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Assessment of Haddock on Eastern Georges Bank for 2017

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

[1]Fisheries and Oceans Canada
531 Brandy Cove Road
St. Andrews, New Brunswick E5B 2L9
Canada

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

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ABSTRACT

The total catch of eastern Georges Bank (EGB) haddock in 2016 was 12,409 mt of the 37,000 mt combined Canada/United States of America (USA) quota. The 2016 Canadian catch decreased from 14,648 mt in 2015 to 11,943 mt while the USA catch in 2016 was 466 mt, a decrease from the 2015 catch of 1,921 mt. Haddock discards from the Canadian scallop fishery and the USA groundfish fishery were estimated at 8 and 125 mt, respectively.

The 2017 beginning of year adult population biomass (ages 3+) is estimated at 274,000 mt. A preliminary estimate for the 2016 year class is 111 million fish at age 1. The current estimate of the 2013 year class is 885 million fish, which is the highest in the time series (1931-1955 and 1969-2016). The exceptional 2003 and 2010 year classes, estimated at 196 million and 243 million age-1 fish, respectively, are the second and third largest. Except for the strong 2000 and 2011 year classes and the exceptional 2003, 2010, 2013, and 2016 year classes, recruitment has fluctuated between 1.8-27.1 million since 1990. Fully recruited fishing mortality increased to levels above F_{ref} = 0.26 from 2010-2014 before dropping below F_{ref} in 2015. In 2016, F was estimated at 0.10. 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 and size at age has declined.

Assuming a 2017 catch equal to the 50,000 mt total quota and F=0.26 (F_{ref}) in 2018 and 2019, a combined Canada/USA catch of 86,000 mt in 2018 results in a neutral risk (50%) that the 2018 fishing mortality rate would exceed F_{ref} = 0.26. The 2010 year class at age 8 is expected to contribute 11% of the catch biomass and the 2013 year class at age 5 is expected to contribute the highest percentage at 86%. Adult biomass is projected to be 243,000 mt, at the beginning of 2019 at the F_{ref} catch level.

A combined Canada/USA catch of 53,000 mt in 2019 results in a neutral risk (50%) that the 2019 fishing mortality rate would exceed F_{ref} = 0.26. The 2010 year class at age 9 is expected to contribute 5% of the catch biomass and the 2013 year class at age 6 is expected to contribute 86%. Adult biomass is projected to be 196,000 mt at the beginning of 2020 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 2017 population numbers (ages 0-9+) for deterministic projections and risk assessments was conducted to beginning year 2020. Assuming a 2017 catch equal to the 50,000 mt total quota and F=0.26 (F_{ref}) in 2018 and 2019, a combined Canada/USA catch of 44,000 mt in 2018 results in a neutral risk (50%) that the 2018 fishing mortality rate would exceed F_{ref} = 0.26. A combined Canada/USA catch of 27,500 mt in 2019 results in a neutral risk (50%) that the 2019 fishing mortality rate would exceed F_{ref} = 0.26.

The F_{ref} catches from the sensitivity projections are considerably lower than the catches from standard projections but they do take into account the consistent retrospective pattern which has occurred over the past four years in this assessment.

RÉSUMÉ

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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 2016. Results from the Fisheries and Oceans Canada (DFO) survey, updated to 2017, the USA National Marine Fisheries Service (NMFS) spring survey, updated to 2017 and the NMFS autumn survey, updated to 2016, 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 15,256 mt in 2005. Catches varied between 12,510 mt and 19,855 mt from 2006 to 2011, decreased to 5,066 mt in 2013 then increased to 14,243 and 16,148 mt in 2014 and 2015 respectively . In 2016, the total catch decreased to 12,409 mt and represented 34% of the combined 37,000 mt quota. Canada caught 55% of its 21,830 mt allocation while the USA caught 3% of its 15,170 mt allocation.

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 2016, at-sea observer coverage represented 79.5% of otter trawl (OTB) and 23% of longline landings, which amounted to an overall observed level of 76% 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. 80% in 2016). So as not to adversely affect the rebuilding of cod on EGB, the winter fishery was closed February 7th in 2016 based on determinations of active cod spawning in the previous year (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 2015-2016 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 14,631 mt in 2015 to 11,935 mt in 2016. 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 90% of the catch and longline vessels about 10%. There has been a declining trend in longline catches since 2012, with the 2016 catch representing only 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 0%). In 2016, the highest landings occurred in July with highest percentage of total Canadian landings occurring in Quarter 3 (41%) (Table 4, Figure 5). The 2016 January/February winter fishery landed 2,883 mt of haddock, accounting for 24% 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 8 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 2016 there were 23 observed scallop trips available for calculating discards which were estimated at 8 mt, lower than the 17 mt reported in 2015 (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 0.62%, 0.28%, and 0.32% of the EGB quota in 2011, 2012, and 2013, respectively).

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 1506 mt in 2015 to 341 mt in 2016. The 2016 USA landings peaked in quarter 2 (55%), primarily due to high landings in June, which represented 27% of total annual landings (Table 6). As in other years, otter trawl gear accounted for nearly all of USA landings (339 mt; Table 7), 84% of which was landed by tonnage class 4 vessels.

For USA fishing year May 1, 2016 to April 30, 2017, the USA catch quota for sectors was 15,063 mt of which only 2.9% was realized in landings (3.7% of quota, including discards). The catch quota for the common pool was 157.3 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 2016 were 125 mt, a decrease from 415 mt in 2015 (Table 1). Discards were similar during the first and second half of the year in 2015, but in 2016 were greater in the second half (66%). USA discards from the otter trawl fishery accounted for 99% and 95% of the USA haddock discard in 2015 and 2016, respectively. Large mesh otter trawl discards were 6.7% and 52.1%, while separator trawl discards accounted for 44% and 17.7% of total discards in 2015 and 2016, respectively. Small mesh otter trawl discards reflected 49% and 24.9% of total discards in 2015 and 2016, respectively. Very minor amounts of discards were estimated for gillnets (0.2, 4 mt), scallop dredge (0.8, 0.3 mt), midwater trawl (0, 2.3 mt), and lobster pots (0.7, 0 mt) in 2015 and 2016.

Size and Age Composition

Ageing Precision and Accuracy

D. Knox provided ages for the 2016 Canadian fishery and 2017 DFO survey and S.J. Sutherland provided ages for the 2016 US fishery and the NMFS 2016 autumn and 2017 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 98% agreement. Inter-lab agreement ranged from 85% to 98%. No bias was detected for the exchange. Intra-reader agreement on non-reference collection samples for the NMFS reader ranged between 95% and 100%. For the DFO reader, intra-reader agreement ranged between 93% 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 2016 Canadian groundfish fishery was determined using port and at-sea samples from all principal gears with 734,835 length measurements and 1,313 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 no 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) = $0.0000158 \times \text{length (cm)}^{2.91612}$; Waiwood and Neilson 1985).

The size composition of haddock discards in the 2016 Canadian scallop fishery was characterized by quarter using length samples obtained from 24 observed scallop trips which comprised 5.5% of the total trips (24 of 435). 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=125) for sets located in the Canadian portion of 5Zjm in 2016 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 2016 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 (average fork length: Longline – 48.5 cm; OTB – 46.5 cm; Dredge – 26.5 cm). For both otter trawl and longline, over 50% of the catch was dominated by age 6 (2010 year class) and over 20% by age 3 (2013 year class) while dredge catches consisted of 42% at age 3 (2013 year class) and 5% at age 6 (2010 year class). Over 49% of dredge catches consisted of catch at age 2 or less. Overall, the 2016 CDN CAA was dominated by age 6 (2010 yc), then ages 3 (2013 yc), 5 (2011 yc), and 4 (2012 yc) representing 51%, 30%, 7% and 6% of the total catch. The 9+ age group represented 3% of quarter 1 Canadian landings, but only about 1% in all remaining quarters (Table 10). The 2010 (age 6) and 2013 (age 3) year classes were predominant in all four quarters, representing 83% of catches.

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 2016, landings of large haddock totaled 20 mt, scrod haddock 257 mt and snapper 52 mt. Length sampling for USA EGB landings in 2016 was available for all market categories except for the “large” category in quarter 3. 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 3,977 lengths and 1,879 ages for calculating the 2016 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 2016 were estimated by half-year from at-sea observer data. In calendar year 2016, the number of observed trips from the at-sea monitoring program was 60, a decrease from the previous year when there were 141. There were 429 trips to EGB for all groundfish gear types, however the fraction of trips sampled varied by gear: 30% of standard otter trawl trips, 100% of separator trawl trips, 37.5% of mid-water trawl trips, 11% of scallop trips, 7% for gillnet, 0% for lobster pot trips (0 out of 0 trips), and 0% for long line trips (0 out of 0 trips).

As 85% of the discarding was due to the otter trawl fleet, there were few length samples from remaining gears (scallop dredge, gillnet, and lobster pot). 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 (1270 ages) to quarters 1 and 2 and from the autumn bottom trawl survey (957 ages) to quarters 3 and 4.

USA landings in 2016 had a modal size of 35 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 34 cm, while without the panel they peaked at 30 and 32 cm. Scallop dredge discards had a modal size of 38 cm, while discards from mid-water trawl peaked at 32 cm. The 2010 year-class (Age 6) represented 30% of the catch at age (CAA) as landings

while the 2013 year class (Age 3) represented 42% of the catch at age as discards (Figure 7; lower panel). Landings of the 9+ age group (mostly the 2003 year class at Age 13) represented < 1% of the CAA (Table 10).

Combined Canada/USA Catch at Age

The 2016 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 2015 catch at age data (Table 12; Figure 8). The catch at age tracks strong year classes well (i.e. 2000, 2003 and 2010) and showed an expansion in age structure in the mid-2000s with the contribution of the strong 2000 and 2003 year classes. The 2016 fishery was dominated by the 2010 year class (Age 6) which represented 44% of the total catch by number (49% by weight), followed by the 2013 (Age 3) year class at 35% by number and 22% by weight. Catches of older fish (7-9+) in 2016 were low but have increased compared to recent years. In comparison to the observed 2016 catch, the age composition of the catch projections made in 2015 and 2016 for the 2016 catch predicted higher percentages in number and weight for the 2013 year class but were lower than observed for the 2010 year class (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 2016 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 (1969-2016). The average weight of age 4 haddock in 2000 was 1.9 kg with an average length of 55 cm. In 2016, the average weight and length of an age 4 haddock was 0.97 kg and 43 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 in the DFO Georges Bank survey. No conversion factors are available for the *Templeman* or *Teleost*, 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, 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 spatial distributions of catches by age group (1, 2, and 3+ for spring and 0, 1 and 2+ for autumn) for the 2016 NMFS fall survey, and the 2017 DFO and NMFS spring surveys are shown in comparison to the average distribution over the previous 10-years (Figure 13-15). During the fall 2016, ages 0 and 1 were generally spread throughout the 5Zjm area similar to the 10 year average. While Age 2 haddock generally occur on the northern half of the bank, they were also caught along the southern edge in 2016. In March (2017 DFO survey), age 1 and 2 haddock were distributed throughout the 5Zjm management unit with higher catches in southern areas similar to the 10-year average, while ages 3+ occurred mostly in Canadian waters along the northern part of the bank similar to the 10-year average, more were caught in US waters compared to previous years. In April-May (2017 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 (1986-2016) but decreased by 48% in 2017. The NMFS fall survey index was highest in 2015 but decreased by 53% in 2016, while the 2017 NMFS spring values increased by 16% from 2016 to 2017.

Age-specific total abundance indices for the three bottom trawl surveys track strong year classes (i.e. 2000, 2003 and 2010) quite well (Figure 17). The 2017 indices of abundance for the 2013 year class (age 4) from the DFO and NMFS spring surveys were at the highest levels observed for age 4 haddock over the time series for the DFO survey (Table 15) and the second highest for the NMFS spring survey (Table 16). The index of abundance for the NMFS fall survey also peaked in 2016 for the 2013 year class (Age 3; Table 17). The next highest index value was for the 2016 year class at Age 0 in the 2016 NMFS fall survey and Age 1 in the DFO and NMFS spring surveys.

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 2017 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…2016 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 2017. 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… 2016.17, 2017.00

s = NMFS spring (Yankee 36), ages a = 1, 2, 3…8, time t = 1969.28…1972.28 and 1982.28… 2016.28, 2017.00

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… 2016.79.

Since the population is calculated to beginning year 2017, the NMFS and DFO spring surveys in 2017 were designated as occurring at time 2017.00.

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 8 exhibit a large relative error of 59% and 68%, and a large relative bias of 12% and 14%, respectively. The relative error for other ages was between 22% and 37% with a relative bias for ages 2 to 7 between 1% and 6% (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 2017 DFO and 2017 NMFS spring surveys (i.e. model predicts higher abundance than 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 two years.

Retrospective Analysis

A retrospective analyses was conducted for 2017-2010 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 four 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 2017. 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 rho of 0.564 was used to adjust age specific stock abundance (for all ages) at the start of 2017 which in turn was used to calculate 3+ biomass at the beginning of 2017. 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 2017. 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 and NMFs spring surveys (Ages 3-8) but was lower than indicated for the NMFS fall survey (Ages 2-7) (Figure 23).

Adult biomass increased during the late 1970s and early 1980s to 37,000 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 (69 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 10,200 mt in 1993 to 71,000 mt in 2003. Adult biomass decreased to 48,000 mt in 2005 but subsequently increased to 93,000 mt in 2009, higher than the 1931-1955 maximum adult biomass of about 90,000 mt. The near tripling of the biomass from 2005 to 2009 was due to the exceptional 2003 year-class, estimated at 195 million age-1 fish. The biomass decreased after the 2009 high and in 2012 the adult biomass was 24,000 mt but increased in 2013, when the 2010 year class joined the 3+ group, to 85,000 mt and again in 2014 to 105,000 mt. After a slight decline in 2015 to 95,000 mt, adult biomass increased to 293,000 mt in 2016 The current estimate for 2017 is 274,482 mt (80% confidence interval: 208,936-359,157 mt; Figure 25).

Recruitment has fluctuated between 1.8 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 is 885 million fish, which is the highest in the time series (1931-1955 and 1969-2016). The 2010 year class is the second highest in the series at 243 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 2010-2014 before dropping below F_{ref} in 2015. In 2016, F was estimated at 0.102 (80% confidence interval: 0.08-0.14; Figure 25), well below F_{ref}.

Consistent with the increase in age at full recruitment into the fishery, the partial recruitment at age for EGB haddock is normalized to ages 4-8 population weighted F for 1969 to 2002 and to ages 5-8 population weighted F from 2003 onwards (Table 26; Figure 27). Average partial recruitment estimates are less variable when weighted by population numbers and are considered more appropriate than the unweighted average. The 10 year average PR values for 2007-2016 were used for projections of stock abundance in 2018 and 2019 (Table 27; Figure 27), except for the 2013 year class where the PR values reflect the 2010 year class.

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 (1987-2017), NMFS Spring (1992-2017) and NMFS fall (1992-2016) 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 (1987-2017) 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).

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 have average lengths at ages 3 and 4 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.

In summary, positive signs of productivity include increased abundance for older ages, broad spatial distribution and large biomass. This stock has produced three exceptional and three strong year classes in the last 15 years. On the negative side, condition has decreased, growth has declined, recruitment from the very large biomass has been extremely variable and M may be increasing on older ages.

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.

For projections, the most recent 3-year survey (2015-2017) and the lowest values for the fishery time series (1969-2016) average weights at age were used for beginning year population (2018-2020) and fishery (2017-2019) weights at age, respectively, except as indicated below. The 2017 DFO survey weights at age were used for the 2017 population weights at age as this is consistent with the assessment results. Considering the substantial contribution of the 2013 year class to both biomass and fishery catch in the projection, the 2013 year class values were determined using a linear regression of previous survey WAA for ages 5 (2018), and 6 (same values for both 2019 and 2020) for beginning weights at age and using the growth rate for the 2010 year class for fishery weights at age for ages 4 and 5 based on the observed weight at age 3 in 2016 fishery. For the 2010 year class values, minimum values in the time series were used for beginning weights at age. Fishery partial recruitment (PR) was based on the 2007 to 2016 population weighted average. The PR used for the 2013 year class was from the 2010 year class (Table 27). Ages 5 to 8 were considered fully recruited to the fishery. 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 2020 (Table 28). Stock size estimates at the beginning of 2017 were used to start the forecasts. Abundance of the 2018, 2019 and 2020 year classes were assumed to be 15.21 million fish at age 1 (the 2007 to 2016 median from the 2016 update results). Natural mortality was assumed to be 0.2. Assuming a 2017 catch equal to the 50,000 mt total quota and F=0.26 (F_{ref}) in 2018 and 2019, a combined Canada/USA catch of 86,000 mt in 2018 results in a neutral risk (50%) that the 2018 fishing mortality rate would exceed F_{ref} = 0.26 (Figure 32). A catch of 71,000 mt in 2018 results in a low risk (25%) that the 2018 fishing mortality rate will exceed $F_{ref.}$ The 2010 year class at age 8 is expected to contribute 11% of the catch biomass and the 2013 year class at age 5 is expected to contribute the highest percentage at 86%. A catch of 17,000 mt in 2018 results in a neutral risk (50%) that the 2018 biomass will not increase by 10%; a catch of 57,000 mt in 2018 results in a neutral risk that biomass will remain the same. Thus, both the low and neutral catch associated with not exceeding Fref will produce a decline in biomass. Adult biomass is projected to be 243,000 mt, at the beginning of 2019 at the F_{ref} catch level.

A combined Canada/USA catch of 53,000 mt in 2019 results in a neutral risk (50%) that the 2019 fishing mortality rate would exceed F_{ref} = 0.26 (Figure 33). A catch of 44,500 mt in 2019 results in a low risk (25%) that the 2019 fishing mortality rate will exceed F_{ref}. The 2010 year class at age 9 is expected to contribute 5% of the catch biomass and the 2013 year class at age 6 is expected to contribute 86%. Even if no catch were taken in 2019, biomass is projected to decline.Adult biomass is projected to be 196,000 mt at the beginning of 2020 at the F_{ref} catch level.

Sensitivity Projections

A sensitivity forecast using the rho adjusted 2017 population numbers (ages 0-9+) for deterministic projections and risk assessments was conducted to beginning year 2020 (Table 29). All other input values for the forecast were the same as in Table 27. Assuming a 2017 catch equal to the 50,000 mt total quota and F=0.26 (F_{ref}) in 2018 and 2019, a combined Canada/USA catch of 44,000 mt in 2018 results in a neutral risk (50%) that the 2018 fishing mortality rate would exceed F_{ref} (Figure 34). A catch of 35,000 mt in 2018 results in a low risk (25%) that the 2018 fishing mortality rate will exceed F_{ref}. The 2010 year class at age 8 is expected to contribute 9% of the catch biomass and the 2013 year class at age 5 is expected to

contribute 88%. A catch of 11,000 mt in 2018 results in a neutral risk (50%) that the 2018 biomass will not increase by 10%; a catch of 32,000 mt in 2018 results in a neutral risk that biomass will remain the same. Thus, both the low and neutral catch associated with not exceeding Fref in 2018 will produce a decline in biomass. Adult biomass is projected to be 126,000 mt, at the beginning of 2019 at the F_{ref} catch level.

A combined Canada/USA catch of 27,500 mt in 2019 results in a neutral risk (50%) that the 2019 fishing mortality rate would exceed F_{ref}=0.26 (Figure 35). A catch of 23,000 mt in 2019 results in a low risk (25%) that the 2019 fishing mortality rate will exceed F_{ref}. The 2010 year class at age 9 is expected to contribute 4% of the catch biomass and the 2013 year class at age 6 is expected to contribute 86%. Even if no catch were taken in 2019, biomass is projected to decline. Adult biomass is projected to be 102,000 mt at the beginning of 2020 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.

Management Advice

There are reasons for considering both the standard projection and the sensitivity projection (rho adjusted) for catch advice. Reasons for using the standard projection include the survey biomass being at or near historic highs, recent recruitment (2010 and 2013) estimated to be the highest in the time series, expanded age structure, and success at projecting age composition of the fishery catch. Reasons for using the sensitivity projection include the overestimation of SSB and underestimation of F in the last four assessments, the observation that terminal year biomass is lower than projected even though only about half of the quota was caught, and previous experience with assessments of other fish stocks of not accounting for retrospective bias leading to overfishing and further changes in perception of the stock status. For these reasons, both projections have been provided for consideration by the Transboundary Management Guidance Committee.

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 2017 quota is caught, the projection indicates that the 2017 F will be above F_{ref} , which is due to retrospective pattern and the decreased weight at age of the 2010 year class in the 2017 projection (Table 28, the F on ages 5-8 in 2017 would be 0.318). Moreover, if the rho adjusted projections are more appropriate, then catching the full 2017 quota would result in F >> Fref (0.607 for ages 5-8, Table 29).

In 2017, a large proportion of the exceptional 2013 year class will be below the current minimum size regulation used by the US, which could lead to significant discarding. The reduction of the

minimum size for the US fishery in July 2013 from 18 inches to 16 inches will help to reduce discarding of haddock. This is not expected to be an issue in the Canadian fishery due to the different gear types and management measures.

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, which has increased since last year's 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.

The table in Appendix C summarizes the performance of the management system. It reports the TRAC advice, expected beginning of year 3+ biomass in the year following the catch year, the TMGC quota decision, actual catch, and realized stock conditions for this stock. Fishing mortality and trajectory of age 3+ biomass from the assessment following the catch year are compared to results from this assessment. These comparisons were kindly provided in 2011 by Tom Nies (staff member of the New England Fishery Management Council, NEFMC) and updated for this assessment. The largest differences in expected and actual results occurred when projection inputs for partial recruitment and weights at age for large dominant year classes (i.e., 2000 and 2003) were higher than the realized values. When year class specific input values were used, expected and actual results were similar. These results indicate that stock biomass is being adequately estimated by the model for management purposes, but, misspecification of partial recruitment and weights at age, especially of very large and influential year classes, can result in higher than expected fishing mortality due to catch advice being set too high.

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Table 1. Nominal catches (mt) of haddock from eastern Georges Bank (EGB) during 1969-2016. 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

[1] 1895 mt excluded because of suspected area misreporting.
[2]The USA quota pertains to the USA fishing year of May 1 to Apr. 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 2001but 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, mimimum 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, mimimum 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, mimimum 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, mimimum 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, mimimum 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, mimimum 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 in. 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, mimimum 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, mimimum 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, mimimum 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, mimimum 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- July14 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.

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

Table 3. Canadian landings (mt) of haddock from eastern Georges Bank during 1969-2016 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

[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 1969-2016.

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

[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 2016 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. 2015 and Jan. 2017, 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)
2016	Jan	0	0	0.113	4352	0.491	0.491
	Feb	836	7403	0.096	11853	1.142	1.633
	Mar	70	1998	0.084	18743	1.566	3.199
	Apr	4	1486	0.017	22048	0.385	3.585
	May	64	4378	0.018	28366	0.506	4.091
	Jun	100	3516	0.036	22954	0.831	4.922
	Jul	258	3757	0.053	17435	0.918	5.841
	Aug	254	4354	0.062	11297	0.701	6.541
	Sep	95	1673	0.067	10235	0.690	7.232
	Oct	327	3996	0.070	7410	0.521	7.752
	Nov	37	872	0.074	5528	0.408	8.160
	Dec	224	3105	0.066	3105	0.204	8.364

Table 6. Monthly landings (mt) of haddock by the United States from eastern Georges Bank during 1969-2016. An allocation algorithm was applied to landings from 1994 to 2016 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

[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 1969-2016 by gear category and tonnage class. An allocation algorithm was applied to landings from 1994 to 2016 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

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:						
2016 Can. Commercial (Q1,2,3,4)	Exchange	Spring 2017	SJS vs DK	148	0.19	98.0
2017 DFO Survey	Exchange	Spring 2017	SJS vs DK	72	3.09	84.7
2016 NMFS Autumn Survey	Exchange	Spring 2017	SJS vs DK	154	2.42	89.0
2016 US Commercial (Q1-2)	Exchange	Spring 2017	SJS vs DK	117	1.53	90.6
2016 US Commercial (Q1-2) and Fall 2016 survey	Exchange	Spring 2017	SJS vs DK	271	2.03	89.7
NMFS testing:						
2017 NMFS Spring Survey	Precision	June 2017	SJS	95	0.00	100.0
2016 NMFS Autumn Survey	Precision	Feb 2017	SJS	100	1.11	97.0
2016 US Commercial (Q4)	Precision	Apr 2017	SJS	100	0.40	97.0
2016 US Commercial (Q2 and Q3)	Precision	Mar 2017	SJS	100	0.00	100.0
2016 US Commercial (Q1)	Precision	Oct 2016	SJS	100	0.51	95.0
Haddock Reference Collection	Accuracy	Apr 2017	SJS	56	0.36	98.2
DFO testing:						
2016 Canadian Commercial (Q4)	Precision	Feb 2017	DK	106	1.85	93.4
2016 Canadian Commercial (Q3)	Precision	Jan 2017	DK	97	0.50	97.9
2016 Canadian Commercial (Q2)	Precision	Jan 2017	DK	105	0.25	98.1
2016 Canadian Commercial (Q1)	Precision	Jan 2017	DK	98	0.69	95.9

Table 9. Haddock age and length samples for landings from the Canadian groundfish fishery and for discards from the scallop dredge fishery in 2016 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	1,816,427	52	57,835	8	1,872	DFO Survey = 125 Port = 278 At Sea = 0 Total =403[16]
		Feb	1,066,883	17	14,606	6	1,395	
	DR[1]		3,199	6	640			
2		June	803,678					Port = 337 At Sea = 0 Total = 337[16]
	OTB			51	95,934	12	2,777	
	GN[2]	June	234					
	LL	June	2,196	1	605	1	231	
	DR[1]		1,723	6	62			
3	OTB	July	1,888,636	89	165,047	13	2,774	Port = 298 At Sea = 4 Total = 302[22]
		Aug	1,872,945	88	155,909	14	3,270	
		Sept	1,088,732	26	114,033	14	3,243	
	LL	July	23,954	4	2,183	2	466	
		Aug	30,657	8	1,382	2	438	
		Sept	22,001	1	400	1	236	
	GN[2]	July	335					
		Aug	278					
		Sept	20					
	DR[1]		2,309	7	374			
4	OTB	Oct	1,899,483	35	50,301	15	3,498	Port = 271 At Sea = 0 Total = 271[29]
		Nov	580,410	26	24,017	5	1,157	
		Dec	821,053	12	28,062	4	930	
	LL	Oct	6,938					
		Nov	9,794	1	349	1	230	
	DR[1]		1,133	5	579			
Totals			11,943,018	435	712,318	98	22,517	1,313

[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 16 length groupings were inferred and are not included in the total.
[5]Ages for 16 length groupings were inferred and are not included in the total.
[6]Ages for 22 length groupings were inferred and are not included in the total.
[7]Ages for 29 length groupings were inferred and are not included in the total.

Table 10. Components of the 2016 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	9+	Total
Canadian Landings											
2016 Q1	0	0	447	193583	254370	132037	1361855	285883	7696	71753	2307624
2016 Q2	0	1	1	165888	27630	38979	456291	14228	0	6772	709790
2016 Q3	1	156	79443	1834514	138706	389969	2139962	15484	0	11171	4609406
2016 Q4	11	1697	18134	1593224	87436	273367	1284663	19429	1515	4854	3284332
Year total	12	1855	98026	3787208	508142	834352	5242771	335025	9211	94550	10911153
United States Landings[1]											
2016 H1											
2016 H2											
Year total	0	0	199	68513	45579	31979	184311	2133	143	1899	334755
Canadian Discards											
2016 Q1	1175	2132	2625	2904	744	75	461	64	5	24	10209
2016 Q2	279	699	420	1891	76	48	401	5	0	0	3819
2016 Q3	881	786	1275	3160	29	41	154	0	0	0	6326
2016 Q4	433	470	333	1574	9	11	93	0	0	0	2923
Year total	2768	4088	4652	9530	857	175	1108	69	5	24	23277
United States Discards[1]											
2016 H1	0	457	2336	104085	1623	385	2962	0	0	253	112101
2016 H2	0	1340	2718	151348	1874	943	7984	0	0	0	166207
Year total	0	1797	5055	255433	3497	1328	10946	0	0	253	278308
Total Catch											
2016	2780	7741	107932	4120683	558075	867834	5439136	337226	9359	96726	11547494

[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 2016 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	9	67	2	4	83
Quarter 2	7	139	38	3	186
Quarter 3	3	41	11	2	57
Quarter 4	1	10	1	2	15
Total	20	257	52	11	340
			Number Lengths measured		
Quarter 1	375	503	331		1209
Quarter 2	896	710	456		2062
Quarter 3		50	102		152
Quarter 4	201	203	150		554
Total	1472	1466	1039	0	3977
			Number aged		
Quarter 1	208	238	153		599
Quarter 2	489	284	171		944
Quarter 3		23	49		72
Quarter 4	94	99	71		264
Total	791	644	444	0	1879
			Discards (mt)		
Quarter 1	N/A	N/A		N/A	
Quarter 2	N/A	N/A		N/A	39
Quarter 3	N/A	N/A		N/A	
Quarter 4	N/A	N/A		N/A	69
Total	N/A	N/A		N/A	108

Table 12. Total annual commercial catch at age numbers (000's) of haddock from eastern Georges Bank during 1969-2016. 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	33018
2016	3	8	176	4098	544	1020	5257	335	9	431	24196

Table 13. Average weight at age (kg) of haddock from the combined Canadian and USA commercial groundfish fishery landings on eastern Georges Bank during 1969-2016. 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	0.159	0.493	0.728	1.037	1.128	1.210	1.440	1.847	1.789
2016	0.307	0.734	0.745	0.969	1.195	1.262	1.472	1.957	1.627
Low	0.159	0.493	0.728	0.942	1.128	1.210	1.440	1.443	1.627
High	0.797	1.216	1.724	2.244	2.662	3.760	4.107	4.086	4.455
Median	0.475	0.966	1.331	1.742	2.066	2.364	2.758	2.758	3.386
Average	0.502	0.916	1.265	1.634	1.944	2.215	2.517	2.760	3.156
2014-16 Avg	0.284	0.591	0.744	0.982	1.162	1.246	1.476	1.749	1.703

Table 14. Average lengths at age (cm) of haddock from the combined Canadian and USA commercial groundfish fishery landings on eastern Georges Bank during 1969-2016. 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		23.5	34.3	39.1	44.7	45.9	46.7	49.9	54.3	53.6
2016	22.2	29.5	39.5	39.7	43.4	47.0	47.7	50.4	55.6	53.0
Low		23.5	34.3	39.1	43.3	45.9	46.7	49.9	50.3	53.0
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	68.0
Average		34.5	42.9	48.2	52.7	56.1	58.6	61.4	63.4	66.1
2014-16 Avg		27.0	36.6	39.7	43.8	46.5	47.5	50.5	53.4	53.3

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 1986-2017.

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

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 1968-2017. 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

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 1963-2016. 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

Table 18. Average weight at age (kg) of eastern Georges Bank haddock from DFO surveys for 1986-2017. 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
Low	0.028	0.168	0.342	0.437	0.729	0.888	0.981	0.953	1.242
High	0.150	0.685	1.227	1.803	3.044	2.848	3.598	3.559	3.918
Median	0.096	0.419	0.780	1.144	1.392	1.829	2.131	2.396	2.805
Average	0.093	0.394	0.748	1.116	1.470	1.768	2.008	2.240	2.639
Avg 2015-17	0.062	0.178	0.390	0.614	0.886	1.002	1.139	1.283	1.585

[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 1986-2017. 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
Low	15.1	26.2	33.1	36.3	42.6	47.2	48.1	47.8	51.5
High	24.7	40.7	49.7	55.7	63.7	62.7	67.8	69.3	71.5
Median	21.8	35.3	42.4	47.4	51.3	56.1	58.3	61.7	64.6
Average	21.1	33.7	41.4	47.1	51.6	55.4	57.3	59.7	62.7
Avg 2015-2017	18.9	26.9	34.7	40.7	45.7	47.3	50.5	53.5	55.1

Table 20. Statistical properties of estimates of population abundance (numbers in 000's) at beginning of year 2017 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	127118	74386	0.585	15541	0.122
2	39877	14744	0.370	2301	0.058
3	7208	2309	0.320	297	0.041
4	493733	131302	0.266	14059	0.028
5	3255	953	0.293	131	0.040
6	4152	1281	0.309	164	0.039
7	51978	11294	0.217	481	0.009
8	53	36	0.681	8	0.148
		Survey Calibration Constants			
DFO Survey, 1986-2017					
1	0.326	0.053	0.164	0.005	1.569
2	0.590	0.093	0.157	0.001	0.002
3	1.062	0.162	0.153	0.014	0.013
4	0.966	0.153	0.158	0.011	0.011
5	0.975	0.154	0.158	0.018	0.019
6	0.837	0.132	0.158	0.012	0.014
7	0.900	0.148	0.165	0.012	0.013
8	0.923	0.155	0.168	0.004	0.004
NMFS Spring Survey, Yankee 36,1969-72/1982-2017					
1	0.168	0.024	0.140	0.001	0.005
2	0.374	0.054	0.144	0.005	0.014
3	0.473	0.067	0.142	0.001	0.003
4	0.432	0.062	0.144	0.001	0.002
5	0.482	0.069	0.144	0.004	0.009
6	0.430	0.061	0.141	0.003	0.007
7	0.423	0.063	0.149	0.002	0.006
8	0.451	0.066	0.147	0.006	0.014
NMFS Spring Survey, Yankee 41, 1973-81					
1	0.228	0.074	0.327	0.011	0.051
2	0.534	0.155	0.290	0.008	0.014
3	0.652	0.211	0.323	0.031	0.048
4	0.806	0.276	0.343	0.047	0.058
5	0.895	0.299	0.334	0.051	0.057
6	0.811	0.289	0.356	0.043	0.053
7	1.488	0.517	0.347	0.069	0.046
8	0.724	0.259	0.358	0.052	0.072
NMFS Fall Survey, 1969-2016					
0	0.186	0.024	0.129	0.002	0.010
1	0.364	0.049	0.135	0.003	0.007
2	0.283	0.037	0.131	0.003	0.011
3	0.263	0.035	0.133	0.002	0.009
4	0.226	0.030	0.135	0.001	0.006
5	0.194	0.026	0.136	0.003	0.013

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

Peel	Age 1 Recruits	Age 3-8 Biomass	Age 5-8 F
1	0.65	0.18	-0.075
2	0.24	0.21	-0.415
3	0.78	0.48	-0.543
4	0.51	0.86	-0.632
5	3.34	1.33	-0.640
6	0.83	1.38	-0.537
7	0.26	0.96	-0.425
Mohn's Rho	**0.95**	**0.77**	**-0.467**
% Adjustment	**0.514**	**0.564**	**1.876**
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 0.564 for Age 3-8 biomass was used to adjust the age 3+ biomass estimate at the beginning of 2017).

Parameter	Original Estimate	Rho Adjusted Estimate	80% CI	95% CI
B_{3+} (mt)	274,482	154,808	208,9360 to 359,157	182,168 to 406,040
F_{5-8}	0.10	0.19	0.08 to 0.14	0.08 to 0.16

Table 23. Beginning of year population abundance (numbers in 000's) for eastern Georges Bank haddock during 1969-2017 from a virtual population analysis using the bootstrap bias adjusted population abundance at the beginning of 2017. 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	16789	16596
1970	3593	658	141	1681	479	447	3659	1299	506	12463	8870	8212
1971	235	2881	463	109	1061	256	249	1961	971	8187	7952	5071
1972	5303	192	1285	155	62	642	69	61	1340	9109	3806	3614
1973	11637	4029	157	702	63	32	441	21	728	17811	6174	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	6973
1976	54073	2807	1787	2701	761	78	112	8	437	62764	8691	5884
1977	6038	43909	2157	1307	1463	501	64	74	348	55860	49823	5914
1978	4057	4942	28724	1706	906	922	263	52	319	41892	37835	32893
1979	52342	3316	3783	14594	1249	587	480	144	287	76782	24440	21124
1980	6237	42662	2699	2910	8083	695	300	199	301	64087	57850	15188
1981	4615	5077	19098	1901	2110	4442	396	130	352	38121	33506	28428
1982	2095	3729	3533	9567	1197	1281	2521	217	358	24498	22403	18674
1983	2551	1714	2396	1943	5278	795	708	1409	356	17150	14599	12885
1984	16093	2079	1268	1367	1094	2838	465	486	1046	26736	10642	8563
1985	1638	13111	1612	805	804	652	1311	214	821	20969	19330	6220
1986	13896	1333	8802	973	496	480	419	731	694	27824	13928	12595
1987	2177	11297	1056	4885	639	278	281	237	972	21822	19645	8348
1988	16013	1782	7376	746	2622	433	176	156	827	30132	14118	12336
1989	1020	13063	1412	4066	500	1345	255	109	673	22442	21422	8359
1990	2374	833	9547	1078	2630	280	790	178	577	18287	15913	15080
1991	2054	1916	675	6604	763	1462	164	495	541	14674	12620	10704
1992	8009	1662	1150	470	3545	544	846	70	663	16959	8949	7287
1993	11961	6513	1136	651	270	1591	365	406	494	23386	11425	4912
1994	11198	9721	5077	610	273	139	706	261	527	28512	17314	7593
1995	5578	9136	7577	3374	333	157	25	407	523	27110	21532	12397
1996	5500	4560	7408	5722	2389	225	106	18	700	26629	21128	16569
1997	16291	4500	3704	5624	3907	1579	130	71	520	36326	20035	15535
1998	7969	13312	3599	2967	4122	2762	1117	95	446	36390	28420	15108
1999	26061	6508	10723	2684	2194	2887	1858	812	401	54129	28068	21560
2000	8095	21312	5289	8101	1910	1572	2052	1291	881	50503	42409	21096
2001	69585	6622	17160	3925	5491	1326	1096	1484	1550	108239	38654	32032
2002	3296	56951	5362	12487	2734	3732	849	713	2091	88217	84921	27970
2003	1847	2698	46327	4194	8520	1896	2452	592	1936	70463	68616	65918
2004	195642	1506	2200	36277	3174	5637	1169	1577	1760	248942	53299	51793
2005	4669	159878	1210	1733	26414	2054	3270	494	2116	201839	197170	37292
2006	8991	3811	130679	965	1217	15436	1209	1938	1880	166125	157134	153324
2007	3102	7343	3106	104720	750	737	8560	779	2492	131589	128487	121144
2008	4518	2538	5977	2379	79111	481	452	5720	2388	103564	99046	96508
2009	1783	3695	2051	4648	1706	56011	302	293	5914	76402	74619	70924
2010	4015	1444	2912	1505	3138	1161	35763	181	4687	54807	50792	49348
2011	243473	3259	1132	2032	950	1811	609	20436	3752	277453	33980	30721
2012	20802	199119	2572	764	1201	573	878	402	14142	240453	219651	20531
2013	9858	16964	162449	1949	512	669	313	380	9933	203026	193168	176205
2014	884917	8049	13711	129880	1386	322	339	191	7795	1046589	161672	153623
2015	10577	723660	6283	10237	95052	715	178	214	6255	853172	842595	118935
2016	45903	8636	590396	4415	5993	68691	414	101	5093	729641	683738	675102
2017	111578	37575	6911	479674	3124	3988	51497	45	3855	698247	586669	549094

Table 24. Fishing mortality rates for eastern Georges Bank haddock during 1969-2016 from a virtual population analysis using the bootstrap bias adjusted population abundance at the beginning of 2017. 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 and 2010.

	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	0.385	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	0.366	0.401	0.330	0.024	0.330	25.6	0.348	26.8
1982	0.001	0.242	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	0.361	0.375	0.420	0.338	0.176	0.383	0.114	0.383	29.0	0.385	29.1
1984	0.005	0.054	0.254	0.330	0.317	0.572	0.577	0.467	0.405	0.467	34.1	0.505	36.2
1985	0.006	0.199	0.305	0.285	0.316	0.242	0.384	0.320	0.170	0.320	25.0	0.330	25.6
1986	0.007	0.033	0.389	0.221	0.379	0.334	0.372	0.304	0.069	0.304	23.9	0.342	26.4
1987	0.000	0.226	0.147	0.422	0.189	0.259	0.391	0.389	0.135	0.389	29.4	0.275	21.9
1988	0.004	0.033	0.396	0.201	0.467	0.331	0.278	0.394	0.143	0.394	29.7	0.437	32.3
1989	0.002	0.114	0.070	0.236	0.378	0.332	0.158	0.265	0.080	0.265	21.2	0.319	24.9
1990	0.014	0.010	0.169	0.146	0.387	0.335	0.266	0.310	0.085	0.310	24.3	0.355	27.3
1991	0.012	0.311	0.161	0.422	0.138	0.347	0.648	0.390	0.132	0.390	29.5	0.316	24.7
1992	0.007	0.180	0.369	0.356	0.601	0.200	0.534	0.529	0.165	0.529	37.6	0.545	38.4
1993	0.007	0.049	0.422	0.670	0.463	0.612	0.133	0.550	0.186	0.550	38.7	0.521	37.1
1994	0.004	0.049	0.209	0.405	0.349	1.521	0.350	0.463	0.106	0.463	33.9	0.489	35.3
1995	0.002	0.010	0.081	0.145	0.193	0.194	0.121	0.151	0.035	0.151	12.7	0.173	14.4
1996	0.001	0.008	0.076	0.182	0.214	0.348	0.205	0.196	0.121	0.196	16.1	0.225	18.3
1997	0.002	0.023	0.022	0.111	0.147	0.146	0.114	0.128	0.075	0.128	10.9	0.146	12.3
1998	0.003	0.016	0.093	0.102	0.156	0.196	0.119	0.148	0.090	0.148	12.5	0.165	13.8
1999	0.001	0.007	0.080	0.140	0.133	0.142	0.164	0.144	0.073	0.144	12.2	0.145	12.3
2000	0.001	0.017	0.098	0.189	0.165	0.161	0.124	0.173	0.088	0.173	14.4	0.153	12.9
2001	0.000	0.011	0.118	0.162	0.186	0.245	0.229	0.189	0.157	0.189	15.6	0.200	16.5
2002	0.000	0.006	0.046	0.182	0.166	0.220	0.161	0.186	0.165	0.186	15.4	0.192	15.9
2003	0.004	0.004	0.045	0.079	0.213	0.284	0.242	0.229	0.143	0.193	16.0	0.229	18.6
2004	0.002	0.019	0.038	0.117	0.235	0.344	0.662	0.347	0.180	0.173	14.4	0.347	26.7
2005	0.003	0.002	0.027	0.154	0.337	0.330	0.323	0.335	0.085	0.326	25.4	0.335	26.0
2006	0.002	0.005	0.021	0.052	0.302	0.390	0.239	0.373	0.095	0.358	27.5	0.373	28.4
2007	0.001	0.006	0.067	0.080	0.244	0.288	0.203	0.212	0.086	0.093	8.0	0.212	17.4
2008	0.001	0.013	0.052	0.132	0.145	0.267	0.233	0.147	0.045	0.146	12.4	0.147	12.4
2009	0.011	0.038	0.109	0.193	0.185	0.249	0.309	0.247	0.073	0.243	19.6	0.247	19.9
2010	0.009	0.044	0.160	0.260	0.349	0.446	0.359	0.361	0.051	0.358	27.4	0.361	27.6
2011	0.001	0.037	0.193	0.325	0.305	0.524	0.216	0.407	0.022	0.400	30.1	0.407	30.5
2012	0.004	0.003	0.077	0.199	0.384	0.403	0.635	0.471	0.174	0.417	31.1	0.471	34.3
2013	0.003	0.013	0.023	0.141	0.261	0.475	0.292	0.364	0.070	0.250	20.1	0.363	27.8
2014	0.001	0.046	0.090	0.109	0.460	0.387	0.254	0.416	0.037	0.114	9.8	0.415	31.0
2015	0.003	0.003	0.145	0.321	0.120	0.343	0.365	0.122	0.036	0.142	12.0	0.122	10.5
2016	0.000	0.021	0.007	0.136	0.192	0.084	1.843	0.103	0.098	0.104	9.0	0.102	8.8

Table 25. Beginning of year biomass (mt) for eastern Georges Bank haddock during 1969-2017. 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 2016 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	5745	3346	14580	14553	13071
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	22592	2016	1965	2915	1175	171	217	1200	32947	32253	9661
1978	466	2543	26855	2565	1805	2162	706	153	1100	38357	37890	35348
1979	6017	1706	3537	21948	2488	1375	1289	421	987	39770	33753	32047
1980	717	21951	2524	4376	16106	1631	805	584	1036	49729	49012	27061
1981	531	2612	17855	2859	4205	10416	1063	380	1212	41132	40601	37989
1982	241	1919	3303	14388	2384	3004	6768	636	1232	33874	33633	31715
1983	293	882	2240	2922	10515	1865	1901	4126	1226	25971	25678	24796
1984	1850	1070	1186	2055	2179	6653	1247	1424	3605	21269	19419	18349
1985	188	6746	1508	1211	1602	1529	3519	625	2829	19757	19569	12823
1986	1871	602	8575	1406	1510	1367	1508	2468	2718	22025	20154	19552
1987	327	5643	756	8170	1285	709	886	746	3528	22050	21723	16079
1988	1557	828	6864	1340	4762	831	478	508	3201	20369	18812	17984
1989	63	6194	917	5661	997	3399	549	311	2114	20206	20143	13949
1990	354	437	8823	1273	4898	581	1980	501	2004	20851	20498	20061
1991	246	1312	540	9982	1293	3559	345	1546	1856	20680	20434	19122
1992	979	1001	1285	499	7367	1178	2291	161	2279	17040	16060	15059
1993	1459	3133	1394	1174	344	3710	855	1112	1620	14801	13342	10208
1994	1195	4561	5314	989	525	299	2227	703	1627	17440	16246	11685
1995	481	4508	7297	5250	740	385	60	1219	1666	21605	21124	16616
1996	762	2257	6808	7554	4615	574	308	47	2513	25438	24676	22419
1997	2153	2279	2895	6779	6501	3437	319	183	1643	26188	24035	21756
1998	855	7127	3726	3446	6470	5398	2914	338	1545	31819	30964	23837
1999	3379	3083	9767	3461	2762	5397	3960	2209	1200	35217	31838	28756
2000	937	11580	5018	11977	3572	2814	4715	3238	2556	46407	45470	33890
2001	6496	3467	17251	5381	9871	2871	2466	3850	4539	56191	49695	46228
2002	315	18884	4172	14206	4084	7333	1848	1574	5663	58080	57764	38881
2003	149	996	39196	4457	12585	3119	5414	1320	4816	72053	71905	70908
2004	12501	467	1719	41762	4146	8784	1897	3083	3899	78259	65758	65291
2005	130	34814	596	1207	32386	2714	5007	790	5174	82817	82687	47873
2006	527	652	50816	634	1059	21085	1923	3376	4428	84502	83974	83322
2007	237	1803	1258	74251	743	1286	13348	1302	4640	98868	98631	96828
2008	483	835	3426	1891	73359	603	782	8439	4530	94349	93866	93031
2009	203	1430	1589	4642	1684	70468	447	786	13175	94425	94222	92792
2010	291	556	2181	1445	3515	1402	47660	321	9686	67057	66766	66210
2011	9359	1049	693	1828	906	1844	682	28014	6456	50830	41471	40422
2012	1463	37004	1176	386	1198	633	952	478	19029	62319	60856	23852
2013	690	4430	66981	1538	559	650	345	434	14474	90100	89410	84980
2014	37201	2600	7360	84184	1263	391	411	182	11165	144759	107557	104957
2015	1076	136903	2557	7231	76745	784	214	290	7770	233570	232494	95590
2016	1886	1538	202123	3086	6719	70038	513	116	10723	296741	294855	293317
2017	4766	6307	2911	209768	2276	3542	50495	60	5429	285555	280789	274482

Table 26. Partial recruitment of haddock normalized to ages 4 to 8 for 1969 to 2002 and to ages 5 to 8 for 2003 to 2016 from the eastern Georges Bank fishery. Average F's used to normalize the partial recruitment were weighted by population numbers. [1]Weighted by population.

	Age Group								
Year	1	2	3	4	5	6	7	8	9+
1969	0.00	0.22	1.13	0.79	1.01	1.06	0.89	1.00	1.00
1970	0.05	0.40	0.15	0.69	1.13	1.02	1.12	1.00	1.43
1971		1.08	1.58	0.65	0.53	1.97	2.13	1.00	1.10
1972	0.22	0.01	1.18	2.06	1.37	0.51	2.84	1.00	1.34
1973	0.20	1.13	0.08	1.45	1.85	0.72	0.18	1.00	0.51
1974	0.11	2.78	1.56		1.24	1.46	0.12	0.83	1.33
1975	0.03	0.60	1.85	1.04	0.24	1.17	1.00	1.00	0.29
1976	0.02	0.17	0.31	1.13	0.59		0.57		0.13
1977	0.00	0.91	0.14	0.67	1.06	1.80	0.00	1.00	0.19
1978	0.01	0.28	1.95	0.46	0.96	1.85	1.66	1.00	0.14
1979	0.01	0.01	0.16	0.97	0.96	1.17	1.69	1.00	0.14
1980	0.02	1.80	0.45	0.36	1.19	1.08	1.91	1.00	0.14
1981	0.04	0.49	1.49	0.80	0.91	1.11	1.22	1.00	0.07
1982	0.00	0.64	1.05	1.05	0.55	1.04	1.01	1.00	0.60
1983	0.01	0.26	0.94	0.98	1.10	0.88	0.46	1.00	0.30
1984	0.01	0.12	0.54	0.71	0.68	1.23	1.24	1.00	0.87
1985	0.02	0.62	0.95	0.89	0.99	0.75	1.20	1.00	0.53
1986	0.02	0.11	1.28	0.73	1.25	1.10	1.22	1.00	0.23
1987	0.00	0.58	0.38	1.09	0.49	0.67	1.01	1.00	0.35
1988	0.01	0.08	1.00	0.51	1.19	0.84	0.70	1.00	0.36
1989	0.01	0.43	0.26	0.89	1.43	1.25	0.60	1.00	0.30
1990	0.05	0.03	0.54	0.47	1.25	1.08	0.86	1.00	0.27
1991	0.03	0.80	0.41	1.08	0.35	0.89	1.66	1.00	0.34
1992	0.01	0.34	0.70	0.67	1.14	0.38	1.01	1.00	0.31
1993	0.01	0.09	0.77	1.22	0.84	1.11	0.24	1.00	0.34
1994	0.01	0.11	0.45	0.87	0.75	3.28	0.76	1.00	0.23
1995	0.01	0.06	0.54	0.96	1.28	1.28	0.80	1.00	0.23
1996	0.00	0.04	0.39	0.93	1.09	1.78	1.05	1.00	0.62
1997	0.02	0.18	0.17	0.86	1.14	1.14	0.89	1.00	0.58
1998	0.02	0.11	0.63	0.69	1.06	1.33	0.81	1.00	0.61
1999	0.01	0.05	0.56	0.98	0.93	0.99	1.14	1.00	0.50
2000	0.00	0.10	0.57	1.10	0.96	0.93	0.72	1.00	0.51
2001	0.00	0.06	0.63	0.86	0.99	1.30	1.21	1.00	0.83
2002	0.00	0.03	0.25	0.98	0.89	1.18	0.86	1.00	0.89
2003	0.018	0.02	0.19	0.34	0.93	1.24	1.06	1.00	0.62
2004	0.005	0.05	0.11	0.34	0.68	0.99	1.91	1.00	0.52
2005	0.010	0.005	0.08	0.46	1.01	0.98	0.96	1.00	0.25
2006	0.006	0.01	0.06	0.14	0.81	1.04	0.64	1.00	0.25
2007	0.004	0.03	0.31	0.38	1.15	1.36	0.96	1.00	0.41
2008	0.007	0.09	0.35	0.90	0.99	1.82	1.59	1.00	0.31
2009	0.043	0.15	0.44	0.78	0.75	1.01	1.25	1.00	0.30
2010	0.024	0.12	0.44	0.72	0.97	1.23	1.00	1.00	0.14
2011	0.003	0.09	0.47	0.80	0.75	1.29	0.53	1.00	0.06
2012	0.008	0.01	0.16	0.42	0.81	0.86	1.35	1.00	0.37
2013	0.007	0.03	0.06	0.39	0.72	1.31	0.80	1.00	0.19
2014	0.003	0.11	0.22	0.26	1.11	0.93	0.61	1.00	0.09
2015	0.021	0.03	1.18	2.62	0.98	2.80	2.98	1.00	0.30
2016	0.002	0.20	0.07	1.33	1.87	0.82	1.87	1.01	0.95
Avg 2014-2016[1]	0.003	0.030	0.085	0.462	1.036	0.842	1.626	1.003	0.387
Avg 2007-2016[1]	0.003	0.026	0.086	0.442	1.011	0.931	1.007	1.000	0.303

Table 27. Input for projections and risk analyses of eastern Georges Bank haddock for the 2017 fishery. A catch of 50,000 mt in 2017 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)									
2017	111578	37575	6911	479674	3124	3988	51497	45	3855
2018	12454	91352	30472	5499	361542	1861	2375	30672	2895
2019	12454	10196	74212	24371	4015	229426	1175	1499	21555
2020	12454	10196	8283	59354	17797	2535	151772	742	17270
Partial Recruitment to the Fishery[1]									
2017	0.00	0.03	0.09	0.26[2]	1.00	1.00	1.00	1.00	0.30
2018	0.00	0.03	0.09	0.44	0.98[2]	1.00	1.00	1.00	0.30
2019	0.00	0.03	0.09	0.44	1.00	0.82[2]	1.00	1.00	0.30
Weight at beginning of year for population (kg)[3]									
2017[4]	0.043	0.168	0.421	0.437[5]	0.729	0.888	0.981[6]	1.340	1.409
2018	0.062	0.178	0.390	0.614	0.587[5]	1.002	1.139	0.953[6]	1.585
2019	0.062	0.178	0.390	0.614	0.886	0.721[5]	1.139	1.283	1.242[6]
2020	0.062	0.178	0.390	0.614	0.886	1.002	0.721[5]	1.283	1.585
Weight at age for catch (kg)[7]									
2017	0.159	0.493	0.728	0.83[8]	1.128	1.210	1.440	1.443	1.627
2018	0.159	0.493	0.728	0.942	0.99[8]	1.210	1.440	1.443	1.627
2019	0.159	0.493	0.728	0.942	1.128	1.11[8]	1.440	1.443	1.627
Maturity									
2017-19	0	0	1	1	1	1	1	1	1

[1]Based on 2007 to 2016 weighted average; used for 2017, 2018, and 2019.
[2] 2013 year class values are adjusted to reflect PR values of the 2010 year class at the same age.
[3]2015-2017 average weights at age from the DFO survey unless indicated otherwise.
[4]2017 average weights at age from DFO survey.
[5]2013 year class average weights at age from DFO survey based on regression of previous growth.
[6]2010 year class average weights at age from DFO survey based on minimum value in the time series.
[7]Lowest values in the time series (1969-2016); used for 2017, 2018 and 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 2018 and 2019 fishery using 15.21 million age 1 recruits (2007 to 2016 median from 2016 update results) for the 2017, 2018 and 2019 year classes, the input values detailed in Table 25 and assuming that the 2017 quota of 50,000 mt is caught and F=0.26 in 2018 and 2019. Natural mortality was assumed to be 0.2. Highlighted values indicate the 2013 and 2010 year classes.

	Age group											
Year	1	2	3	4	5	6	7	8	9+	1+	2+	3+
Population Numbers (000s)												
2017	111578	37575	6911	479674	3124	3988	51497	45	3855			
2018	12454	91352	30472	5499	361542	1861	2375	30672	2895			
2019	12454	10196	74212	24371	4015	229426	1175	1499	21555			
2020	12454	10196	8283	59354	17797	2535	151772	742	17270			
Population Biomass (mt)												
2017	4766	6307	2911	209768	2276	3542	50495	60	5429	285555	280789	274482
2018	770	16294	11889	3377	212225	1863	2706	29230	4590	282946	282176	265881
2019	770	1819	28955	14968	3556	165370	1338	1924	26771	245472	244702	242883
2020	770	1819	3232	36454	15763	2539	109397	951	27381	198305	197535	195716
Fishing Mortality												
2017	0	0.01	0.029	0.083	0.318	0.318	0.318	0.318	0.095			
2018	0	0.008	0.023	0.114	0.255	0.26	0.26	0.26	0.078			
2019	0	0.008	0.023	0.114	0.26	0.213	0.26	0.26	0.078			
Projected Catch Numbers (000s)												
2017	0	324	177	34566	776	990	12788	11	319			
2018	0	643	639	540	74018	388	495	6392	197			
2019	0	72	1556	2392	837	40067	245	313	1468			
Catch Biomass (mt)												
2017	0	160	129	28690	875	1198	18414	16	518	50000	50000	49840
2018	0	317	465	508	73278	469	713	9224	321	85295	85295	84978
2019	0	35	1133	2254	944	44475	353	451	2388	52032	52032	51997

Table 29. Bias adjusted sensitivity projection results for eastern Georges Bank haddock for the 2018 and 2019 fishery with a rho adjustment (=0.564) applied to the 2017 population numbers for ages 0-9+. The projections use 15.21 million age 1 recruits (2007 to 2016 median from 2016 update results) for the 2017, 2018 and 2019 year classes, the input values detailed in Table 27; and assume that the 2017 quota of 50,000 mt is caught and F=0.26 in 2018 and 2019. Natural mortality was assumed to be 0.2. Highlighted values indicate the 2013 and 2010 year classes.

	Age group											
Year	1	2	3	4	5	6	7	8	9+	1+	2+	3+
Population Numbers (000s)												
2017	62930	21193	3898	270536	1762	2249	29044	25	2174			
2018	7024	51523	17038	3022	189181	787	1004	12965	1495			
2019	12454	5751	41855	13627	2207	120050	497	634	9317			
2020	12454	10196	4672	33476	9951	1393	79416	313	7456			
Population Biomass (mt)												
2017	2688	3557	1642	118309	1284	1998	28479	34	3062	161053	158365	154808
2018	434	9190	6648	1856	111049	788	1144	12356	2370	145835	145401	136211
2019	770	1026	16331	8369	1954	86532	566	813	11572	127933	127163	126137
2020	770	1819	1823	20560	8813	1395	57243	402	11821	104647	103876	102058
Fishing Mortality												
2017	0	0.018	0.055	0.158	0.607	0.607	0.607	0.607	0.182			
2018	0	0.008	0.023	0.114	0.255	0.26	0.26	0.26	0.078			
2019	0	0.008	0.023	0.114	0.26	0.213	0.26	0.26	0.078			
Projected Catch Numbers (000s)												
2017	0	346	188	35867	734	936	12092	11	329			
2018	0	363	357	297	38731	164	209	2702	102			
2019	0	41	878	1338	460	20966	103	132	634			
Catch Biomass (mt)												
2017	0	171	137	29770	827	1133	17412	15	535	50000	50000	49829
2018	0	179	260	279	38343	198	301	3899	166	43626	43626	43447
2019	0	20	639	1260	519	23272	149	191	1032	27082	27082	27062

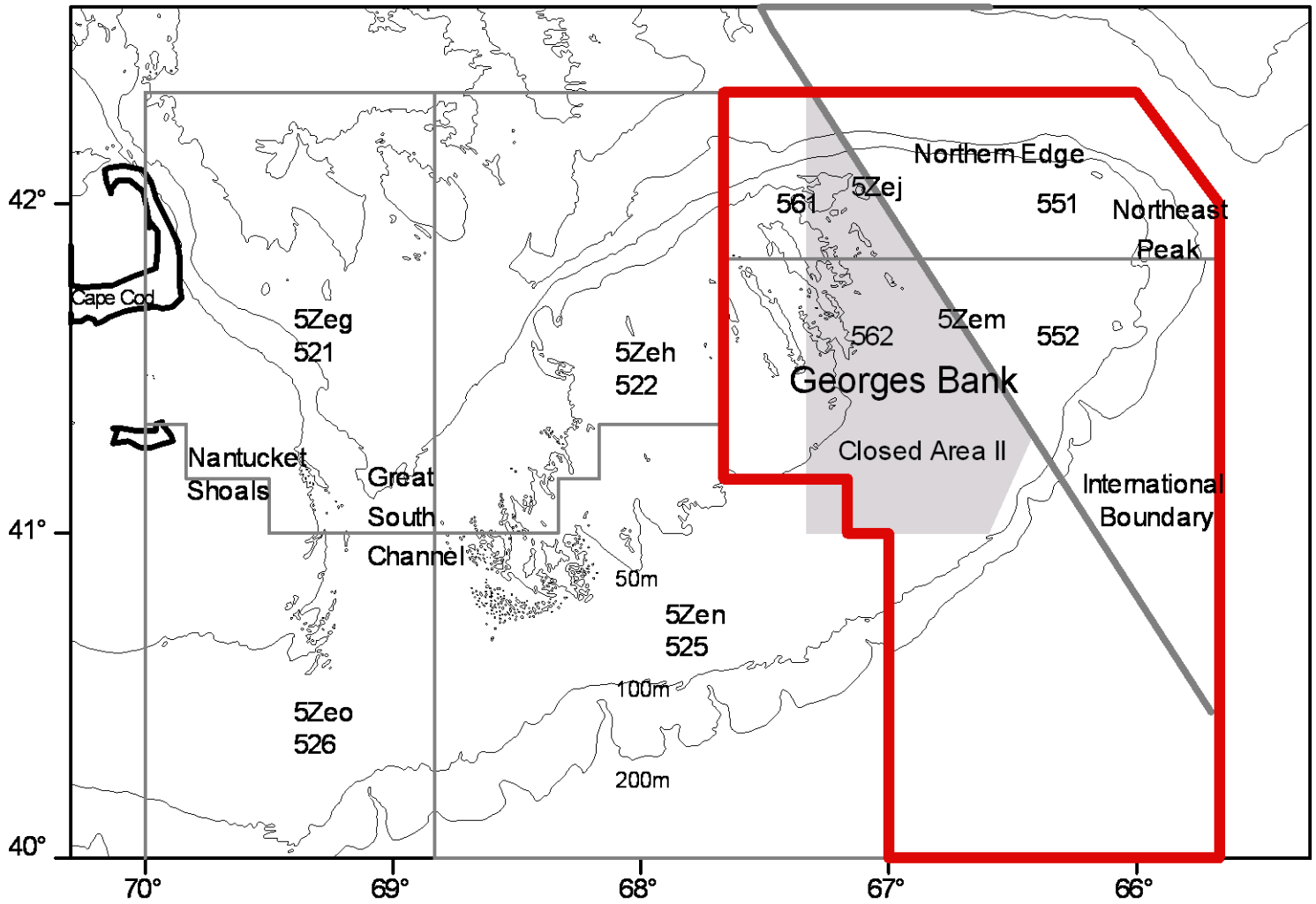

Figure 1. Fisheries statistical unit areas in North Atlantic Fisheries Organization Subdivision 5Ze. Alpha-numeric codes, e.g. 5Zej, are the Canadian Department of Fisheries and Oceans designations and numeric codes, e.g. 561, are National Marine Fisheries Service designations. The eastern Georges Bank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

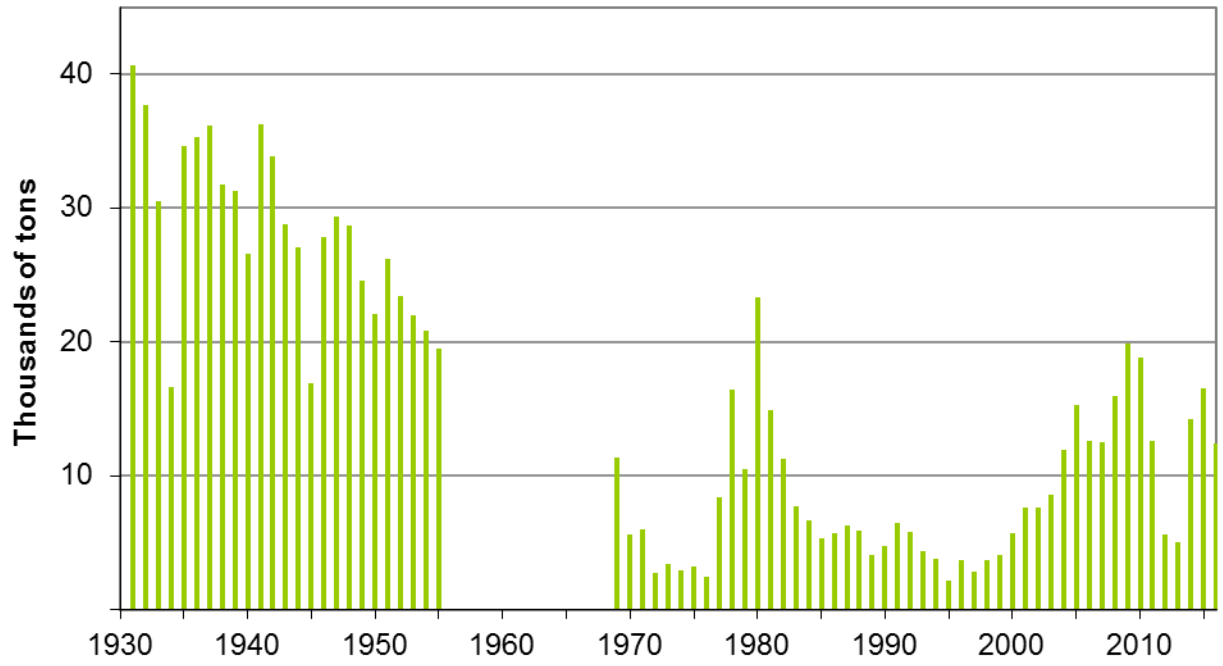

Figure 2. Historical catch of eastern Georges Bank haddock during 1931-1955 (Gavaris and Van Eeckhaute 1997) compared to recent catches during 1969-2016. Catch data for 1956 to 1968 were not available by unit area.

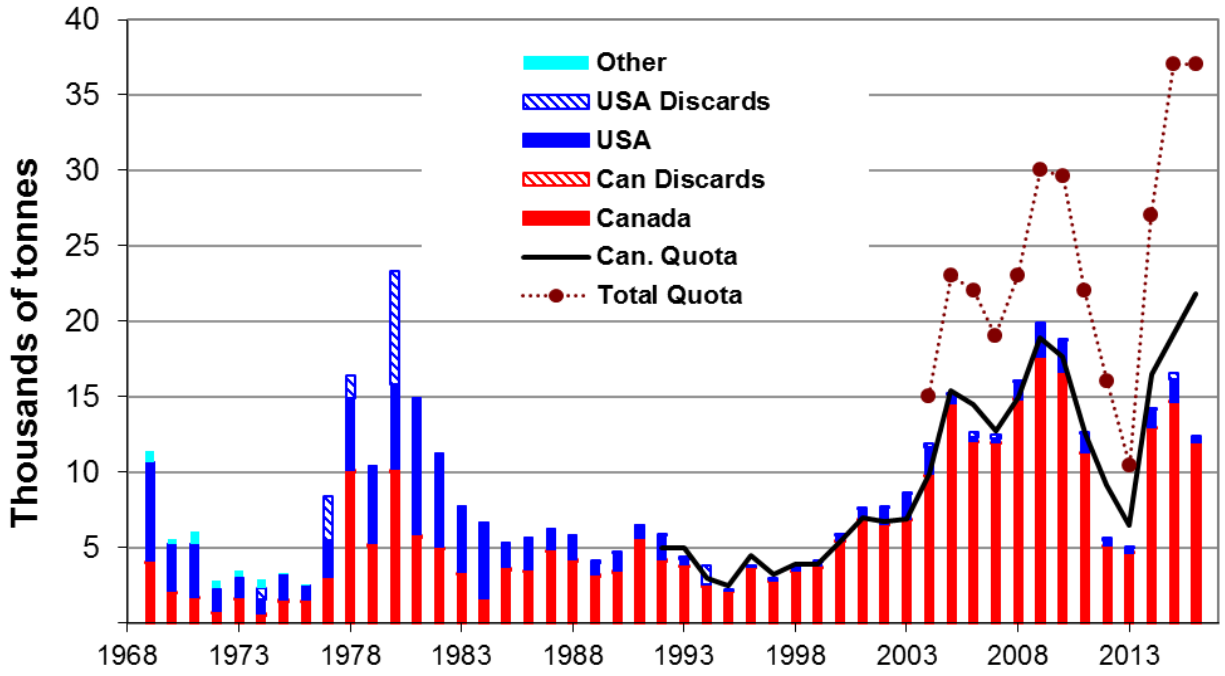

Figure 3. Nominal catches of eastern Georges Bank haddock during 1969-2016.

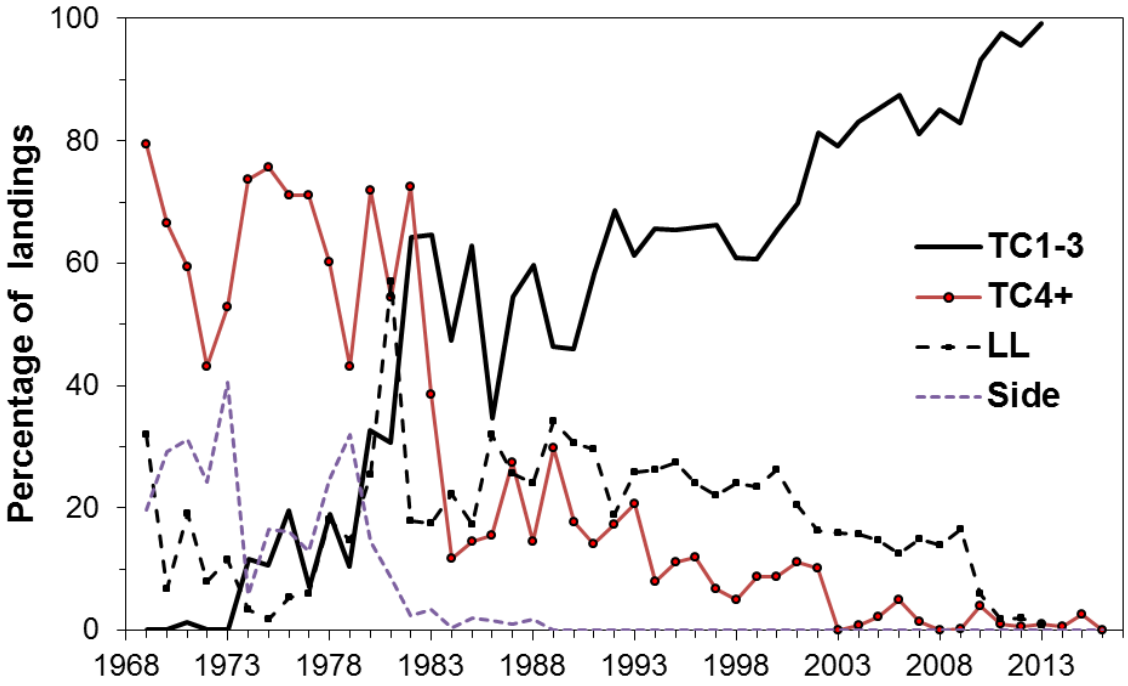

Figure 4. Percentage of annual landings (t) by gear type for the Canadian EGB haddock fishery, 1969-to 2016. TC 1-3 = otter trawl tonnage class 1-3; TC 4+ = otter trawl tonnage class 4+; LL = longline; Side = side otter trawl.

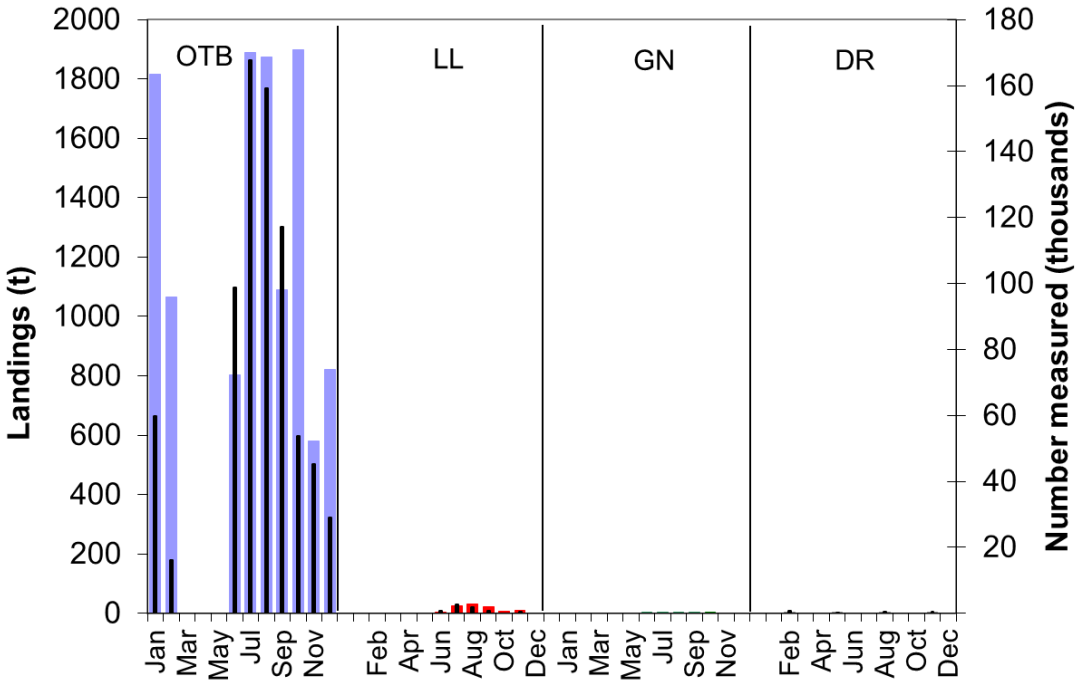

Figure 5. Haddock landings by the Canadian commercial groundfish fishery and discards from the scallop fishery from eastern Georges Bank by month and gear in 2016 (wide bars) with sampling levels (narrow bars). Landings from the gillnet fishery were very low and no samples were available. OTB=otter trawl bottom, LL= longline, GN=gill net, DR=scallop dredge.

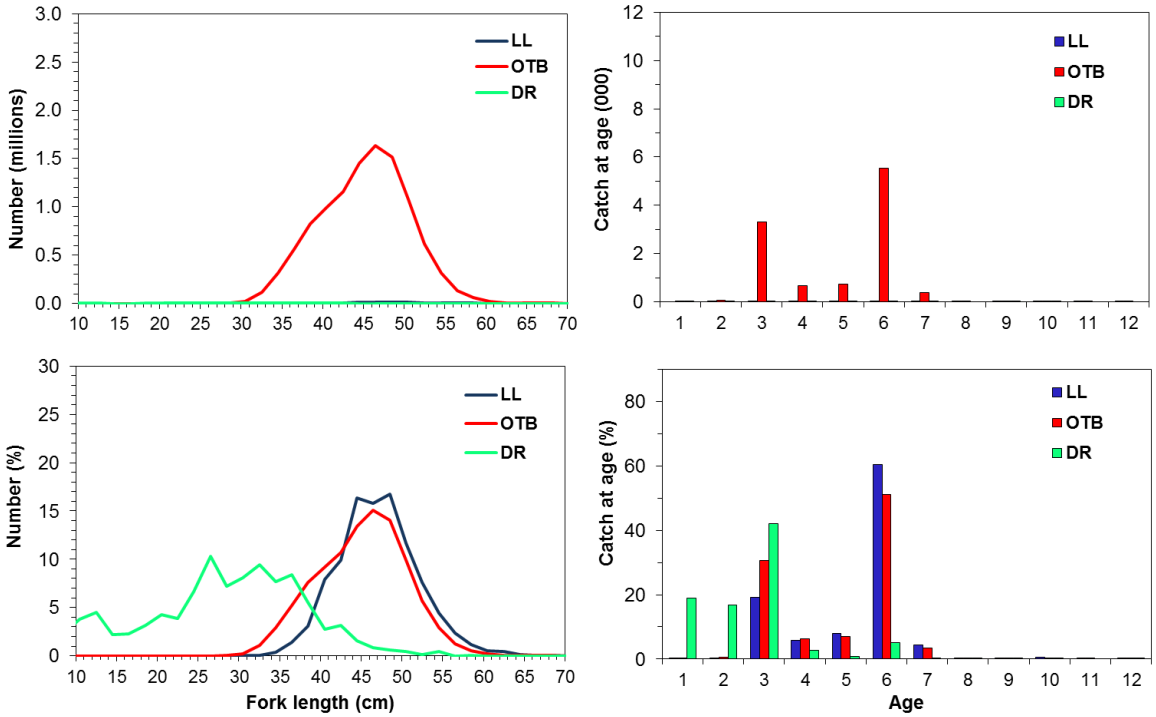

Figure 6. Canadian Eastern Georges Bank haddock fishery catch at size (left panels) and catch at age right panels) in numbers and percentage by gear category for 2016. OTB=otter trawl bottom, LL=longline, DR=scallop dredge.

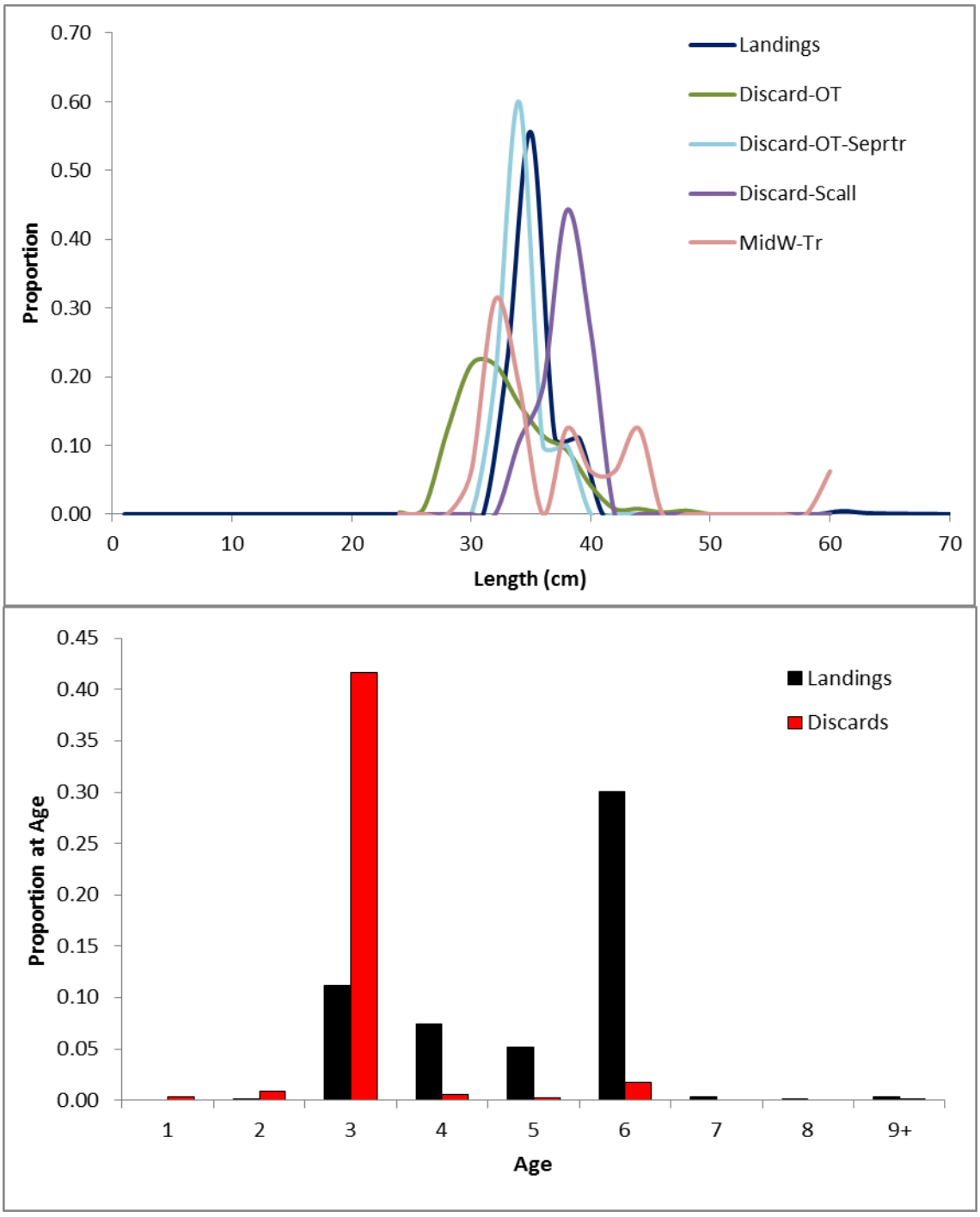

Figure 7. USA Eastern Georges Bank haddock fishery catch at size (top panel) and catch at age (bottom panel) in percentage for landings and discards in 2016.

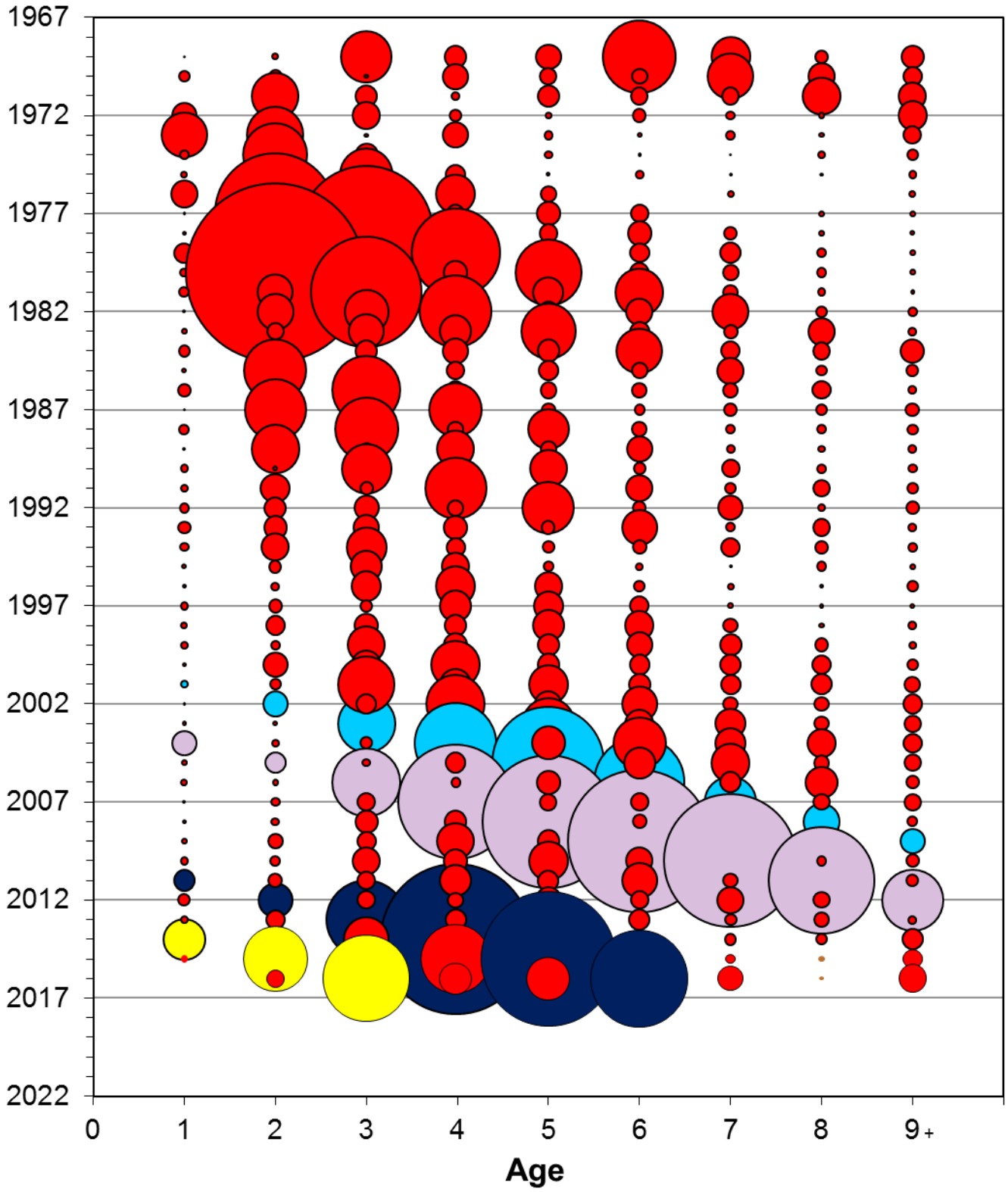

Figure 8. Total commercial catch at age (numbers) of eastern Georges Bank haddock during 1969-2016. The 2000, 2003, 2010 and 2013 year classes are indicated in blue, purple, dark blue, and yellow respectiviely. The bubble area is proportional to catch magnitude.

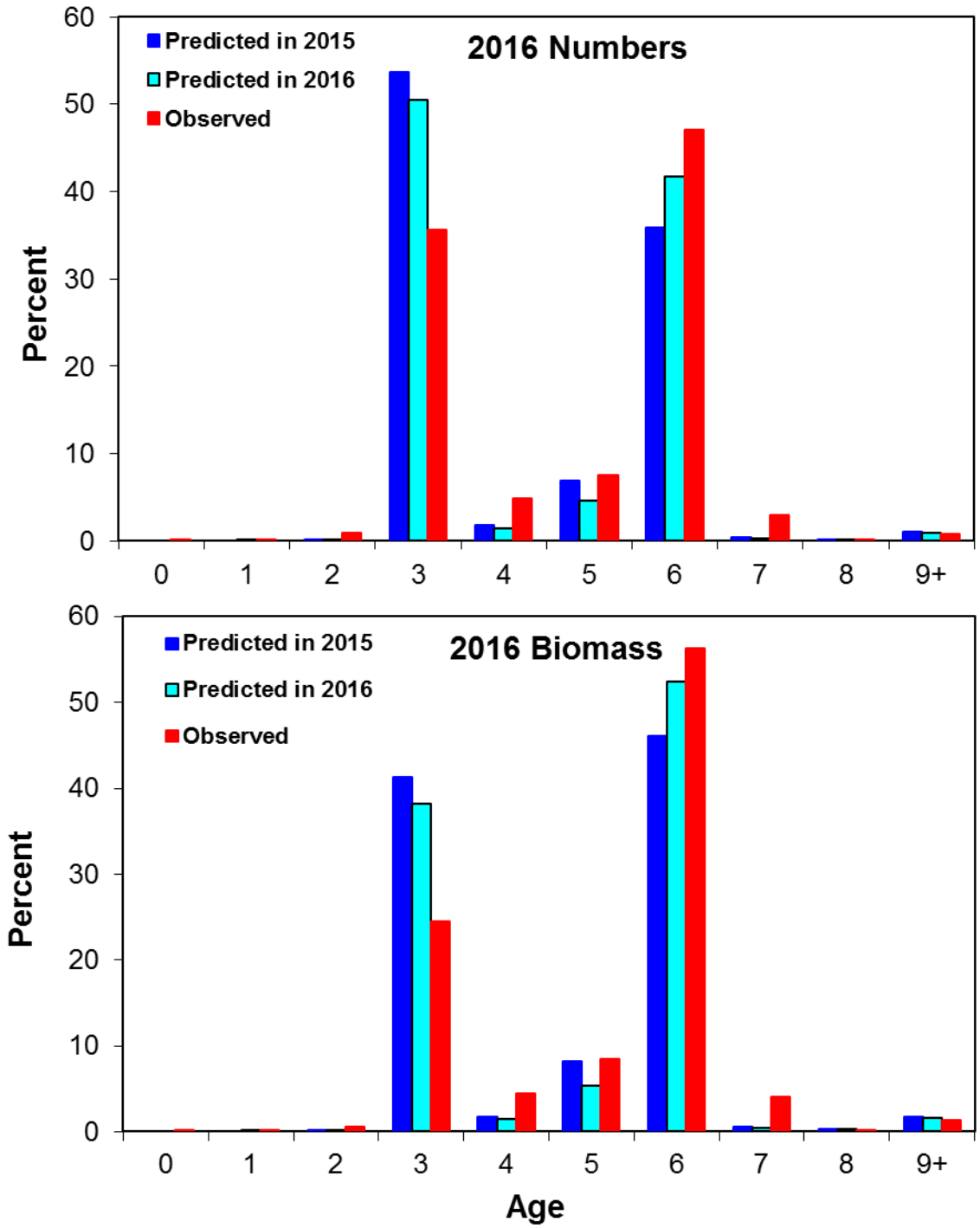

Figure 9. Percent compostion in numbers and biomass of 2016 observed eastern Georges Bank haddock landings predicted in 2015, upon which the quota was based, and in 2016.

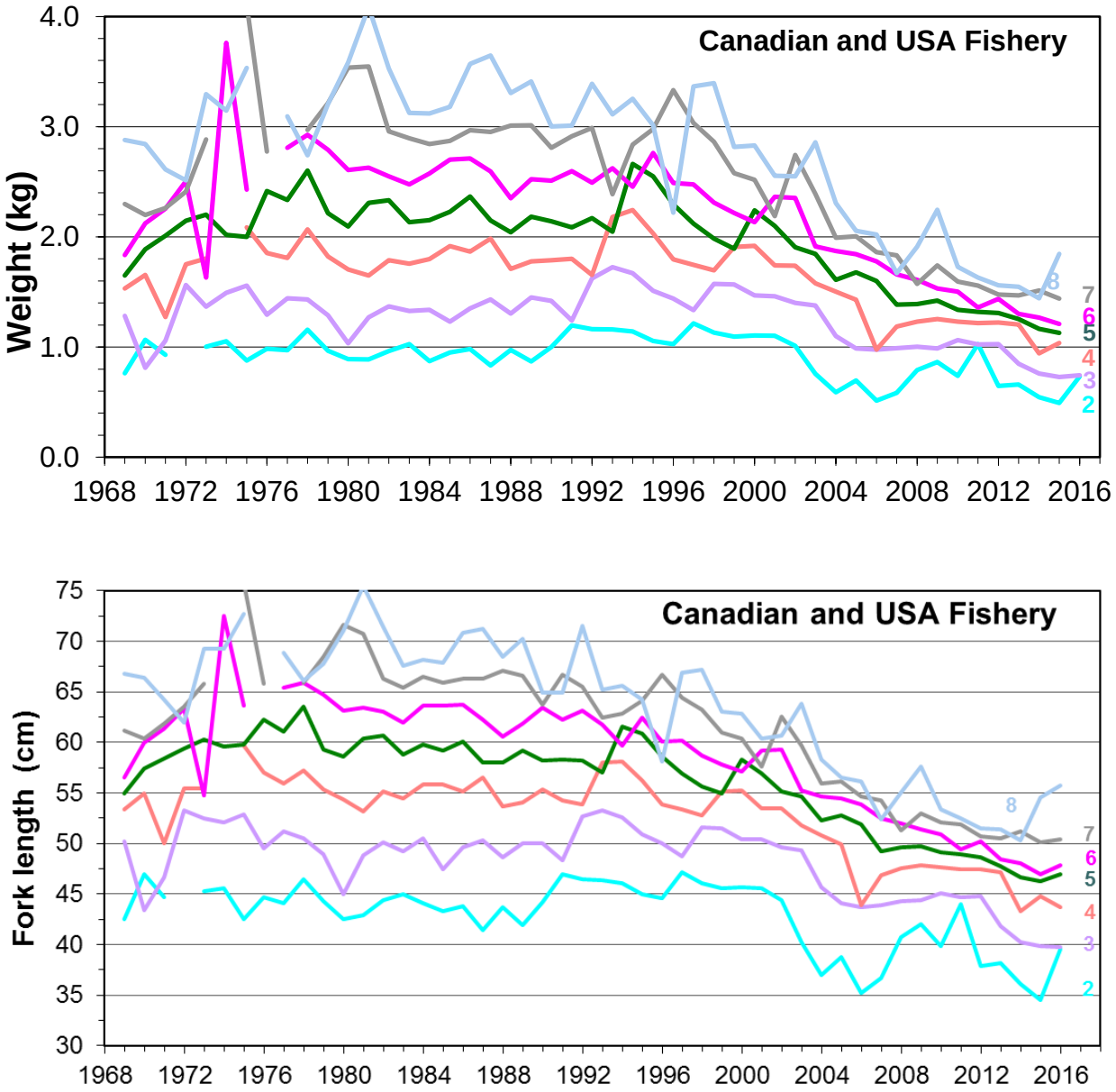

Figure 10. Average weights at age (Upper Panel) and lengths at age (Lower Panel) for eastern Georges Bank haddock from the combined Canadian and USA commercial groundfish fishery for 1969-2016.

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

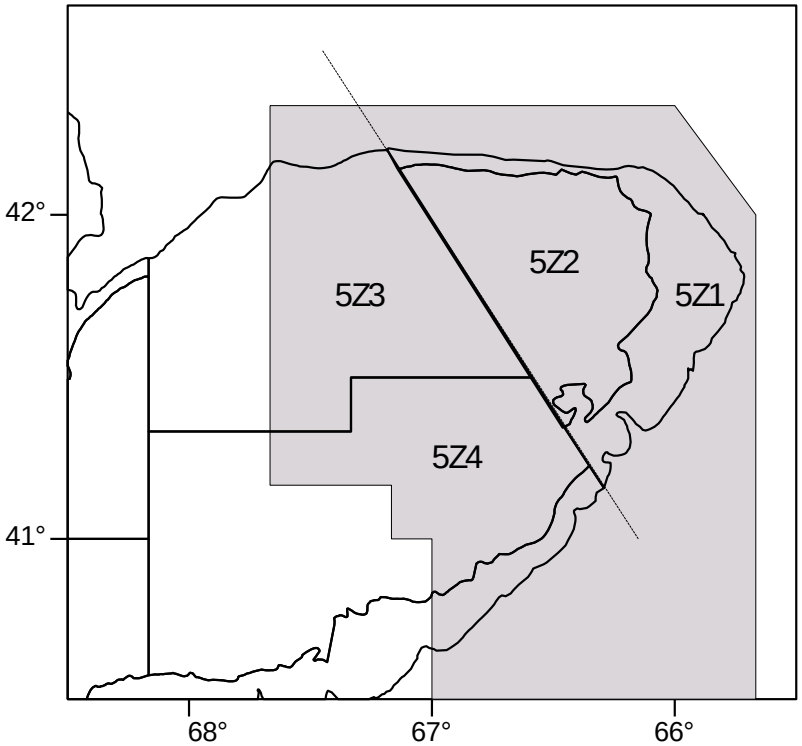

Figure 12. Stratification scheme used for the Canadian Department of Fisheries and Oceans (DFO) survey. The eastern Georges Bank management area is indicated by shading.

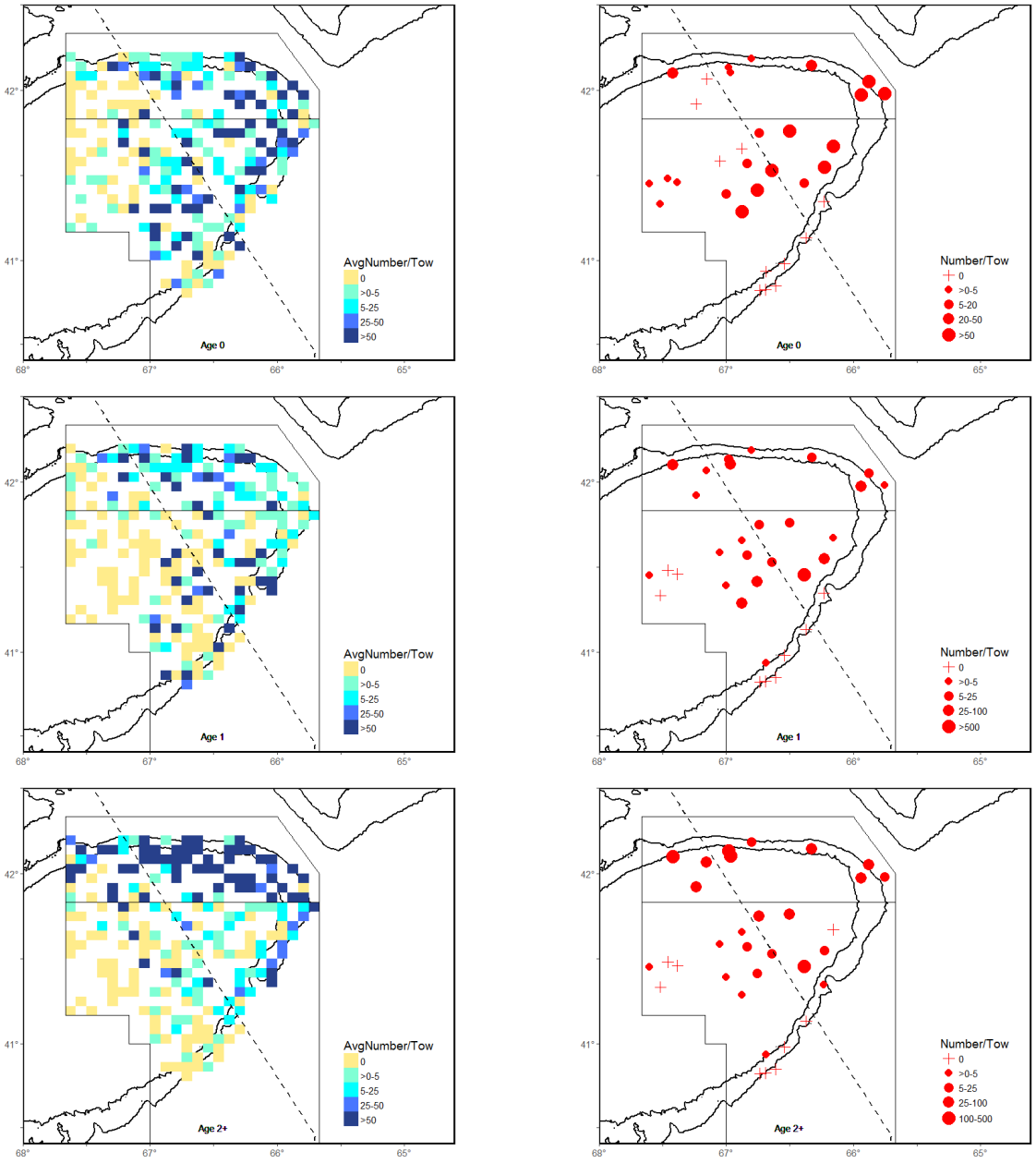

Figure 13. Distribution of eastern Georges Bank haddock abundance (number/tow) as observed from the NMFS **fall** survey for ages 0, 1 and 2+. The squares (left panels) are shaded relative to the average survey catch for 2004 to 2015. The expanding symbols (right panels) represent the **2016** survey catches. Length based conversion coefficients have been applied since the 2009 survey to make them comparable to surveys undertaken by the *Albatross IV*.

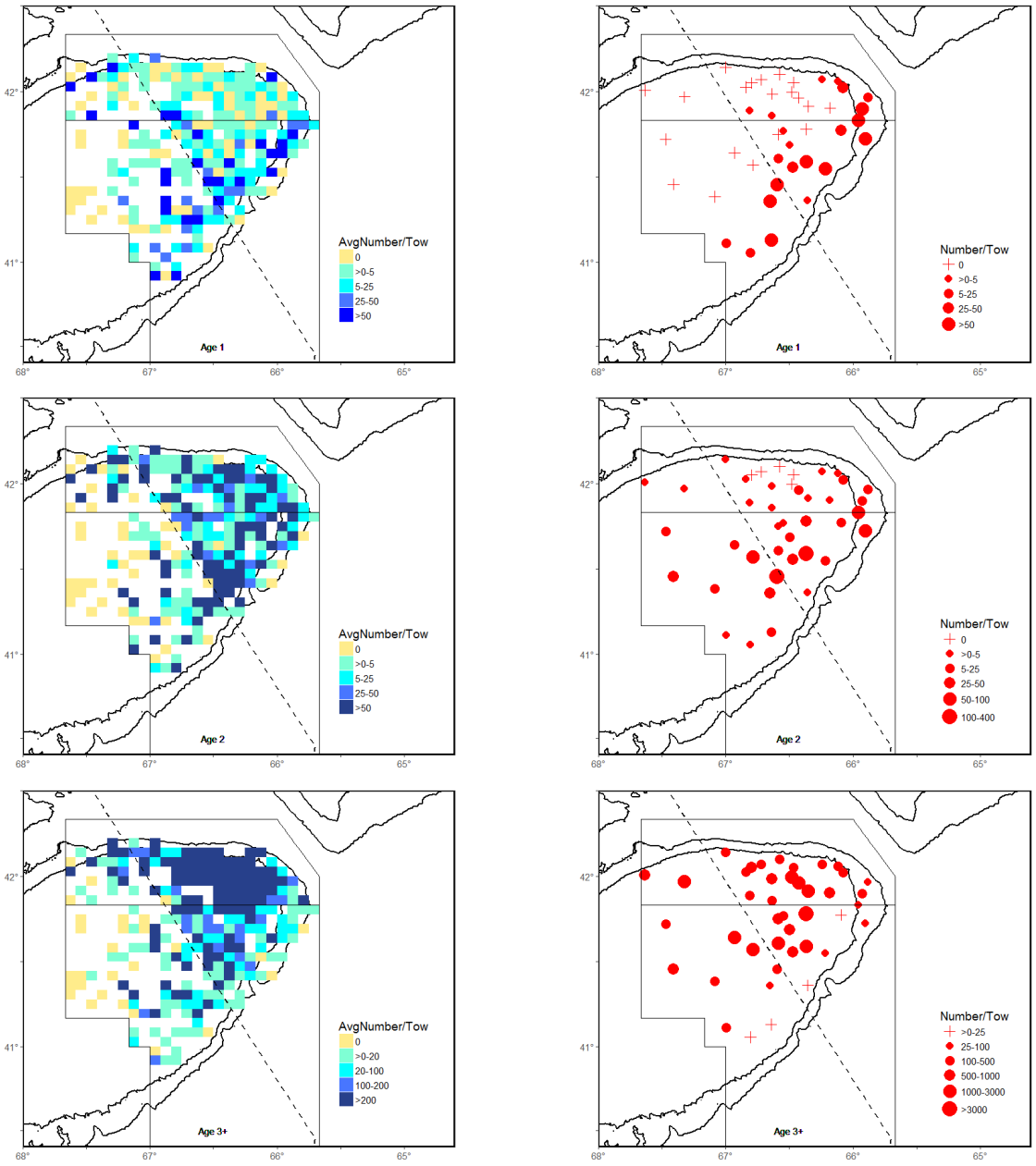

Figure 14. Distribution of eastern Georges Bank haddock abundance (number/tow) as observed from the DFO winter survey for ages 1, 2 and 3+. The squares (left panels) are shaded relative to the average survey catch for 2004 to 2016. The expanding symbols (right panels) represent the **2017** survey catches.

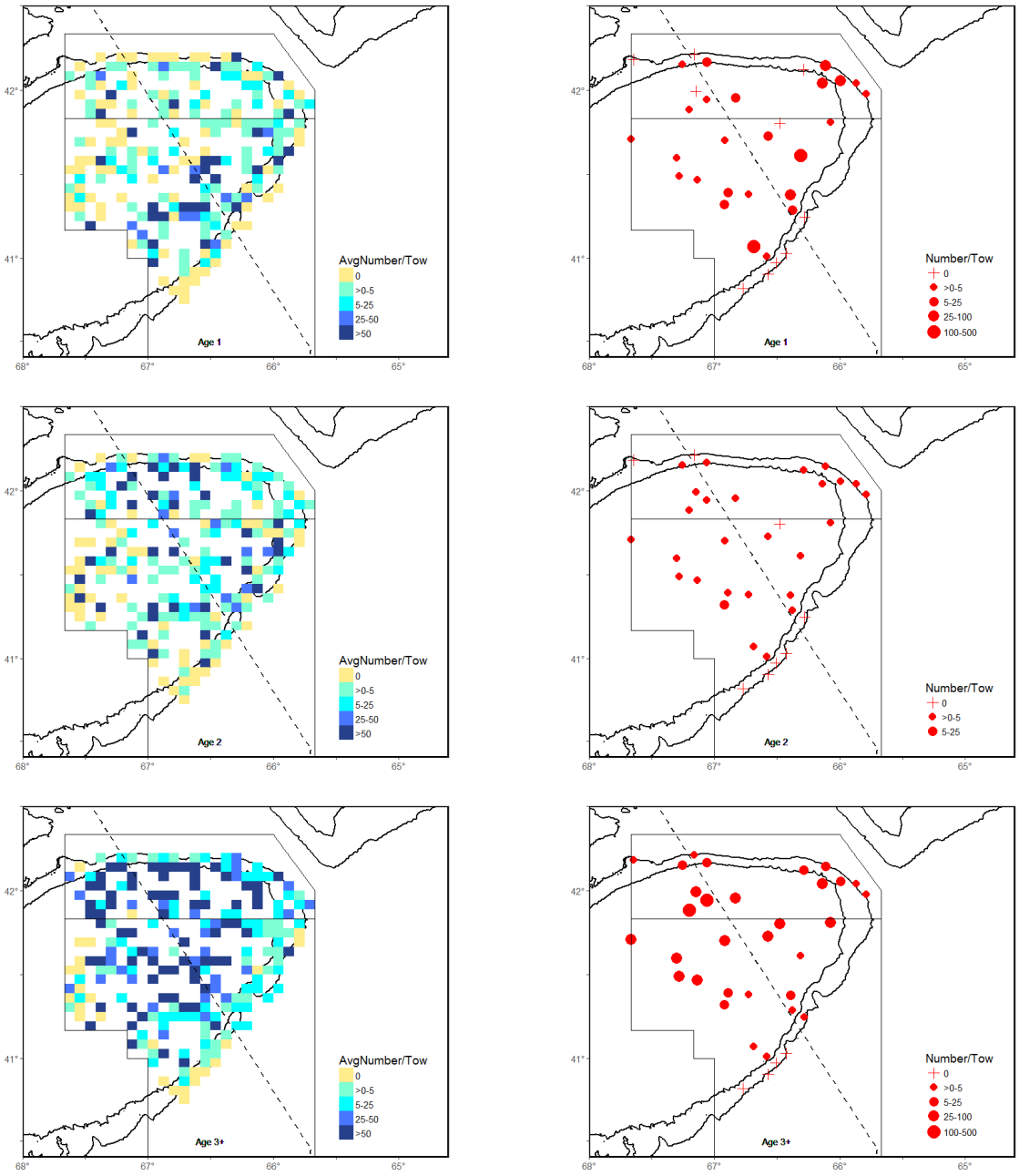

Figure 15. Distribution of eastern Georges Bank haddock abundance (number/tow) as observed from the National Marine Fisheries Service **spring** survey. The squares (left panels) are shaded relative to the average survey catch for 2005 to 2016. The expanding symbols (right panels) represent the **2017** survey catches. Length based conversion coefficients have been applied since the 2009 survey to make them comparable to surveys undertaken by the *Albatross IV*.

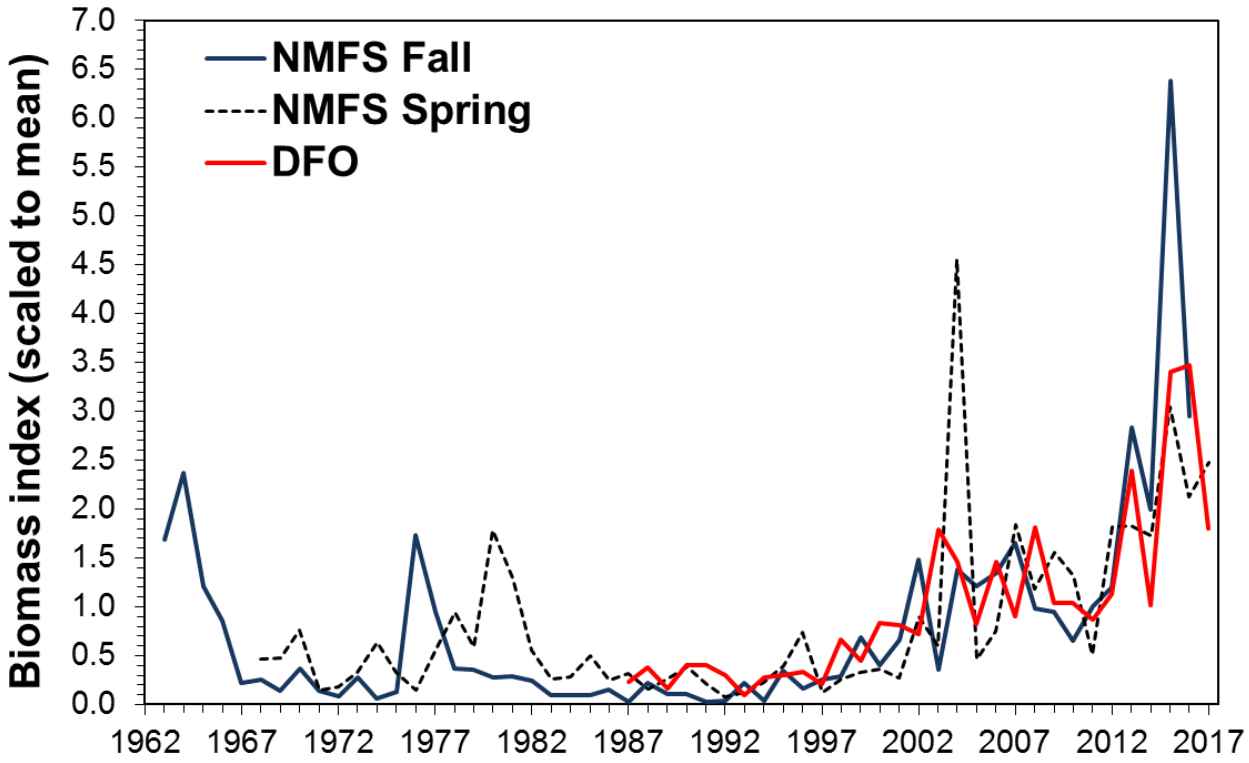

Figure 16. Scaled total biomass indices from NMFS fall (1963-2016), NMFS spring (1968-2017) and DFO (1987-2017) research surveys for eastern Georges Bank. Biomass conversion coefficients have been applied to the NMFS surveys to adjust for changes in door type (BMV *vs* Polyvalent; 1968-1984), vessel (*Delaware II vs Albatross IV;* 1968-2008) and vessel/net (*Albatross IV* vs *Henry B. Bigelow;* Yankee 36 *vs* 4 seam-3 bridle; 2009-2017).

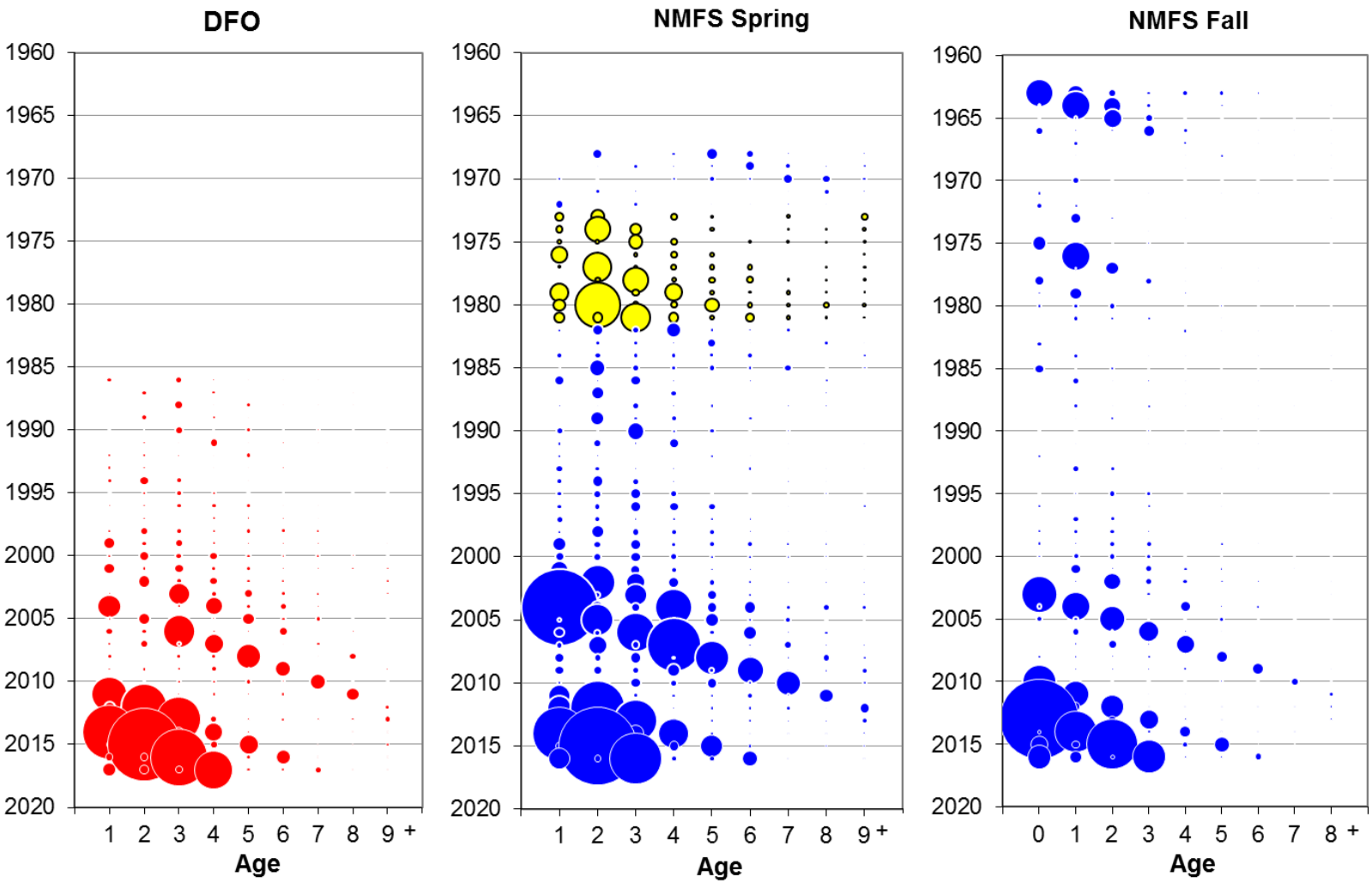

Figure 17. Estimated abundance at age (numbers in 000's) of eastern Georges Bank haddock for the Canadian Department of Fisheries and Oceans (DFO) for 1986 to 2017, the National Marine Fisheries Service (NMFS) spring survey for 1968 to 2017 and the NMFS fall survey for 1963 to 2016. Bubble area is proportional 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.

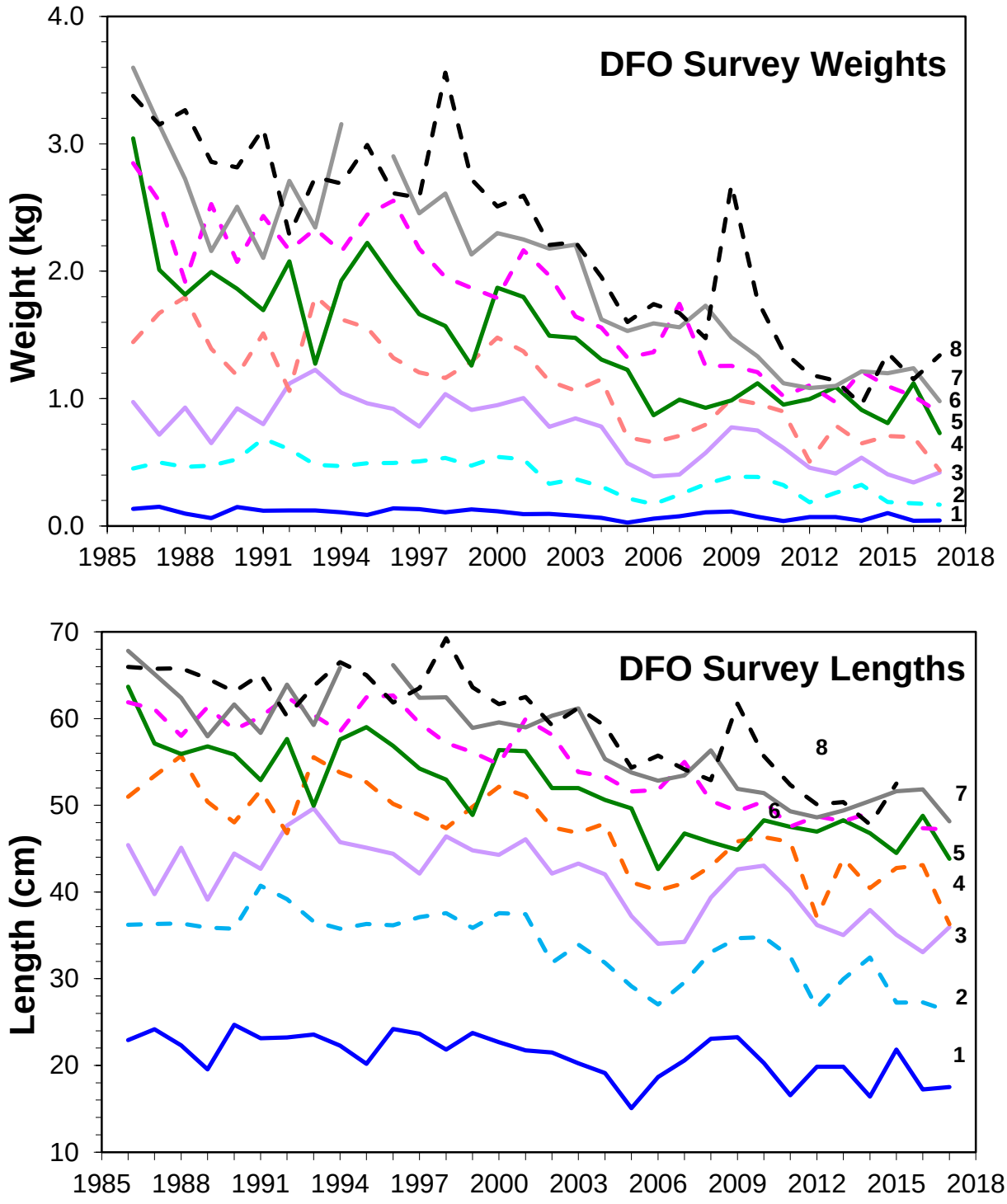

Figure 18. Average weights (upper panel) and lengths (lower panel) at age for eastern Georges Bank haddock derived from DFO winter surveys during 1986-2017.

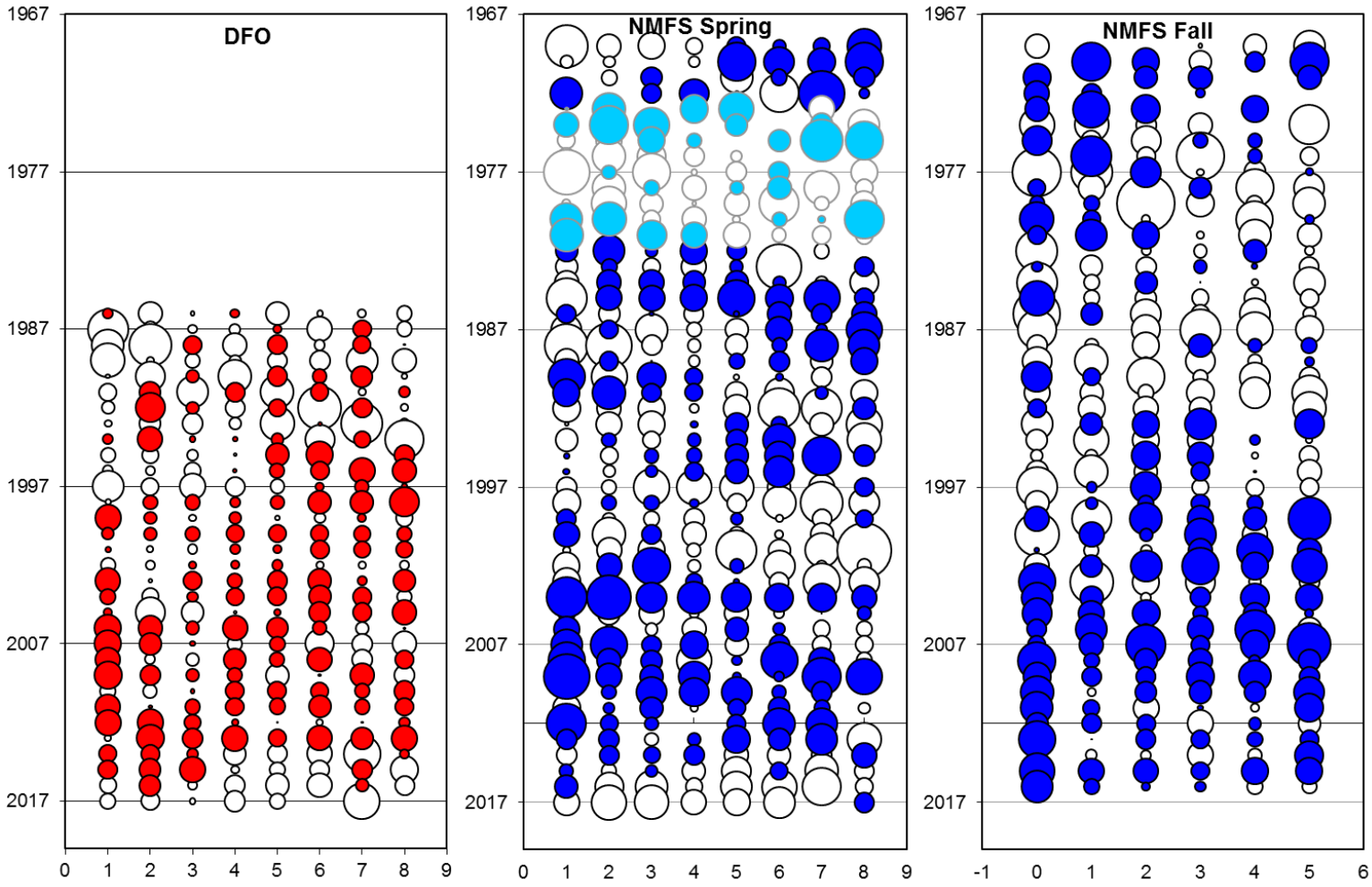

Figure 19. Residuals of survey abundance indices by year and age group from the DFO survey (1986-2017), the NMFS spring survey (1969-2017) and the NMFS fall survey (1969-2016)for eastern Georges Bank haddock. Solid symbols indicate positive values (i.e. model predicts lower abundance than surveys), open 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.

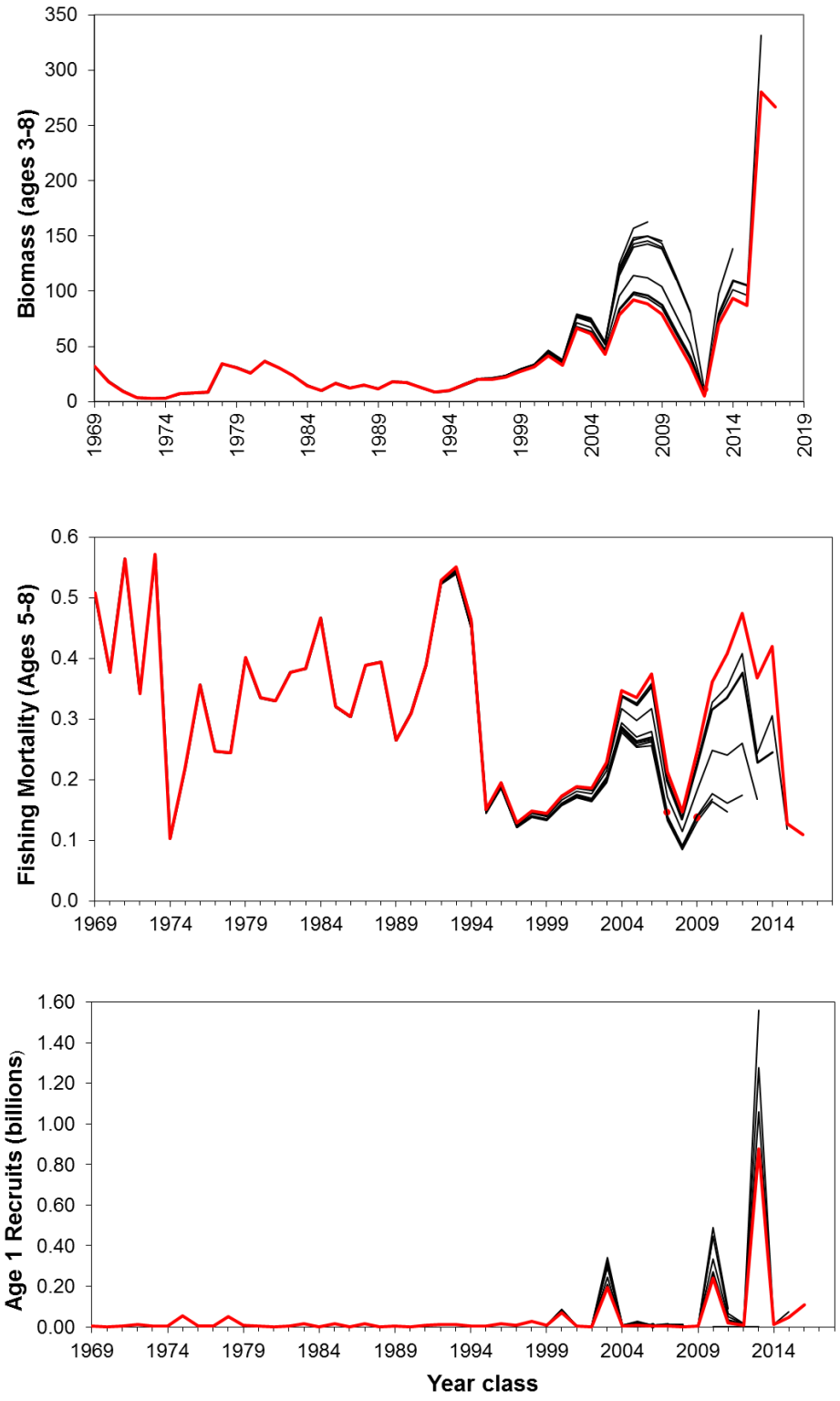

Figure 20. Retrospective results from virtual population analysis for eastern Georges Bank haddock for biomass (ages 3-8), fishing mortality (ages 5-8) and recruitment (age 1) as successive years of data are removed from the assessment. The most recent assessment results are indicated in red.

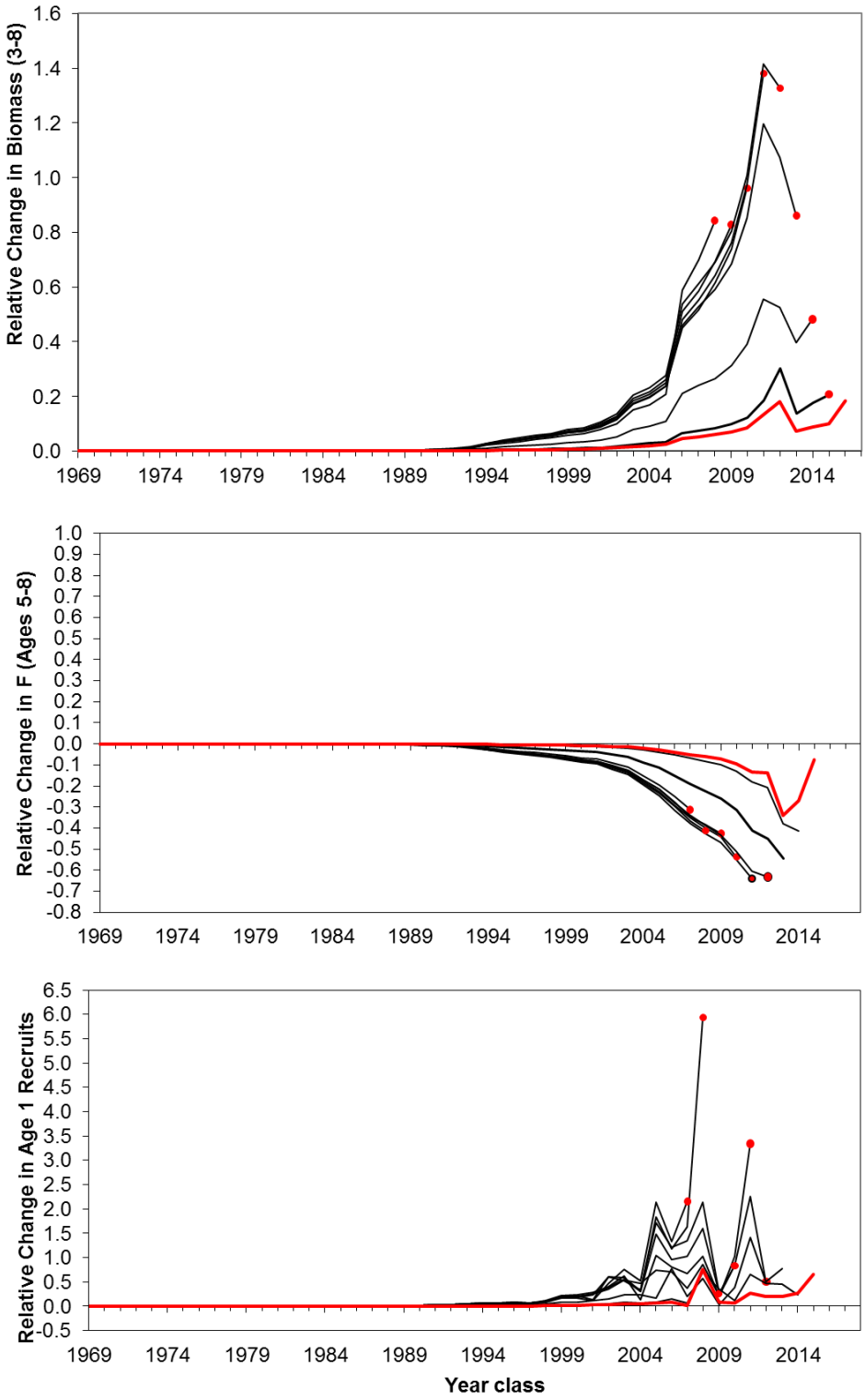

Figure 21. Relative retrospective results from virtual population analysis for eastern Georges Bank haddock for biomass (ages 3-8), fishing mortality (ages 5-8) and recruitment (age 1) as successive years of data are removed from the assessment. Changes are relative to the 2017 assessment.

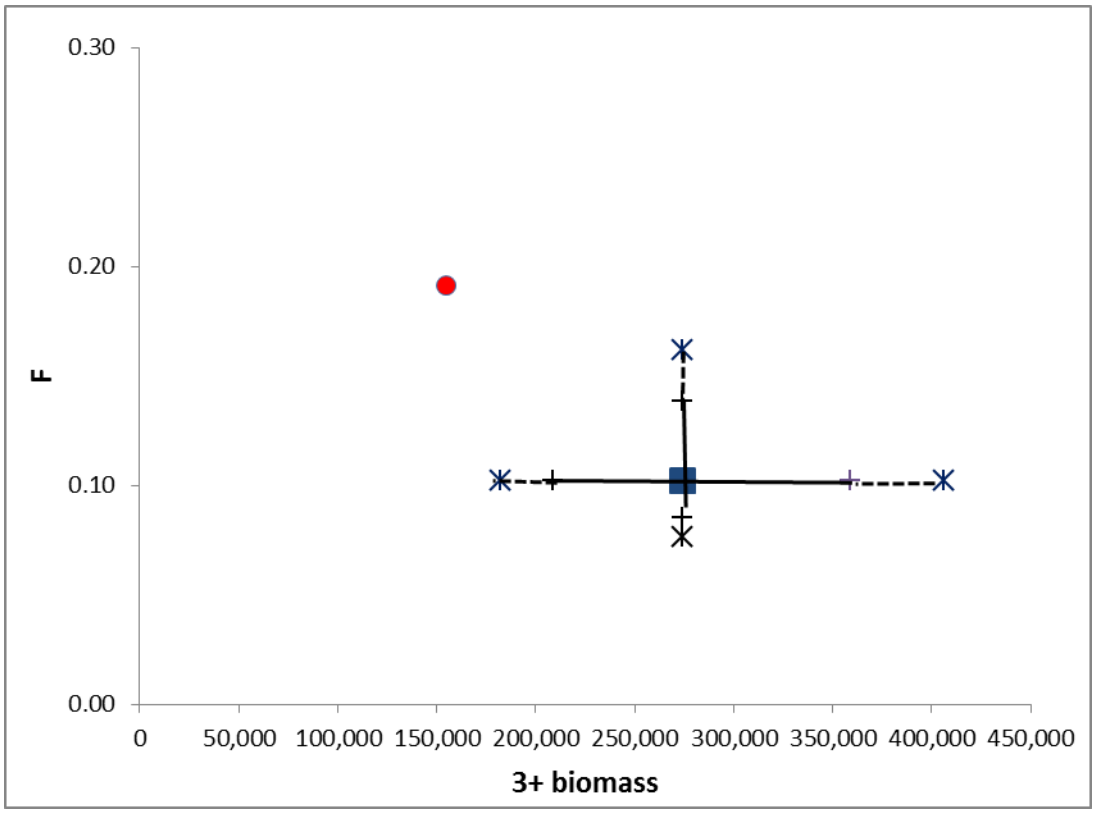

Figure 22. Estimate of fishing mortality on ages 5 to 8 and ages 3+ biomass estimated using the Benchmark VPA formulation (blue square) and the rho adjusted value (red circle). The solid lines show the 80% confidence interval around the benchmark estimate, while the dotted lines show the 95% confidence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

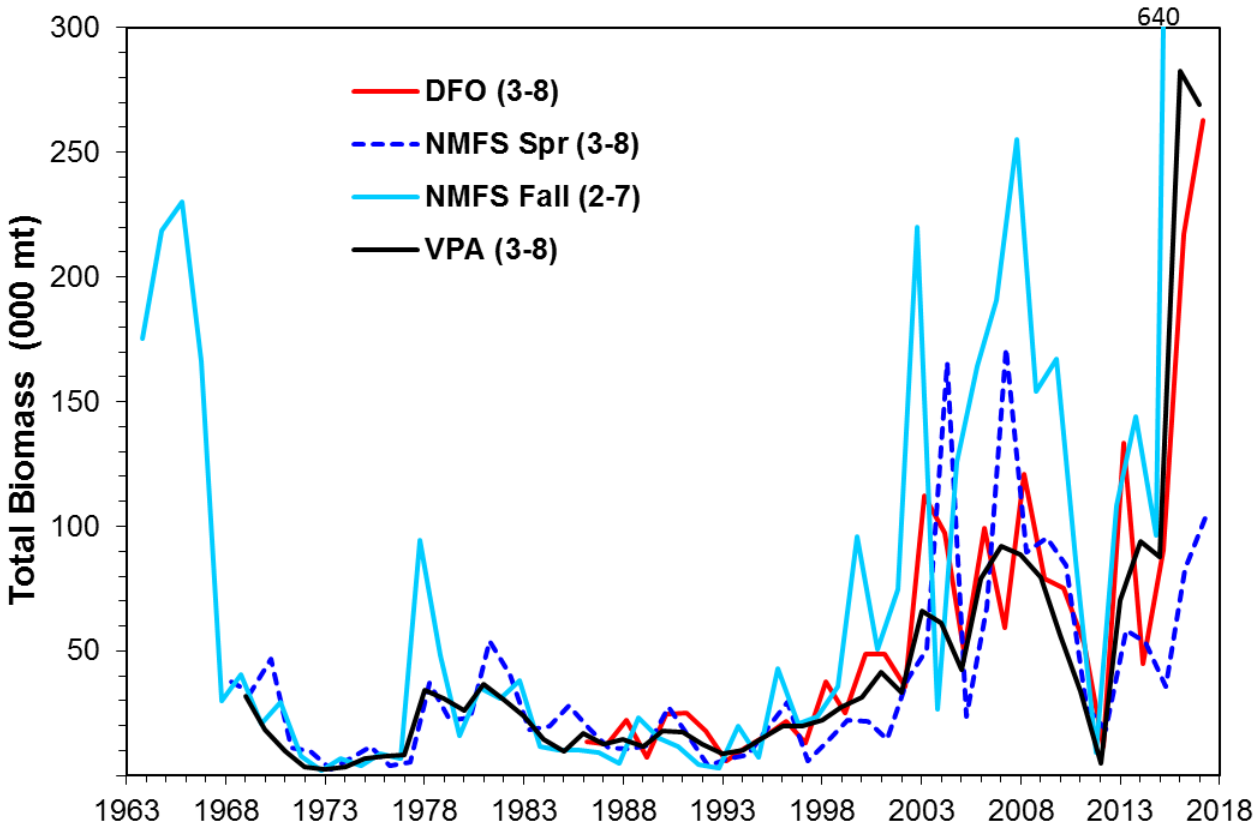

Figure 23. The 1969 to 2017 eastern Georges Bank adult haddock (ages 3-8) biomass from virtual population analysis compared with the survey adult biomass (scaled with catchabilities) for ages 3-8 (DFO and NMFS spring) and ages 2-7 (NMFS fall).

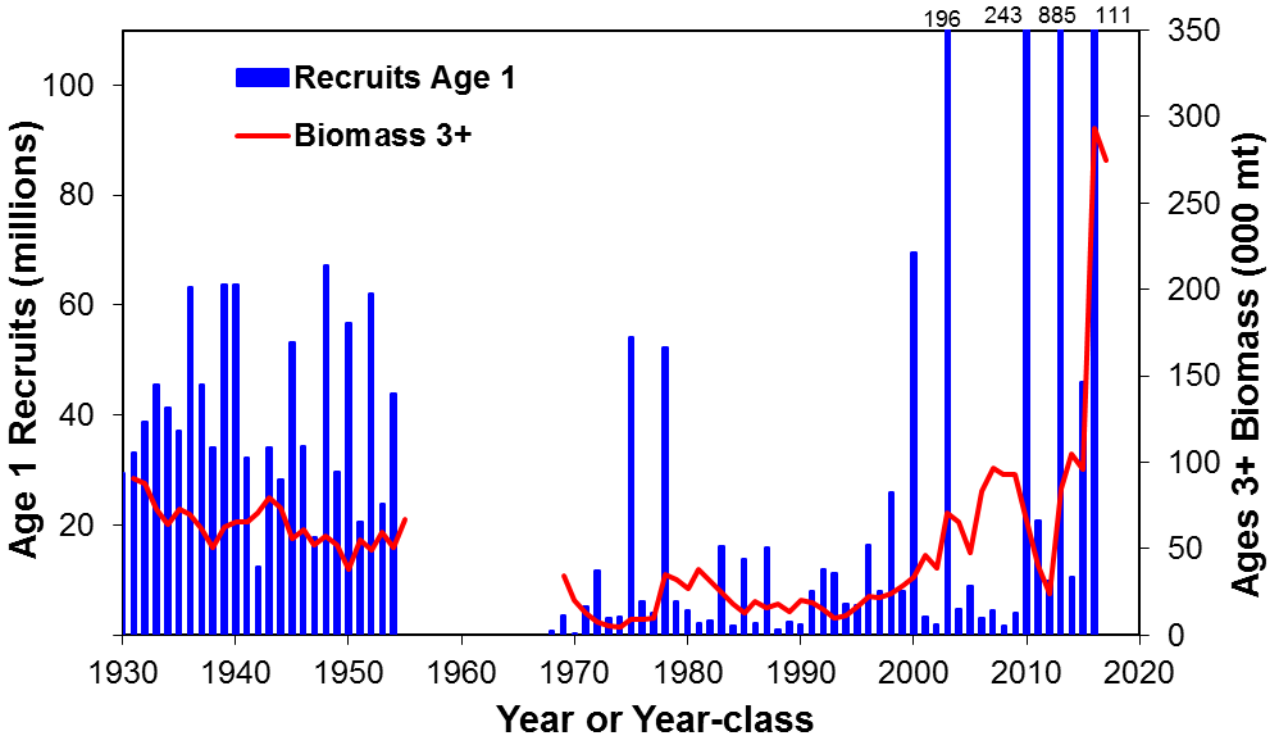

Figure 24. Beginning of year adult (3+) biomass and number of age 1 recruits for eastern Georges Bank haddock during 1931-1955 and 1969-2017.

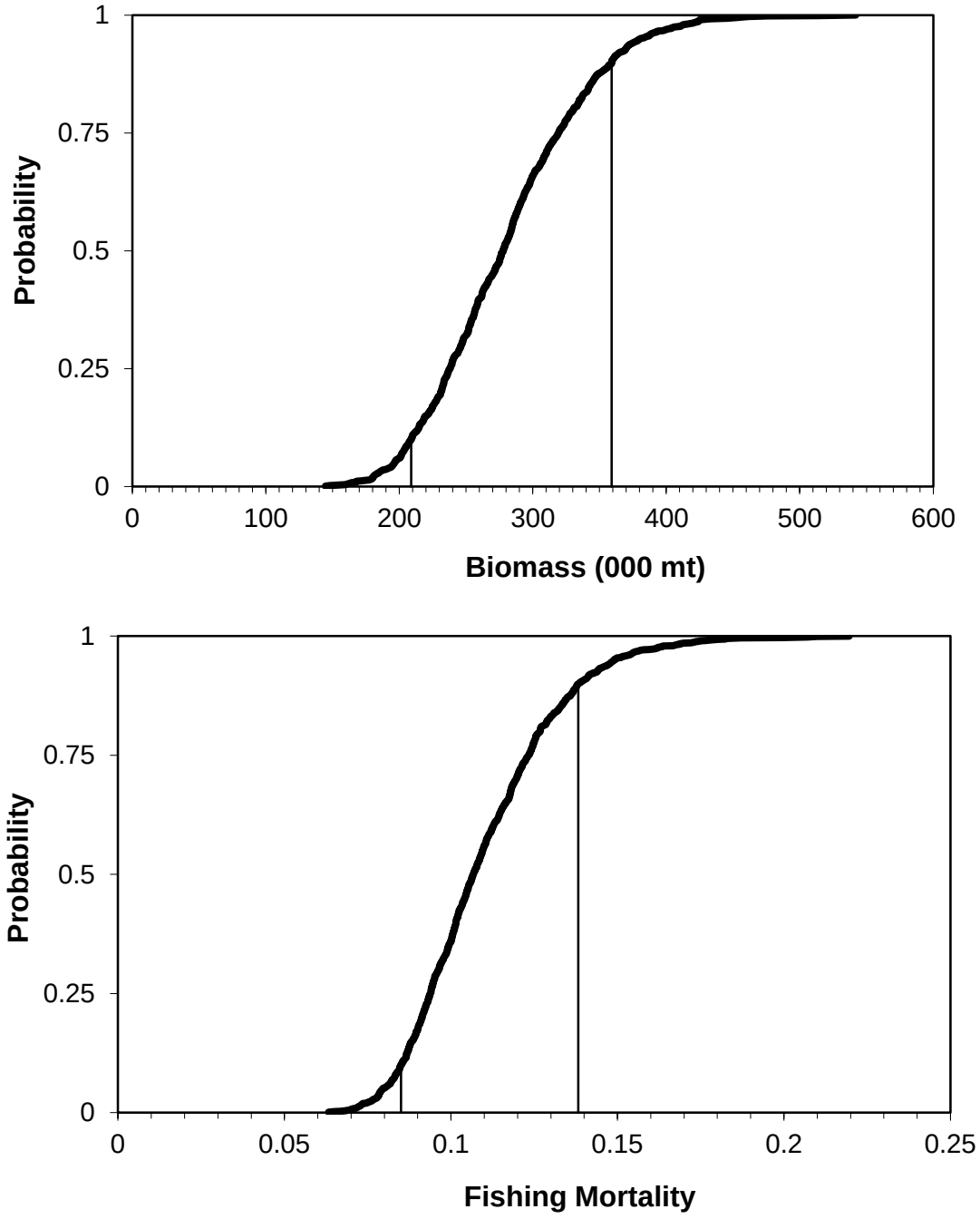

Figure 25. Cumulative probability distribution with 80% confidence intervals for 2017 age 3+ biomass (000 mt) and 2016 age 5-8 fishing mortality for eastern Georges Bank haddock. CI for biomass = 208,936-359,156 mt; CI for F = 0.08-0.14.

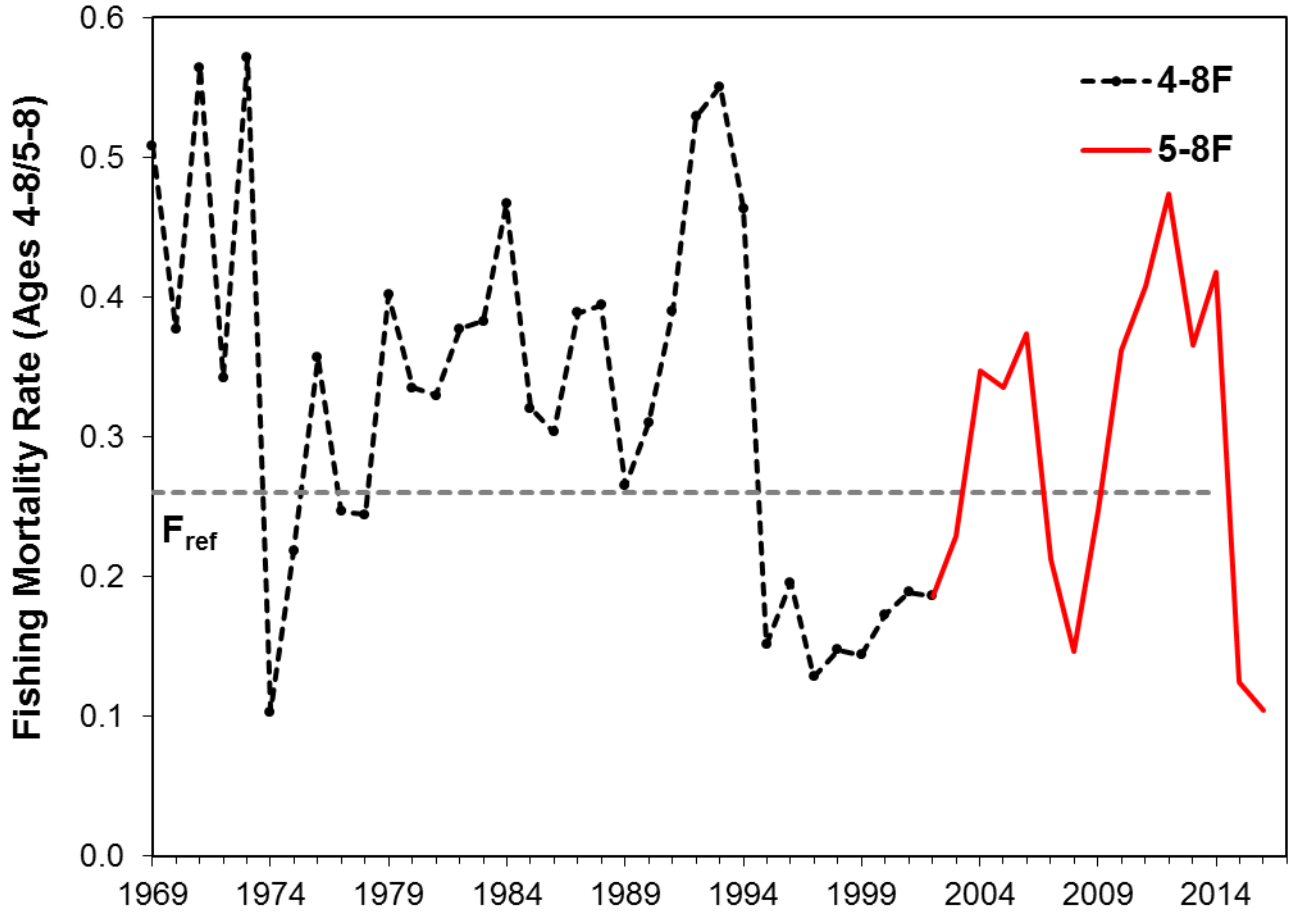

Figure 26. Fishing mortality rate (weighted by population) for eastern Georges Bank haddock ages 4+ and 5+ during 1969-2016 and the fishing mortality threshold reference established at F_{ref} = 0.26.

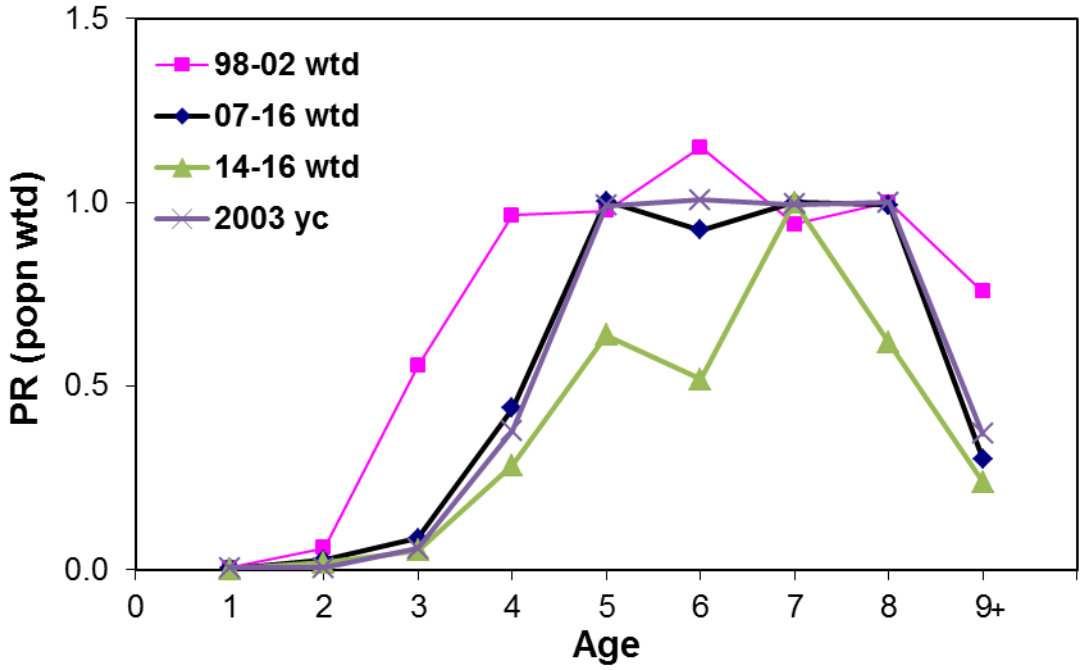

Figure 27. Partial recruitment of eastern Georges Bank haddock for the population weighted average of 1998-2002, 2007-2016, 2014-2016 and for the 2003 year class. The partial recruitment is normalized to ages 4-8 for years before 2003 and to ages 5-8 for years after 2002.

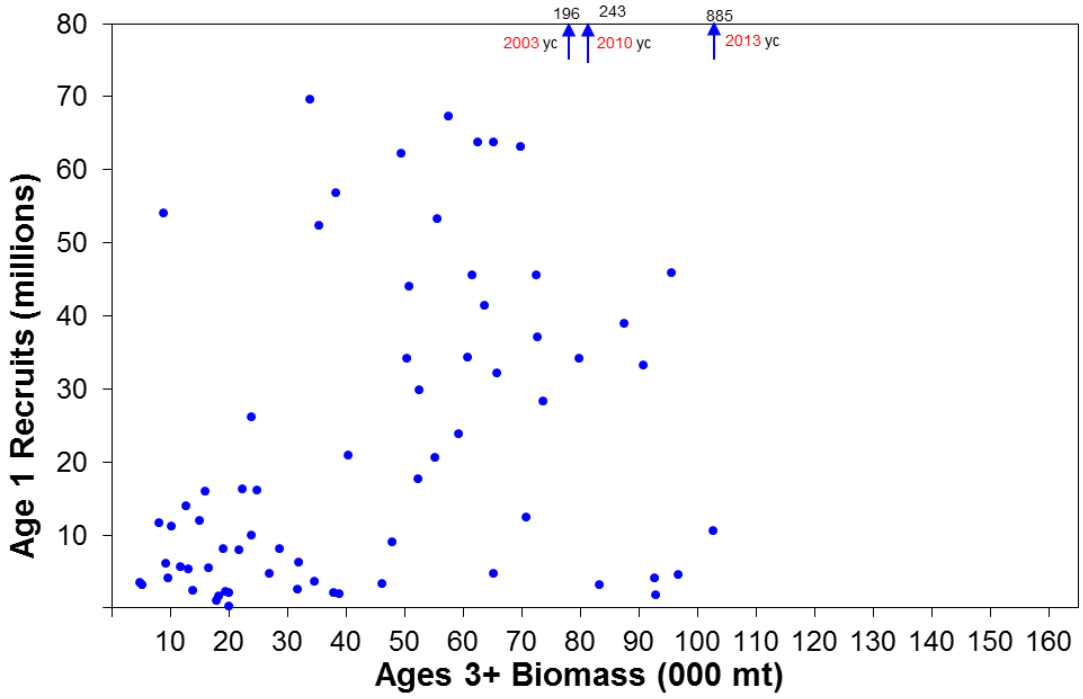

Figure 28. Relationship between eastern Georges Bank adult (ages 3+) haddock biomass during 1931-1955 and 1969-2016 and recruits at age 1. The year classes since the 2000 are labeled in red font.

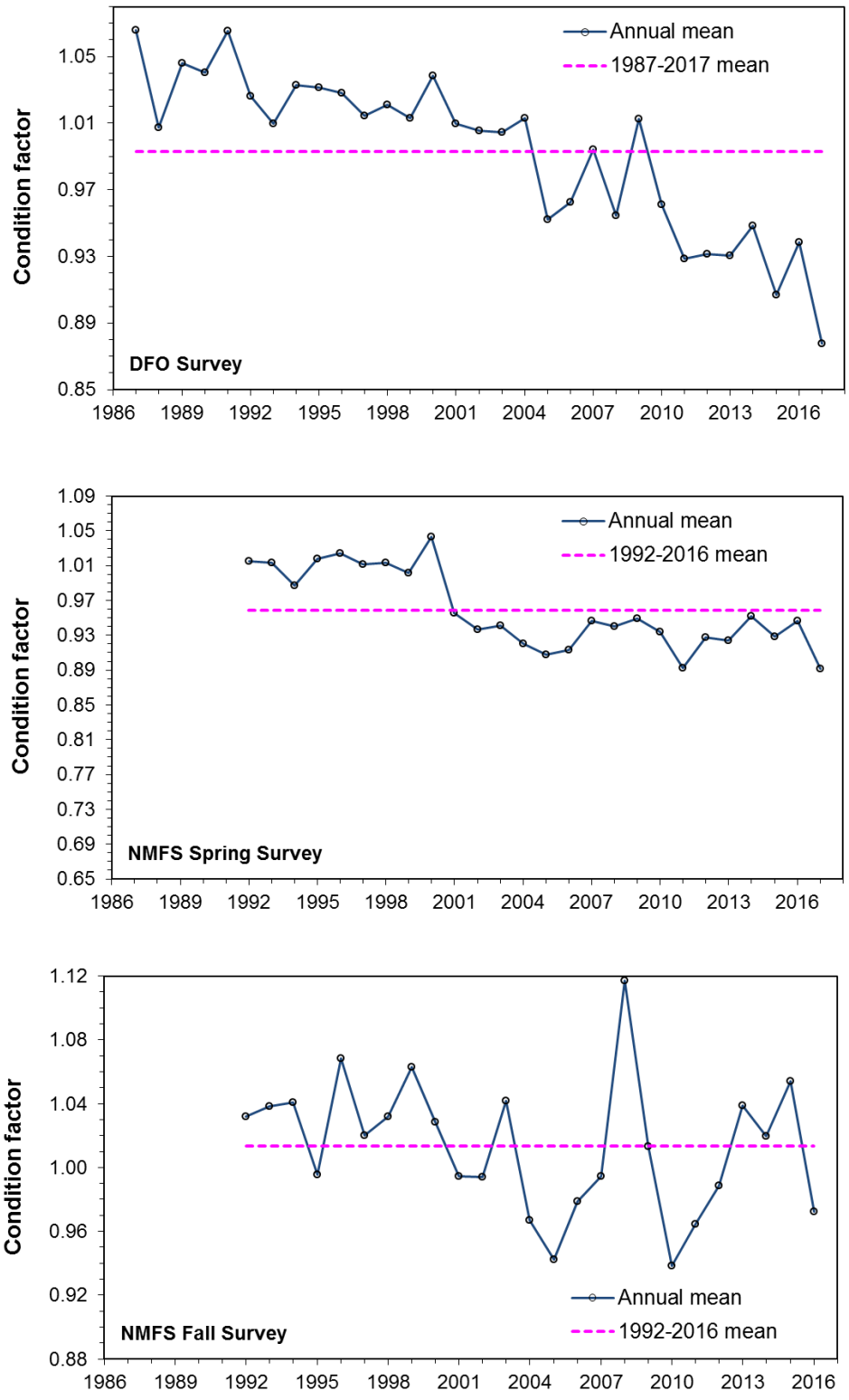

Figure 29. Annual mean condition as indicated by Fulton's K (W/L^3) for eastern Georges Bank haddock (30-70 cm FL) from the DFO survey (1986-2017; top panel), NMFS Spring Survey (1992-2017; middle panel) and NMFS fall survey (1992-2016; lower panel). Red dashed line is mean value for survey time series.

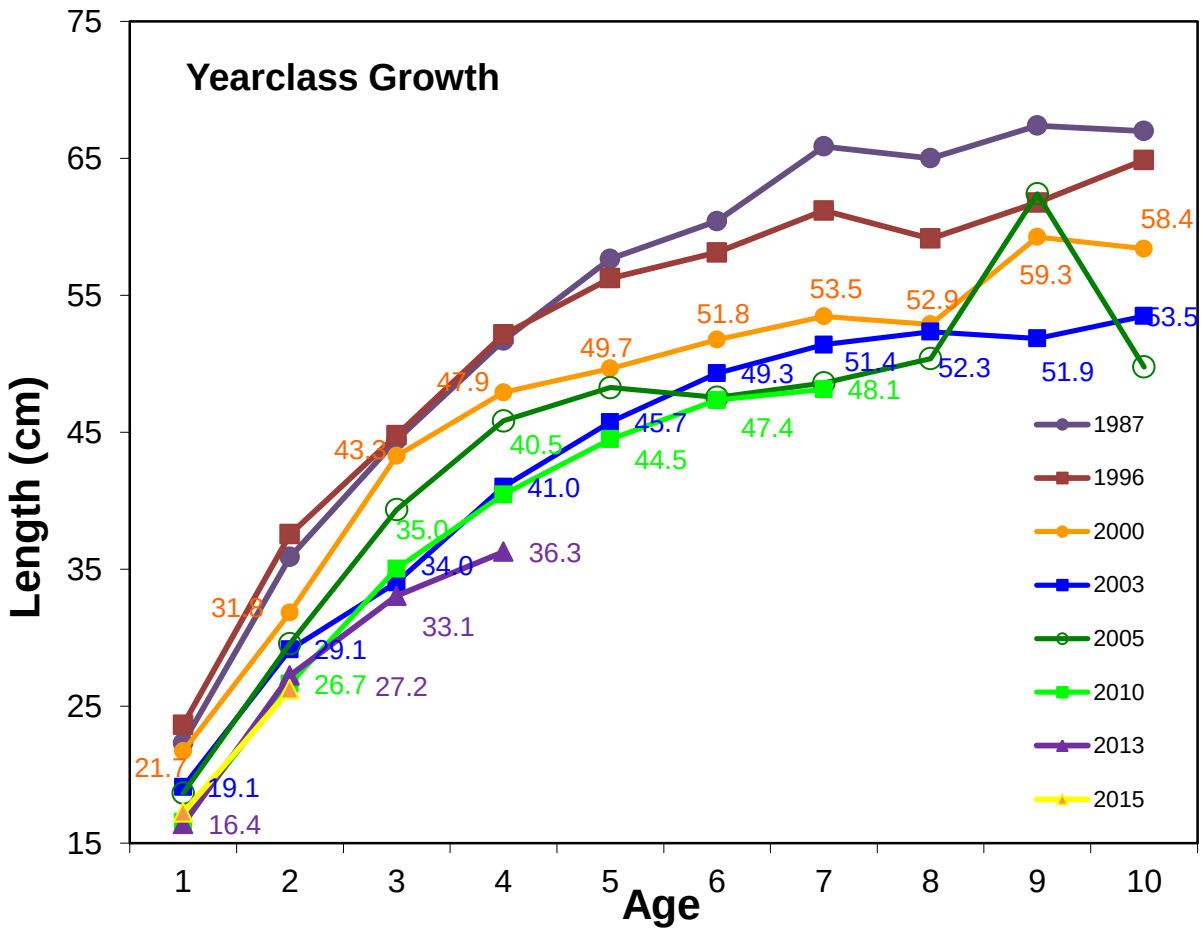

Figure 30. Mean length at age for selected year classes of eastern Georges Bank haddock sampled from the DFO survey.

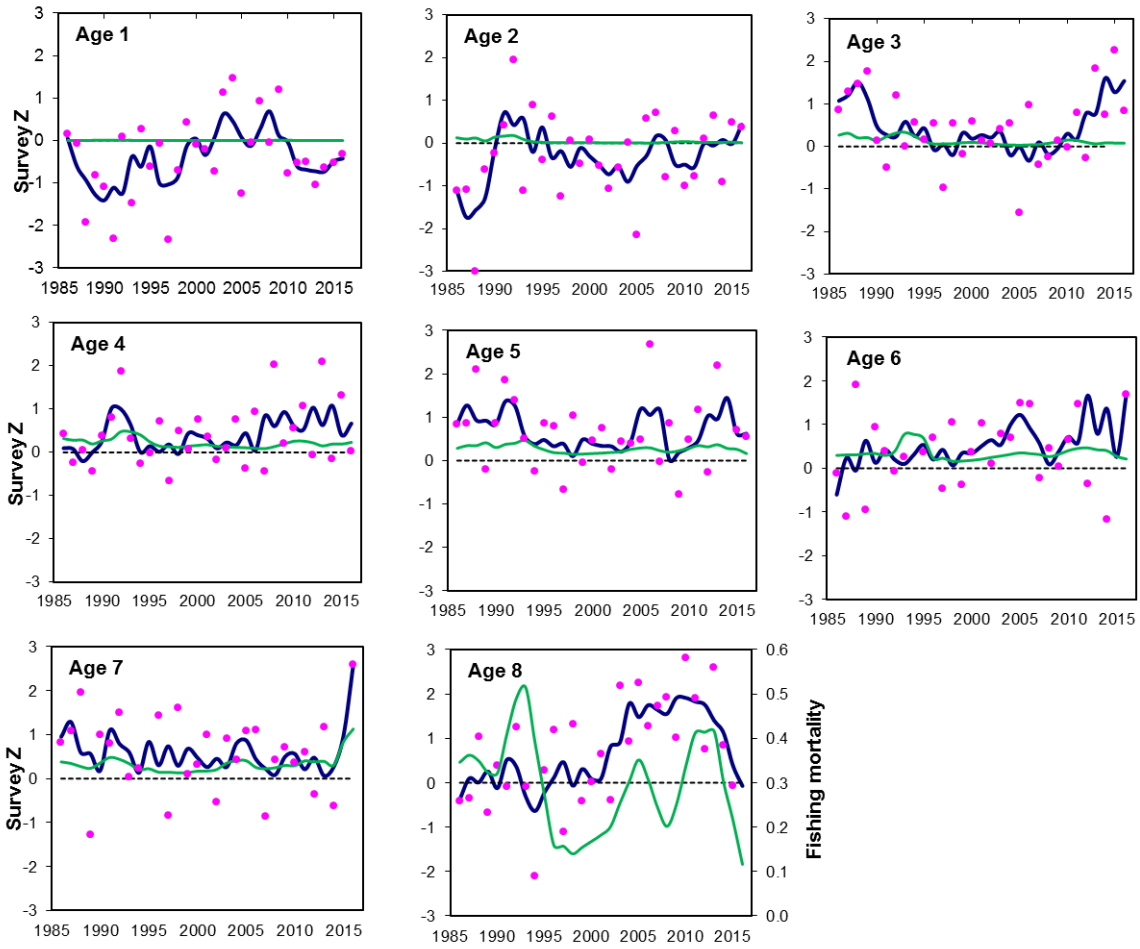

Figure 31. Eastern Georges Bank haddock total mortality (Z; 3-year smooth, navy blue line and pink circles are the annual z value) for ages 1-8 from DFO survey catch at age data, 1986-2016 compared to F for age 1-8 (F; 3-year smooth, green line) calculated from the 2017 VPA model output.

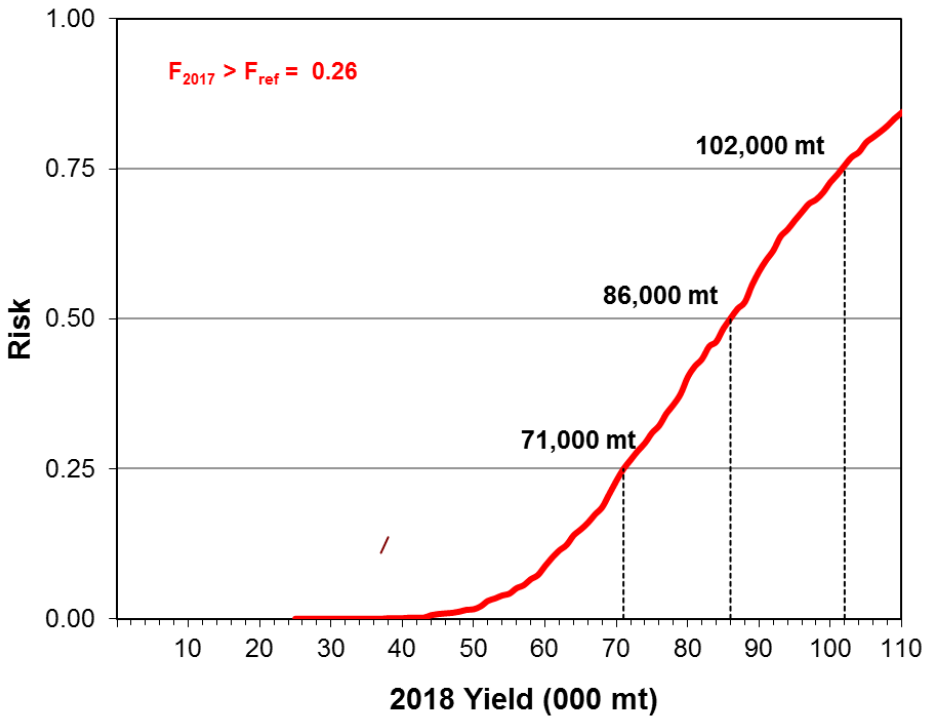

Figure 32. Risk of 2018 fishing mortality exceeding F_{ref} = 0.26 for eastern Georges Bank haddock for increasing catch quotas.

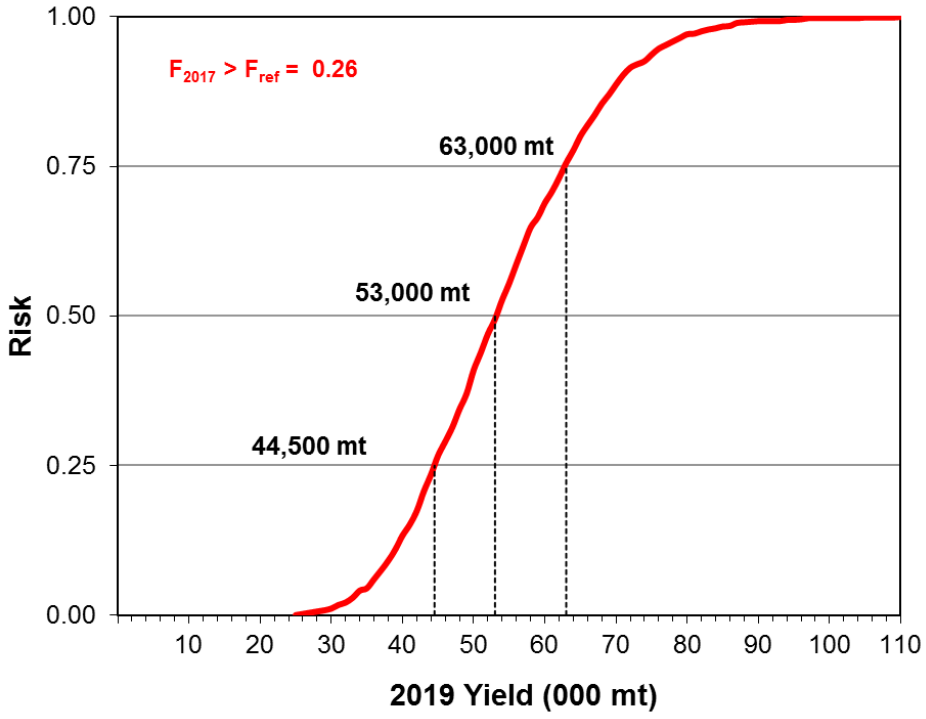

Figure 33. Risk of 2019 fishing mortality exceeding F_{ref} = 0.26 for eastern Georges Bank haddock for increasing catch quotas.

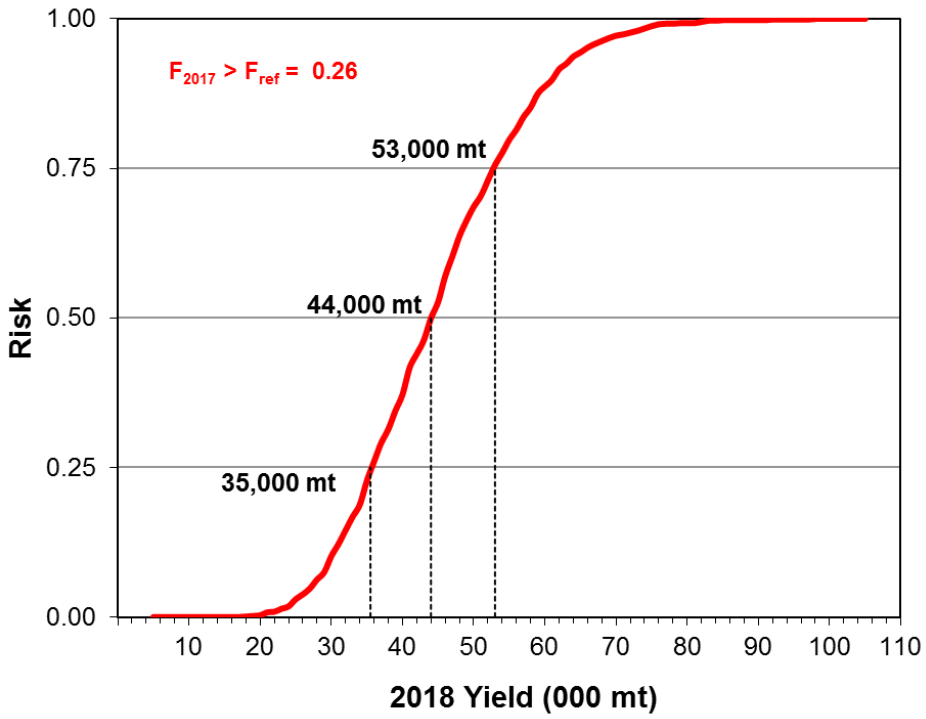

Figure 34. Sensitivity risk analysis of 2018 fishing mortality exceeding F_{ref} = 0.26 for eastern Georges Bank haddock for increasing catch quotas. A rho adjustment (0.564) was applied to down weight the 2017 population estimates prior to conducting risk calculations.

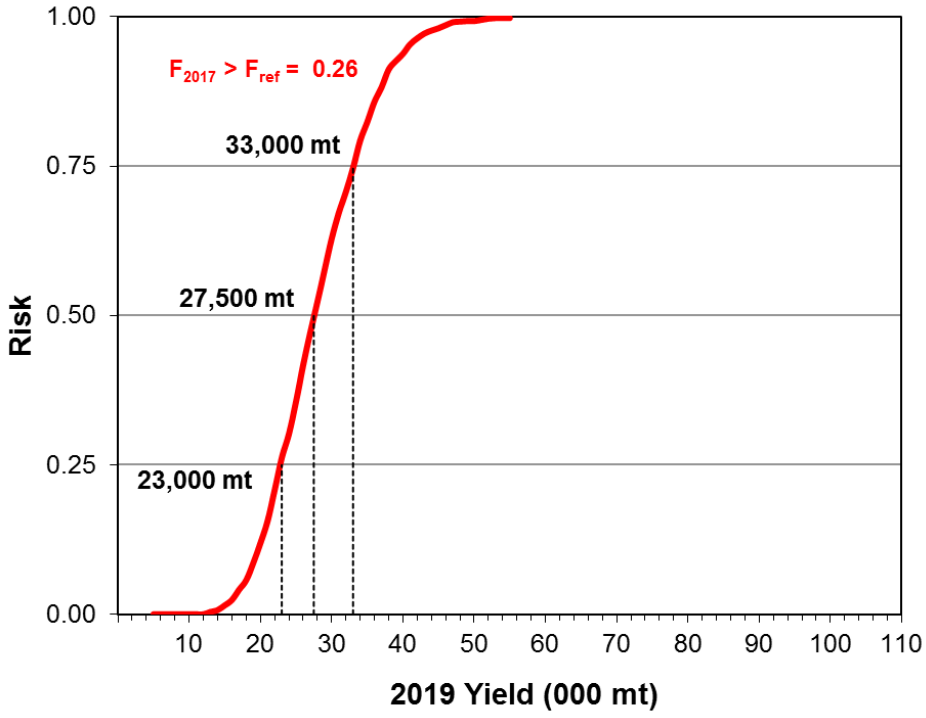

Figure 35. Sensitivity risk analysis of 2019 fishing mortality exceeding F_{ref} = 0.26 for eastern Georges Bank haddock for increasing catch quotas. A rho adjustment (0.564) was applied to down weight the 2017 population estimates prior to conducting risk calculations.

Appendix A. Comparison of contemporary estimates of F40% and F0.1 to current Fref for Eastern Georges Bank Haddock

The current fishing mortality reference (F_{ref}) of 0.26 for EGB Haddock was adopted by TMGC in 2003 (TMGC 2003). This value 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 (Figure A1). 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.

Using the output from a VPA run updated to 2015, the fishery partial recruitment (PR) was calculated from the population number weighted average of fishing mortality. It showed that fishery partial recruitment (PR) changed around 2002 due to fish growth, fishery minimum size and mesh size changes. The fully recruited age changed from age 4 to age 5 (Figure A2). Considering the declining trends in weight-at-age since 2002 (Figure A1) and changes in PR (Figure A2), there were two runs completed for the contemporary estimates of $F_{40\%}$ and $F_{0.1}$. The most recent 5 year (2011-2015) and longer time series (2002-2015) average of PR (weighted by population) and fish growth data were used for the calculation of $F_{0.1}$ and $F_{40\%}$, respectively. The data input for the two runs are shown in Table A1.

Using two different time period data, both $F_{0.1}$ and $F_{40\%}$ were greater than the current F_{ref} of 0.26 with $F_{40\%}$ values lower than $F_{0.1}$ for the 5 year average, and $F_{40\%}>F_{0.1}$ for the 10 year average (Table A2), which reflects the impact of PR and fish growth changes.

To illustrate the sensitivity of $F_{0.1}$ and $F_{40\%}$ to the assumed PR on older ages, and in particular the plus group, two sensitivity cases were examined for both the 5 year and the longer time series average inputs. For the 5 year average, sensitivity case 1 set PR at ages 9+ to 0.7 (equal to the PR at ages 7 and 8, so only slight doming), while sensitivity case 2 set PR at ages 7 and older to 1 (flat selectivity). For the longer time series average, sensitivity case 1 set PR at ages 9+ to 0.7 (for comparison with the 5 year average run), while sensitivity case 2 set the PR at ages 9+ to 1. The estimated values for $F_{0.1}$ and $F_{40\%}$ reduce substantially as selectivity on the older ages increases from the severe dome (PR=0.2 or 0.3), to a slight dome (PR=0.7), to fully selected (PR=1.0).

The sensitivity runs show that PR at older ages can be very influential on $F_{0.1}$ and $F_{40\%}$. It is important to keep the consistency for the PR between F_{ref} calculation, VPA model output and projection. Otherwise, the Fref might lose its intended meaning, which could lead to increased risk or precaution. If a dome-shaped PR was used in the Fref calculation, a projection using flat topped PR would result in a risk of catch exceeding F_{ref}. On the other hand, if the F_{ref} calculation was based on flat-topped PR, a dome-shaped PR at older ages in the projection would lead to forgo yield.

In order to be consistent with the assessment model, normally F_{ref} is re-calculatd at benchmark meeting. The analysis here is for information only, as Fref is a negotiated value.

Table A1. Data inputs for the per-recruit analysis using a 5 year (2011-2015) average (A) and longer time series (2002-2015) average (B) for PR, fishery WAA and spawning stock weights at age.

A)

Age	M	PR	Fishery Weight	Spawning Weight	Maturity
1	0.2	0	0.271	0.065	0
2	0.2	0.02	0.674	0.256	0
3	0.2	0.1	0.877	0.485	1
4	0.2	0.4	1.125	0.710	1
5	0.2	0.7	1.235	0.952	1
6	0.2	1	1.315	1.081	1
7	0.2	0.7	1.491	1.143	1
8	0.2	0.7	1.605	1.203	1
9+	0.2	0.2	1.801	1.440	1

B)

Age	M	PR	Fishery Weight	Spawning Weight	Maturity
1	0.2	0	0.361	0.073	0
2	0.2	0.02	0.735	0.288	0
3	0.2	0.2	1.049	0.587	1
4	0.2	0.5	1.299	0.837	1
5	0.2	1	1.496	1.083	1
6	0.2	1	1.666	1.338	1
7	0.2	1	1.825	1.496	1
8	0.2	1	1.995	1.667	1
9+	0.2	0.3	2.276	1.962	1

Table A2. Contemporary estimates for fishing mortality ($F_{40\%}$ and $F_{0.1)}$ using the 5 year (2011-15) average and longer time series (2002-2015) average of spawning WAA, fisheries WAA and PR. Two sensitivity analyses were explored for each time series average case.

Time period	$F_{0.1}$	$F_{40\%}$
5 year average (2011-2015)	0.63	0.55
(Sensitivity 1) 5 year average, PR(age 9+)=0.7	0.44	0.51
(Sensitivity 2) 5 year average, PR(ages 7 to 9+)=1.0	0.34	0.47
14 year average (2002-2015)	0.45	0.38
(Sensitivity 1) 14 year average, PR(age 9+)=0.7	0.36	0.36
(Sensitivity 2) 14 year average, PR(age 9+)=1.0	0.31	0.35

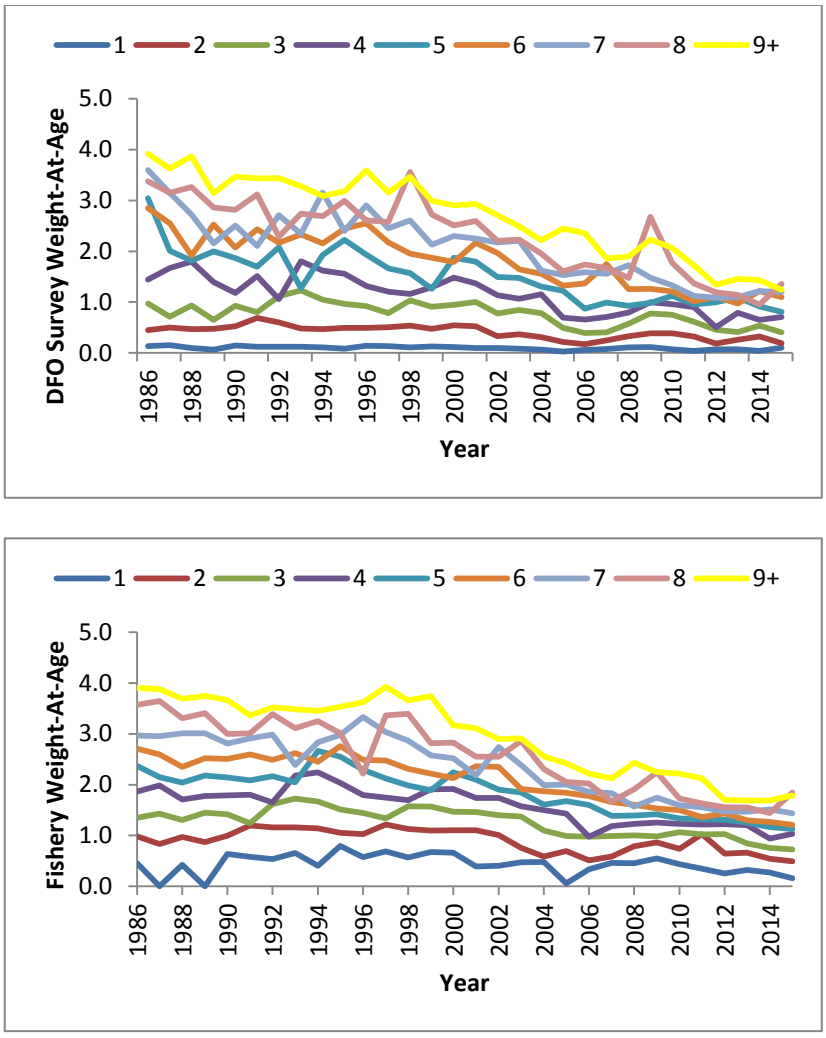

Figure A1. Eastern Georges Bank haddock weights at age from DFO Survey(upper panel) and fisheries (lower panel) for 1986-2015.

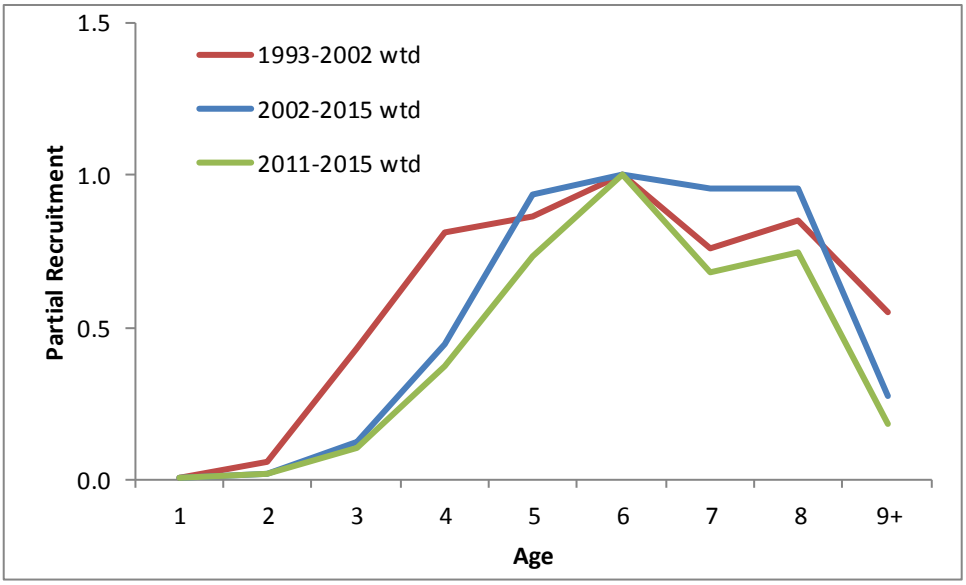

Figure A2. Average partial recruitment of Eastern Georges Bank haddock for three time block (1993-2002, 2002-2015, and 2011-2015).

Appendix B. 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. VPA 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 C. 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 2013 assessment. This table was kindly provided by Tom Nies (New England Fisheries Management Council) in 2011 and updated to the 2013 assessment.

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} = 0.316 Age 3+ biomass decreased 25% 2004 to 2005 3+ B_{2005}=53,000 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} = 0.297 Age 3+ biomass increased 89% 2005 to 2006 3+ B_{2006}=100,500 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} = 0.316 Age 3+ biomass increased 19% 2006 – 2007 3+ B_{2007}=120,100 mt	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	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} = 0.171 Age 3+ biomass decreased 2% 2007 to 2008 3+ B_{2008}=117,500 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} = 0.113 Age 3+ biomass increased 3% 2008 to 2009 3+ B_{2009}=121,500 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} = 0.182 Age 3+ biomass decreased 25% 2009 to 2010 3+ B_{2010}=91,400 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} = 0.246 Age 3+ biomass decreased 33% 2010 to 2011 3+ B_{2011}=61,500 mt	2003 and 2005 year class specific values for projection inputs.
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} = 0.237 Age 3+ biomass decreased 34% 2011 to 2012 3+ B_{2012}=40,600 mt	2003 and 2005 year class specific values for projection inputs.

TRAC	Catch Year	TRAC Analysis/Recommendation		TMGC Decision		Actual Catch/ Compared to Risk	Results	Comments[2]
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} = 0.251 Age 3+ biomass increased 208% 2012 to 2013 3+ B_{2013}=125,165 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*	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}	N/A	N/A	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	N/A	N/A	N/A	N/A	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} Adult biomass will increase by 10% from 2016 to 2017 3+B2017=522,000 mt					Persistent retrospective pattern
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					Persistant retrospective pattern

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