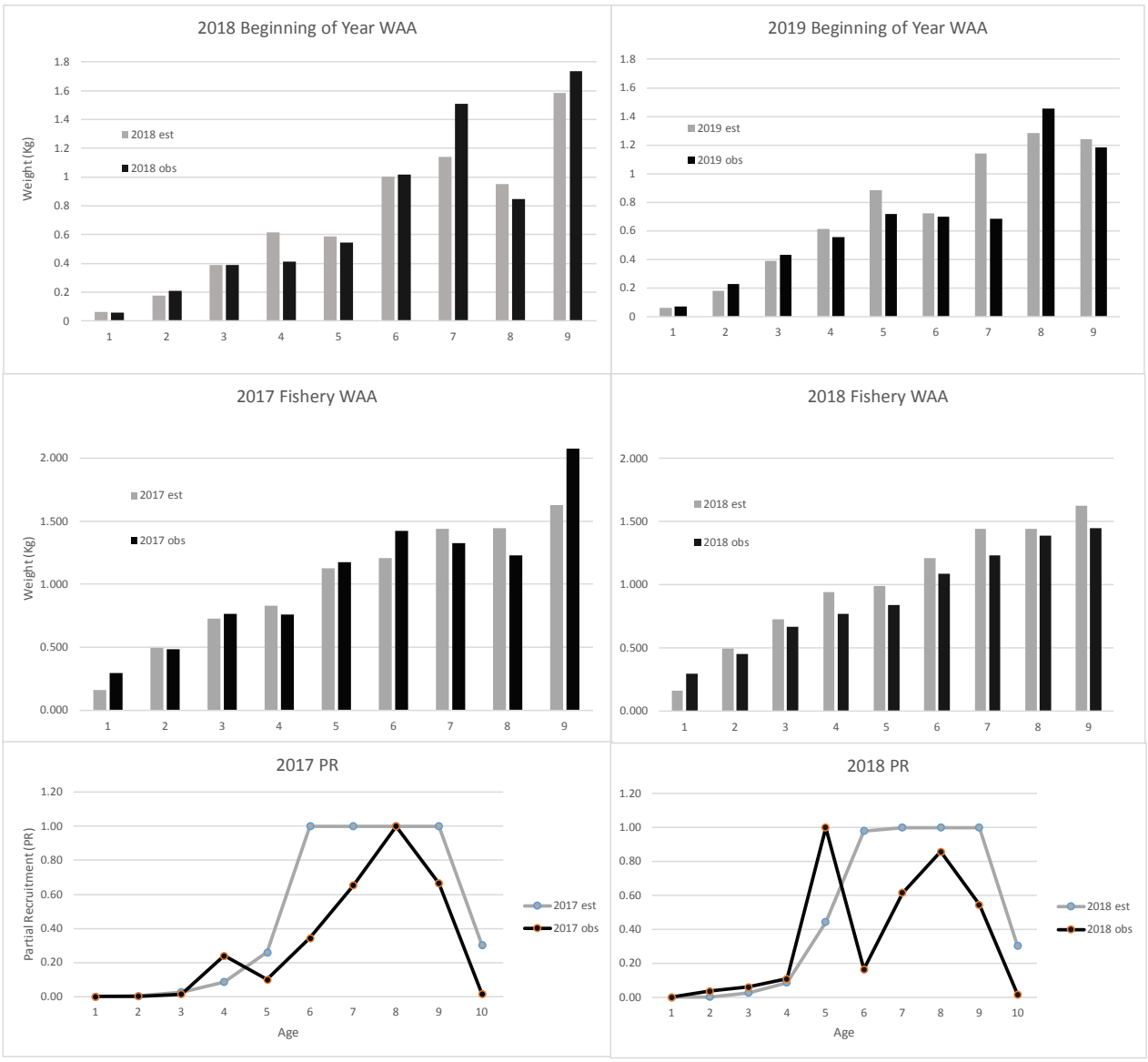

Figure 37. A comparison of the beginning of year weight at age, fishery weight at age (kg), and the partial recruitment used in the 2017 assessment projections (grey) versus the realized values (black).

Appendix A. Data and model changes to the eastern Georges Bank haddock assessment framework from 1998 to 2017.

Assessment Year	Change
1998	Framework: Random error in catch at age negligible. Error in abundance indices assumed independent and identically distributed after taking the natural logarithms. Annual natural mortality rate (M) = 0.2. Fishing mortality (F) on age 8 = weighted F on ages 4 to 7. 9+ age group calculated but not calibrated to indices. In Q1 of first year, 9+ based on assumption that F9+ = popn weighted F4-8. In Q1 of subsequent years, 9+ abundance calculated as sum of age 8 and 9+ at end of last quarter of previous year. Quarterly catch at age: 0,1,2…8,9+; 1969.0, 1969.25, 1969. 75, 1970.0…1996.75. DFO survey: ages 1,2,3…8; 1986.16, 1987.16…1998.0. NMFS spring (Yankee 36): age 1,2,3…8; 1969.29, 1970.29…1997.29. NMFS spring (Yankee 41): age 1,2,3…8; 1973.29, 1974.29…1981.29. NMFS fall: 0,1,2…5, 1969.69, 1970.69…1997.69. Zero survey observations treated as missing data.
1999	Minor differences in the handling of zero terminal catches for a year class were implemented as a refinement to the software to afford more flexibility.
2003	NMFS spring (Yankee 36): age 1,2,3…8; 1969.29, 1970.29…2003.25. (In previous years, the last survey available was the same year as the last catch at age year.) Catch of 0 was assumed for the 1st quarter of 2003 and the population calculated to beginning of 2003.25.
2005	Discards ages 1 and older from Canadian scallop fishery included in catch at age but age 0 set to zero. Population calculated to beginning year 2005. NMFS and DFO spring surveys in 2005 set to time=2005.00.
2007	Discards at age 0 included in catch at age.
2008	1) an annual catch at age instead of a quarterly catch at age. 2) revised survey timing: DFO spring from 0.16 to 0.17, NMFS spring from 0.29 to 0.28 and the NMFS fall survey from 0.69 to 0.79. 3) a change from ages 4 to 7 to 5 to 7 (weighted by population numbers) used to estimate oldest age F from 2003 to present.
2009	USA 2007 catch corrected from previous year (calculation error). The landings at age for 2006 to 2007 were recalculated. USA landings for 1994 to 2007 revised using new methodology. (Effect was negligible.) USA landings at age from 1991 to 2005 were revised to reflect the recalculated landings using a scalar adjustment. USA discards recalculated using ratio of discarded haddock to kept of all species for 1989 to 2007. Discards at age were not revised for 1989 to 2000 as amounts were low, except for 1994 (old=258 vs new=1,021 mt). No adjustment to the 1994 discards at age was made due to the uncertainty of this estimate. Discard at age estimates for 2001 to 2007 were revised by a scalar. 2009 NMFS spring survey not used (no conversion factors).
2010	9+ group in catch at age expanded to 9 to 16+; ages 15 and 16 dropped; 9+ group reconstructed from ages 9 to 14. Revisions made to USA landings, Canadian scallop discards and USA groundfish fishery discards at age. Largest change for 1994 discards from 258 mt to 1279 mt.
2011 - 2013	No additional changes.

	Note that the 2010 fall survey was used at twice its actual value in the 2011 and 2012 assessments. The effect on the 2012 assessment results are as follows: • 2010 yc declined from 589 M to 532 M • 1+ population declined from 644,586 K to 597,434 K • 3+ population declined from 57,745 to 55,964 K • 3+ biomass declined from 70,679 mt to 68,521 mt • risk analysis for 2013 F_{ref} catch declined by 700 mt from 10,400 mt to 9,700 mt
2014	NMFS 2012 spring survey: For the 2012 and 2013 assessments the survey results did not incorporate some lengths for which there were no ages. The numbers involved were small. Updated values also reflect an increase in the number of tows, changes to the numbers per tow and a large increase in the numbers aged. NMFS 2011 fall survey: The NMFS 2011 fall survey used incorrect stratum area values for strata 5Z3 and 5Z4 for the 2012 and 2013 assessments. Updated values also reflect changes to the numbers per tow. Canadian scallop discards: Revised 2005 to 2012 to reflect updated values due to change from freezer trawler equivalents to hours x meters as new effort measure and other data changes. Largest percent difference from previous values for age/year was 19%. Largest annual change was 7%. Canadian scallop discards contribute a very small amount to the total catch.
2015	Retrospective pattern which emerged in 2014 persisted in 2015
2016	Haddock Interim Report, full assessment not conducted.
2017	Retrospective pattern which emerged in 2014 persisted in 2017. Projection inputs changed for beginning and fisheries weight-at-ages for 2013 year class to take into account the slower growth of this year class.

Appendix B. Comparison of EGB haddock TRAC catch advice, TMGC quota decision, actual catch, resulting fishing mortality and biomass changes. All catches are calendar year catches. In the "Results" column, values in italics are assessment results in the year immediately following the catch year; values in normal font are results from the 2017 assessment. This table was kindly provided by Tom Nies (New England Fisheries Management Council) in 2011 and updated to the 2013 assessment. Updates from 2013 were performed by Jamie Cournane (New England Fisheries Management Council).

TRAC	Catch Year	TRAC Analysis/Recommendation		TMGC Decision		Actual Catch/ Compared to Risk Analysis	Results	Comments[2]
		Amount	Rationale/Biomass	Amount	Rationale			
1999[1]	1999	6,300 mt	$F_{0.1}$	NA	NA	4,093 mt	*Below $F_{0.1}$*	
2000[1]	2000	8,800 mt	$F_{0.1}$	NA	NA	5,774 mt	*Below $F_{0.1}$*	
2001[1]	2001	9,700 mt	$F_{0.1}$	NA	NA	7,597 mt	*Below $F_{0.1}$*	
2002[1]	2002	10,700 mt	$F_{0.1}$	NA	NA	7,623 mt	*Below F_{ref} = 0.26*	
Transition to TMGC process in following year; note catch year differs from TRAC year in following lines *F's below are based on Age 5+*								
2003	2004	(1) 20,000 mt (2) 8,000 mt	(1) Low risk of exceeding F_{ref} (2) Neutral risk of biomass decline	15,000 mt	Low risk of exceeding F_{ref} and reduction in biomass > 10%	11,919 mt Low risk of exceeding F_{ref}	*F_{2004} = 0.17* *Age 3+ biomass decrease of 27% 2004 to 2005* *3+ B_{2005}=49,900 mt* F_{2004} = 0.347 Age 3+ biomass decreased 25% 2004 to 2005 3+ B_{2005}=47,900 mt	In projection, PR on age 4 (2000 year class) was set to 1. Realized was 0.3. Fully recruited ages now 5 – 8.
2004	2005	26,000 mt	Neutral risk of exceeding F_{ref} Adult biomass will increase substantially 3+ B_{2006}=513,700 mt	23,000 mt	Low risk of exceeding F_{ref} Adult biomass will increase substantially	15,257 mt Low risk of exceeding F_{ref}	*F_{2005} = 0.29* *Age 3+ biomass increase of 142% 2005 to 2006* *3+ B_{2006}=122,700 mt* F_{2005} = 0.335 Age 3+ biomass increased 75% 2005 to 2006 3+ B_{2006}=83,300 mt	Higher F due to lower realized PR and weights at age for 2003 year class and lower weights for 2000 year class. Large biomass increase due to 2003 year class.
2005	2006	22,000 mt/18,000 mt	Neutral/low risk of exceeding F_{ref} 3+ B_{2007}=157,400 mt	22,000 mt	Neutral risk of exceeding F_{ref}	12,630 mt Low risk of exceeding F_{ref}	*F_{2006} = 0.36* *Age 3+ biomass increase of 26% 2006 to 2007* *3+ B_{2007}=145,300 mt* F_{2006} = 0.373	Higher F due to lower realized PR and weights at age for 2003 year class and lower weights for 2000 year class.

TRAC	Catch Year	TRAC Analysis/Recommendation		TMGC Decision		Actual Catch/ Compared to Risk Analysis	Results	Comments[2]
		Amount	Rationale/Biomass	Amount	Rationale			
							Age 3+ biomass increased 15% 2006 – 2007 3+ B_{2007}=96,800 mt	

TRAC	Catch Year	TRAC Analysis/Recommendation		TMGC Decision		Actual Catch/ Compared to Risk Analysis	Results	Comments[2]
		Amount	Rationale	Amount	Rationale			
2006	2007	19,000 mt/16,000 mt	Neutral/low risk of exceeding F_{ref} 3+ B_{2008}=161,900 mt	19,000 mt	Neutral risk of exceeding F_{ref}	12,510 mt Low risk of exceeding F_{ref}	*F_{2007} = 0.14 Age 3+ biomass increase of 4% 2007 – 2008 3+ B_{2008}=158,100 mt* F_{2007} = 0.212 Age 3+ biomass decreased 4% 2007 to 2008 3+ B_{2008}=93,000 mt	2003 year class specific values for projection inputs.
2007	2008	26,700 mt/ 23,000 mt	Neutral/low risk of exceeding F_{ref} 3+ B_{2009}=145,700 mt	23,000 mt	Low risk of exceeding F_{ref}	16,003 mt Low risk of exceeding F_{ref}	*F_{2008} = 0.09 Age 3+ biomass increase of 7% 2008 to 2009 3+ B_{2009}=155,600 mt* F_{2008} = 0.147 Age 3+ biomass decreased <1% 2008 to 2009 3+ B_{2009}=92,800 mt	2003 year class specific values for projection inputs.
2008	2009	33,000 mt /28,000 mt	Neutral/low risk of exceeding F_{ref} 3+ B_{2010}=125,500 mt	30,000 mt	Low to neutral risk of exceeding F_{ref}	19,855 mt Low risk of exceeding F_{ref}	*F_{2009} = 0.13 Age 3+ biomass decrease of 21% 2009 to 2010 3+ B_{2010}=125,100* F_{2009} = 0.247 Age 3+ biomass decreased 40% 2009 to 2010 3+ B_{2010}=66,200 mt	2003 year class specific values for projection inputs.
2009	2010	29,600 mt/ 25,900 mt	Neutral/low risk of exceeding F_{ref} 3+ B_{2011}=94,700 mt	29,600 mt	Low to neutral risk of exceeding F_{ref}	18,794 mt Low risk of exceeding F_{ref}	*F_{2010} = 0.148 Age 3+ biomass decrease of 28% 2010 to 2011 3+ B_{2011}=93,400 mt* F_{2010} = 0.361 Age 3+ biomass decreased 40% 2010 to 2011 3+ B_{2011}=40,400 mt	2003 and 2005 year class specific values for projection inputs.

TRAC	Catch Year	TRAC Analysis/Recommendation		TMGC Decision		Actual Catch/ Compared to Risk Analysis	Results	Comments[2]
		Amount	Rationale	Amount	Rationale			
2010	2011	22,000 mt/ 19,000 mt	Neutral/low risk of exceeding F_{ref} 3+ B_{2012}=67,800 mt	22,000 mt	Neutral risk of exceeding F_{ref}	12,656 mt Low risk of exceeding F_{ref}	*F_{2011} = 0.135* *Age 3+ biomass decrease of 29% 2011 to 2012* F_{2011} = 0.407 Age 3+ biomass decreased 36% 2011 to 2012 3+ B_{2012}=23,900 mt	2003 and 2005 year class specific values for projection inputs.
2011	2012	16,000 mt/ 13,900 mt	Neutral/low risk of exceeding F_{ref} Adult biomass will increase substantially from 2012 to 2013 (2010 year class) 3+ B_{2013}=188,700 mt	16,000mt	Neutral risk of exceeding F_{ref}	5,633 mt Low risk of exceeding F_{ref}	*F_{2012} = 0.157* *Age 3+ biomass increased 193% 2012 to 2013* *3+ B_{2013}=183,600 mt* F_{2012} = 0.471 Age 3+ biomass increased 350% 2012 to 2013 3+ B_{2013}=85,000 mt	2003, 2005 and 2010 year class specific values for projection inputs. PR_{9+} for projection higher than model estimate.
2012	2013	10,400 mt/ 9,300 mt	Neutral/low risk of exceeding F_{ref} Adult biomass will increase substantially from 2012 to 2013 (growth of 2010 year class) 3+B_{2014}= 306,200mt	10,400 mt	Neutral risk of exceeding F_{ref}	5,066 mt Low risk of exceeding F_{ref}	*F_{2013} = 0.157* *Age 3+ biomass increased 28% 2013 to 2014* *3+ B_{2014}=160,300 mt* F_{2013} = 0.363 Age 3+ biomass increased 25% 2013 to 2014 3+ B_{2014}=105,000 mt	2003 year class values for 2010 year class inputs. Model estimate for PR_{9+} used for projection.
2013	2014	31,500 mt/ 27,000 mt	Neutral/low risk of exceeding F_{ref} Adult biomass will decrease slightly from series maximum projected for 2014. 3+B_{2015}=240,000 mt	27,000 mt	Low risk of exceeding F_{ref}	16,470 Low risk of exceeding F_{ref}	*F_{2014} = 0.229* *Age 3+ biomass decreased 7% 2014 to 2015* *3+ B_{2015}=117,000 mt* F_{2014} = 0.415 Age 3+ biomass decreased 10% 2014 to 2015 3+ B_{2015}=95,600 mt	2003 year class values for 2010 year class inputs. Model estimate for PR_{9+} used for projection.
2014	2015	44,000 mt/ 37,000mt	Neutral/low risk of exceeding F_{ref} Adult biomass will increase substantially from 2015 to 2016 3+B_{2016}=231,200 mt	37,000 mt	Low risk of exceeding F_{ref}	19,200 Low risk of exceeding F_{ref}	*Interim Update* *No estimates available.* F_{2015} = 0.122 Age 3+ biomass increased 300% 2015 to 2016 3+ B_{2016}=293,300 mt	2013 year class downsized to size of 2010 year class for projection.
2015	2016	37,500 mt/ 32,000 mt	Neutral/low risk of exceeding F_{ref}	37,000 mt	Neutral/low risk of exceeding F_{ref}	21,830 Low risk of exceeding F_{ref}	*F_{2016} = 0.102* *Age 3+ biomass decreased 5% 2016 to 2017* *3+ B_{2017}=274,500 mt*	Persistent retrospective pattern

TRAC	Catch Year	TRAC Analysis/Recommendation		TMGC Decision		Actual Catch/ Compared to Risk Analysis	Results	Comments[2]
		Amount	Rationale	Amount	Rationale			
			Adult biomass will increase by 10% from 2016 to 2017 3+B2017=522,000 mt					
2015	2017	81,000 mt/ 66,000 mt	Neutral/low risk of exceeding Fref Adult biomass will not increase from 2017 to 2018 3+B2017=463,900 mt	50,000 mt	Low risk of exceeding F_{ref}	N/A	N/A	Persistant retrospective pattern

[1] Prior to implementation of US/CA Understanding
[2]Comments by L. Van Eeckhaute