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Assessment of Eastern Georges Bank Haddock for 2011

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ABSTRACT

The total catch of eastern Georges Bank (EGB) haddock in 2010 was 18,794 mt of the 29,600 mt combined Canada/United States of America (USA) quota. The 2010 Canadian catch decreased from 17,648 in 2009 to 16,592 mt while the USA catch in 2010 was 2201 mt, and was very similar to the 2009 catch of 2208 mt. Haddock discards from the Canadian scallop fishery and the USA groundfish fishery were estimated at 14 and 34 mt, respectively. Under restrictive management measures, combined Canada/USA catches declined from over 6,500 mt in 1991 to a low of about 2,200 mt in 1995, averaged about 3,600 mt during 1996-1999 and have generally increased since then. Catches are declining as the outstanding 2003 year class moves through the fishery.

Adult population biomass (ages 3+) has increased from near an historical low of 10,300 mt in 1993 to 83,600 mt in 2003. It decreased to about 60,000 mt at the beginning of 2005 but subsequently tripled to a record-high 162,800 mt in 2009, higher than the 1931-1955 maximum of about 90,000 mt. Adult biomass subsequently decreased to 93,400 in 2011. The exceptional 2003 year class, estimated at 304 million age-1 fish, was the largest observed in the assessment time series (1931-1955 and 1969-2010) up to 2010. The preliminary estimate for the 2010 year class is outstanding at 557 million fish at age 1. Except for the strong 2000 year class, the exceptional 2003 and 2010 year classes, recruitment has fluctuated without trend about an average of 9 million since 1990. Fishing mortality fluctuated between 0.25 and 0.5 during the 1980s and early 1990s. Fishing mortality was below F_{ref} = 0.26 during 1995 to 2003, fluctuated around F_{ref} during 2004 to 2006, then declined and was 0.15 in 2010.

Positive signs of productivity include expanded age structure, broad spatial distribution, large biomass, improved growth at the younger ages and an exceptional year class from the very large biomass in 2010. On the negative side, condition has decreased substantially and growth of older fish has declined and, except for 2 outstanding year classes, recruitment has been poor.

Assuming a 2011 catch equal to the 22,000 mt total quota, a combined Canada/USA catch of 16,000 mt in 2012 results in a neutral risk (50%) that the 2012 fishing mortality rate would exceed F_{ref} = 0.26. A catch of 13,900 mt in 2012 results in a low risk (25%) that the 2012 fishing mortality rate will exceed F_{ref}. The 9+ group, of which the 2003 year class is the major component, is expected to constitute 72% of the 2012 catch biomass. The 2005 year class at age 7 is expected to contribute 11% of the catch biomass. Due to the entry of the 2010 year class into the 3+ group in 2013, the estimated probability that the adult biomass will decline from 2012 to 2013 is virtually zero. Adult biomass is projected to increase to 124,600 mt at the beginning of 2013.

RÉSUMÉ

Les captures totales d'aiglefin de l'est du banc Georges s'élevaient à 18 794 tm en 2010, sur un quota combiné de 29 600 tm pour le Canada et les États-Unis. Les prises canadiennes sont passées de 17 648 tm en 2009 à 16 592 tm en 2010. Très semblables à celles de 2009, qui s'élevaient à 2 208 tm, les prises américaines s'élevaient à 2 201 tm en 2010. On estime les rejets d'aiglefin dans la pêche canadienne du pétoncle et dans la pêche du poisson de fond aux États-Unis à 14 tm et à 34 tm respectivement. En raison des mesures de gestion rigoureuses qui ont été mises en place, les captures combinées du Canada et des États-Unis sont passées de plus de 6 500 tm en 1991 à 2 200 tm en 1995. Elles ont atteint en moyenne 3 600 tm entre 1996 et 1999, et elles ont généralement augmenté depuis. Les prises diminuent tandis que l'exceptionnelle classe d'âge 2003 est exploitée par la pêche.

La biomasse de la population d'adultes (âges 3 +), qui frôlait un plancher historique en 1993 (10 300 tm), est passée à 83 600 tm en 2003. Elle a baissé à environ 60 000 tm au début de 2005 puis a pratiquement triplé pour atteindre un plafond de 162 800 tm en 2009, dépassant ainsi la valeur la plus élevée observée sur la période 1931-1955 (environ 90 000 tm). Elle a ensuite baissé à 93 400 tm en 2011. L'exceptionnelle classe d'âge 2003 – estimée à 304 millions de poissons d'âge 1 – est la plus importante jamais observée dans les séries chronologiques des évaluations (1931-1955 et 1969-2010) jusqu'en 2010. L'estimation préliminaire pour la classe d'âge 2010 est exceptionnelle, s'élevant à 557 millions d'individus d'âge 1. Si l'on exclut la forte classe d'âge 2000 et les exceptionnelles classes d'âge 2003 et 2010, le recrutement a varié sans afficher de tendance particulière depuis 1990, se situant en moyenne à 9 millions d'individus. La mortalité par pêche a fluctué entre 0,25 et 0,5 durant les années 1980 et au début des années 1990. La mortalité par pêche se situait sous $F_{réf.}$ = 0,26 entre 1995 à 2003, elle a fluctué autour de $F_{réf.}$ de 2004 à 2006, puis elle a baissé pour atteindre 0,15 en 2010.

Parmi les signes encourageants de productivité, citons l'élargissement de la structure d'âges, la vaste répartition spatiale, la forte biomasse, une plus forte croissance des jeunes aiglefins et une classe d'âge exceptionnelle d'une biomasse très élevée en 2010. Parmi les signes négatifs, on note une détérioration importante de la condition, une baisse de la croissance des poissons plus âgés et, sauf pour les deux classes d'âge exceptionnelles, un faible recrutement.

En supposant que les captures de 2011 soient égales au quota total de 22 000 tm, des captures combinées du Canada et des États-Unis de 16 000 tm en 2012 se traduiraient par un risque neutre (50 %) que la mortalité par pêche en 2012 dépasse $F_{réf.}$ = 0,26. Des captures de 13 900 tm en 2012 aboutiraient à un faible risque (25 %) que le taux de mortalité par pêche dépasse $F_{réf.}$ cette même année. Le groupe d'âge 9 +, principalement composé de la classe d'âge 2003, devrait constituer 72 % de la biomasse des captures de 2012. Pour ce qui est de la classe d'âge 2005 (âge 7), elle devrait constituer 11 % de la biomasse des captures. En raison de l'entrée de la classe d'âge 2010 dans le groupe d'âge 3 + en 2013, la probabilité estimée d'un déclin de la biomasse des adultes de 2012 à 2013 est pratiquement de 0 %. La biomasse de la population d'adultes devrait augmenter pour atteindre 124 600 tm au début de 2013.

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 *et al*. (2010) to Canadian and USA fisheries information updated to 2010. Results from the Fisheries and Oceans Canada (DFO) survey, updated to 2011, the USA National Marine Fisheries Service (NMFS) spring survey updated to 2011 and the NMFS autumn survey, updated to 2010, were incorporated. The NMFS surveys since 2009, which used a new vessel, the *Henry B. Bigelow*, a new net and protocols, were made equivalent to surveys undertaken by the *Albatross IV* with length based conversion factors.

FISHERY

Commercial Catches

Haddock on Georges Bank have supported a commercial fishery since the early 1920s (Clark *et al*. 1982). Catches from EGB during the 1930s to 1950s ranged between 15,000 mt and 40,000 mt (Figure 2), averaging about 25,000 mt (Schuck 1951, R. Brown *pers. com.*). Records of catches by unit area for 1956 to 1968 have not been located; 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 in the late 1970s and early 1980s (Table 1), reached a maximum of 23,344 mt and were associated with good recruitment. Substantial quantities of small fish were discarded in those years (Overholtz *et al*. 1983). Catches subsequently declined and fluctuated 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 about 3,000 mt and 4,000 mt until 1999, and increased to 15,256 mt in 2005 (Figure 3). Combined catches decreased to 12,508 mt in 2007, increased to 19,856 mt in 2009 and then decreased to 18,794 mt in 2010 under a combined Canada/USA quota of 29,600 mt. Canada caught 94% of its 17,612 mt quota while the USA caught 18% of its 11,988 mt quota. The total catch is well below the quota due to bycatch restrictions on the USA fishery.

Canadian

Several 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. At-sea observers monitored 17% of otter trawl, 9% of longline and 9% of gillnet landings which amounted to an overall observed level of 12% of the haddock landed by weight in 2010.

Between 1994 and 2004, the Canadian fishery for groundfish on EGB was disallowed from 1 January to 30 May. In 2005, increasing haddock abundance led to a request by industry to conduct an exploratory fishery in January and February. This winter fishery has continued since that time. So as not to adversely affect the rebuilding of cod on EGB, the winter fishery was

closed February 7th in 2010 when it was determined that cod were actively spawning, i.e. when 30% of cod were in the spawning or post-spawning stages.

Canadian Landings

Canadian landings in 2010 decreased to 16,592 mt from 17,648 mt in 2009 which was the highest on record since 1969. In recent years, the Canadian fishery has been conducted primarily by vessels using otter trawls and longlines with some handlines and gillnets. In 2010, almost all of the catch was taken by tonnage class 1, 2 and 3 (less than 150 tons) vessels, corresponding roughly to vessels less than 65 ft in overall length. Otter trawl gear accounted for 85% and longline gear accounted for 15% of the Canadian haddock landings and there were modest landings from gillnet and handline (Table 3). The highest catches occurred in August, followed by July, January and September, in that order (Table 4, Figure 4). The January/February winter fishery landed 3,924 mt of haddock, accounting for 18% of the landings, somewhat lower than the previous year. Quarter 3 had the highest percentage of landings at 54%.

Prior to 1996, Canadian landings include haddock landings 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.

Canadian Discards

Since 1996, the scallop fishery has been prohibited from landing haddock and this species is therefore discarded. Discards from this fleet ranged between 29 and 186 mt since 1969 (Table 1; Van Eeckhaute *et al*. 2005 and 2010, Gavaris *et al*. 2007, 2008 and 2009). Discards in 2010 were estimated at 14 mt (Van Eeckhaute *et al*. 2011).

Discarding and misreporting of haddock by the groundfish fishery have been negligible since 1992.

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). In 2008, the USA portion of the EGB management area was closed to vessels fishing with trawl gear from May 1 to July 31. 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 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. 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. 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.

USA Catch and Landings

USA landings of EGB haddock in 2010 were derived from mandatory fishing vessel reports (VTRs) and dealer reports. Statistical methodology was applied to allocate unknown landings to statistical area from 1994 to 2010 (Wigley *et al*. 2008a, Palmer 2008). For the 2011 TRAC, landings were re-estimated for 2007-2009 because of known audits that occurred to the database. There were slight differences in landings estimates for 2007-2009, which also then affected the discard estimates in those years. Differences in landings were 5-7% (12-141 mt) and differences in discards were 3-18% (about 8 mt in each year).

USA calendar year catches (Table 1) of EGB haddock increased in 2010 to 2,167 mt from 2,152 mt in 2009. The 2010 USA landings were fairly evenly distributed across all quarters (20-31% of total, depending on quarter) (Table 5). As in other years, the otter trawl gear accounted for the majority (92%) of the USA landings (2004 mt; Table 6). The contribution by other gear, 162 mt, was 7%.

For USA fishing year May 1, 2010 to Apr. 30, 2011, the USA catch quota for sectors was 11,913 mt of which only 15% was realized in landings (18% of quota, including discards). The catch quota for the common pool was 75 mt, none of which was caught. In recent years, catch has been constrained in part by the low cod quota as well as the delayed opening of the EGB area to trawlers until August 1, in effect since 2008. The use of the Ruhle and Separator trawls may have reduced interactions with the cod quota. As was true for fishing year 2009, in fishing year 2010, slower growing fish of the 2003 year class had mostly attained a legal size by August 1, and this explains the increase in the landed fraction of the haddock catch.

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 2010 were 34 mt, a slight decrease from 2008 and 2009, where discards were 52 and 55 mt, respectively (Table 1). Discards were similar between the first and second half of the year (Table 7). USA discards from the large mesh otter trawl fishery decreased from 289 mt in 2007 to 23 mt in 2010. Discards from this fleet accounted for 1% (by weight) of the USA haddock catch in 2010. Longline, small mesh otter trawl, gillnet and the scallop fisheries contributed small amounts of discards in 2010 (Figure 5).

Size and Age Composition

Ageing Precision and Accuracy

D. Knox provided ages for the 2010 Canadian fishery and the 2011 DFO survey, and S.J. Sutherland provided ages for the 2010 US fishery and the NMFS 2010 autumn and 2011 spring surveys. Age testing was conducted between the DFO reader and the NMFS reader and intra-reader testing was conducted at both labs. The NMFS reader also completed a test against their haddock reference collection which resulted in 88% agreement. Inter-lab agreement ranged from 86% to 95%. Intra-reader agreement for the NMFS reader ranged between 88% and 99% and for the DFO reader between 89% and 97%. Age determinations at

both labs were considered to be reliable for characterizing catch at age (Table 8; http://www.nefsc.noaa.gov/fbi/QA-QC/age-results.html).

Canadian

The size and age composition of haddock in the 2010 Canadian groundfish fishery was characterized using port and at-sea samples from all principal gears by calendar quarters (Table 9). June gillnet landings were combined with the quarter 3 gillnet landings since samples were available for September only and landings were low. For trips that were sampled by both at-sea observers and port samples, the length frequencies from the two sources were combined before using to characterize the catch at age. . The size composition of haddock discards in the 2010 Canadian scallop fishery was characterized by quarter using length samples obtained from 24 observed scallop trips which comprised 11% of the total effort for this fishery. The 2010 DFO survey ages, augmented with port samples, were applied to the 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.

The modal length of haddock landings in the Canadian fishery was 50.5 cm for otter trawlers and longliners (Figure 6). Haddock discarded by the scallop fleet had a peak at 48.5 cm and a peak at 10.5 cm.

The 2003 year-class dominated all quarters of the Canadian landings and accounted for 81% in numbers of the Canadian catch. The 2005 year class (age 5) was the next highest contributor (Table 10 and Figure 7). Age 0 (2010 year class) made the highest contribution, in numbers, to the Canadian discards followed by the 2003 year class.

USA

USA landings of EGB haddock are sorted into “large” and “scrod” market categories (Figure 8) at sea and are sampled in port for lengths and ages. Landings of large haddock totaled about 317 mt and scrod haddock totaled 1848 mt in 2010 (Table 7). Length sampling for USA EGB landings in 2010 was limited so length and age samples were pooled to estimate catch at age by half-year rather than by quartes (Table 7). There were a total of 2,984 lengths from EGB commercial landings and a total of 1,455 ages.

USA fishermen are required to discard haddock under the legal size limit (18 inches/45.7 cm). A new regulation for the 2010 fishing year requires vessels participating in a sector to retain all legal sized haddock. USA discards at age of EGB haddock for calendar year 2010 were estimated by half-year from at-sea observer data. The total number of observed trips doubled from 78 in 2007 to 157 in 2008, and was at a similar level for 2009 with 166 observed trips. In fishing year 2010, the number of observed trips from the at-sea monitoring program was 129. Sampled lengths from EGB were not augmented with samples from the adjacent areas of 522 and 525 as has been done in the past when sampling intensity (or stock level) was much lower. As most of the discarding was due to the otter trawl fleet, there were few length samples from remaining gears (hook, gillnet, and ‘other’). 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 (425 ages) to quarters 1 and 2 and from the autumn bottom trawl survey (570 ages) to quarters 3 and 4.

The length composition of USA 'scrod' landings peaked between 50 and 54 cm and 'large' landings peaked at about 60 cm for both halves of the year (Figure 9). The discard length frequency was bimodal, with a peak at 48.5 cm (above the minimum size of 45.7 cm in effect during 2010), and another peak at about 28 cm (mostly age 1 fish) (Figure 5). The 2003 year-class dominated the landings (Figures 8 and 10) but the discards were dominated by age 1 (2009 year class; Table 10)**.**

Combined Canada/USA Catch at Age

The 2010 Canadian and USA landings and discards at age estimates (Table 10) were summed to obtain the combined annual catch at age and appended to the revised 1969-2009 catch at age data (Van Eeckhaute and Brooks 2010; Table 11; Figure 11). The average fishery weights at age are presented in Table 12 and Figure 12 and the average lengths at age in Table 13. The catch at age tracks year classes well. The contribution from older ages in recent years has increased when compared to the 1990s. The age composition of the catch projections made in 2009 and 2010 for 2010 agree well with the observed age composition (Figure 13). The 2003 year-class (age 7) dominated the fishery in 2010.

Age 2 had contributed a large proportion of the catch during 1969 to 1994 but its contribution decreased dramatically in subsequent years (Figure 14). This shift in age is attributable primarily to a change in mesh type, from diamond to square, and an increase in mesh size (Table 2). Ages 5 and 6 are dominant in the catch during 2005 to 2009, a reflection of the large 2000 and 2003 year-classes in the population. The age composition during the 1969 to 1974 period was atypical since it was dominated by the outstanding 1962 and 1963 year-classes which continued to contribute substantially at ages 6 and older.

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 (Figure 15 and 16). The *CCGS Alfred Needler* is the standard vessel used for the DFO Georges Bank survey, but, due to unavailability of the *Needler*, the *CCGS Wilfred Templeman*, a sister ship to the *Needler*, was used in 1993, 2004, 2007 and 2008. No conversion factors are available for the *Templeman*, however, this vessel is 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 (Table 14), 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.

Since spring 2009, the NMFS surveys have been conducted with the NOAA *FRV Henry B. Bigelow*, a new net (4 seam, 3 bridle) and revised protocols. Length based conversion factors have been calculated (Table 15 and Figure 17) and were applied by dividing *Bigelow* catches at length by the length specific conversion value to make the *Bigelow* surveys equivalent to the *Albatross IV* catches (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 2010 NMFS fall survey, the 2011 DFO survey, and the 2011 NMFS spring survey are shown in comparison to the average distribution over the previous 10 year period (Figures 18-20). During the fall, age 0 is spread throughout the 5Zjm area, and age 1 haddock are also spread out over the bank but are more concentrated on the Canadian side than age 0. Older haddock migrate to deeper water along the northern edge and peak and to a lesser extent along the southern edge so are mainly found on the Canadian side at this time. In Feb/March, the DFO survey finds ages 1 and 2 distributed near the bank edges and mostly in the eastern part of the management unit. Ages 3 and older are concentrated on the bank near the northeast peak and edge and also in 5Zm near the Canada/US boundary and spreading eastward from there just north of 41°30'. In March/April the NMFS survey finds age 1 concentrated along the southern flank, age 2 is spread throughout the 5Zjm area and similar to the adults, which are now more widely dispersed than they were earlier in the year as observed from the DFO survey. All three surveys had very high catches of the 2010 year class, especially the DFO and fall surveys. Although catches of this year class by the NMFS spring survey were lower, there were five large catches to the west, outside the 5Zjm area, four of which were to the south and one just north of the Great South Channel (Figure 21). Two very large catches numbering 10,394 and 3,641 haddock of the 2010 year class were caught during the DFO survey within 5Zjm very near the 5Zjm boundary along the southern flank. Near these two tows but outside the 5Zjm area, a large catch of 2,206 age 1 haddock was taken and further to the south-west a tow of 644 age 1 haddock was taken by the DFO survey. Catches of the 2009 year class were generally small with typical distribution. Adult haddock were caught in abundance by all 3 surveys, although the signal from the NMFS spring was not as strong, and were typically distributed.

Age-specific, swept area abundance indices show that the three surveys are consistent and track year-class strengths well (Tables 16, 17 and 18; Figure 22). Some year effects are evident. For example, low spring catches occurred in 1997 in both the DFO and NMFS surveys. The abundance of the older ages in the 2000s has increased in comparison to the 1980s and 1990s. Survey adult biomass indices (ages 2-8 in autumn; 3-8 in spring) peaked during the early 1960s (Figure 23). After declining to a record low in the early 1970s, they peaked again in the late 1970s, though at a lower level, and again during the early 1980s at about half the level of the 1970s peak. Adult biomass generally increased during the late 1990s and was high throughout the 2000s. The NMFS spring survey adult biomass declined substantially in 2011 from the previous year, there was a slight increase in the NMFS autumn survey in 2010 and a slight decrease for the 2011 DFO survey. The age 3 and older index values for the 2003 year-class are the highest within the respective age groups for all 3 surveys. The fall index for this year class decreased only slightly, the NFMS spring index decreased significantly and the decrease for the DFO survey was intermediate between the fall and NMFS spring surveys. The indices for the 2010 year class are the highest in the DFO and NMFS fall survey series, far surpassing those of the 2003 year class, and is second highest in the NMFS spring survey, though at a much lower level than that year class. The three new 2009 year class recruitment indices are bracketed by the previous year's values, on a par with recent weak year classes (Figure 24).

Georges Bank groundfish fishermen corroborated the findings of the surveys with regard to the high abundance of the 2010 year class. They reported that large numbers of cod, pollock and also haddock had small haddock in their stomachs and that they were catching a relatively large number of small haddock in amongst their groundfish catches.

GROWTH

Canadian and USA fishery weight at age trends show similar patterns (Figure 12). Low sampling for small year classes at older ages results in increased variability. Except for age 3, combined fishery weights at age (Table 12) in 2010 decreased. A declining trend is visible starting around 2001. DFO survey weights and lengths at age in 2011 (Table 19 and 20; Figure 25 and 26) decreased for all ages. After displaying a decreasing trend since about 2000, the increasing trend in DFO survey weights that started in 2005 with the 2004 year class for the younger ages, was arrested in recent surveys. Little improvement is evident for ages 5 to 8, which display a downward trend apparent since the late 1990s. Average size at age for older haddock has declined substantially so that haddock age 4 and older are now at, or smaller, than the size that the next younger age group was in previous years before the declines occurred. The 2010 year class size at age 1 is the second lowest in the DFO time series.

Changes in growth in response to changes in stock abundance and episodes of very strong recruitment have been observed throughout this stock's history. 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 1960s and early 1970s 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.

Weights at age from the DFO survey are considered 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. Fishery weights are derived from the lengths using a length-weight relationship (Waiwood and Neilson 1985).

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).

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 Gavaris and Van Eeckhaute (1998). Minor changes that were made since 1998 are summarized in Table 21.

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…2010 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 2011. 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… 2010.17, 2011.00

s = NMFS spring (Yankee 36), ages *a* = 1, 2, 3…8, time *t* = 1969.28, 1970.28… 2010.28, 2011.00

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… 2010.79.

Since the population is calculated to beginning year 2011, the NMFS and DFO spring surveys in 2011 were designated as occurring at time 2011.00.

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 age 1 and 2 exhibited a large relative error of 61% and 39%, respectively, and a large relative bias at age 1 of 15%, while the relative error for other ages was between 19% and 31% with a relative bias for ages 2 and older between 1% and 6% (Table 22). While trends in the three surveys are generally consistent, the survey indices exhibit high variability and the average magnitude of residuals is large relative to other assessments. Although several large residuals were apparent, these do not appear to have a substantial impact on estimates of current abundance (Figures 27-31). Some patterns in the residuals (by cohort and by age) suggest year-class and/or year effects.

Retrospective Analysis

Retrospective analyses were used to detect any trends to consistently overestimate or underestimate biomass, fishing mortality and recruitment relative to the terminal year estimates (Figure 32 and 33). Retrospective analysis showed a trend toward overestimating adult biomass (ages 3-8) but relative differences were low, i.e. less than 20%. No persistent patterns in estimates of fishing mortality (ages 5-8) were evident and relative differences were low. Although recruitment estimates may sometimes change substantially when more data becomes available, e.g., the 2003 and 2008 year classes, and there has been a tendency to overestimate initial year class size, subsequent estimates exhibited only minor deviation from terminal year estimates.

A historical retrospective analysis which incorporates all data and model formulation changes by plotting the results from previous assessments back to the last benchmark in 1998 instead of peeling back years from the current assessment and is illustrated in Figure 34. It illustrates that the perception of the stock has remained fairly stable through the data and model changes.

STATE OF RESOURCE

Evaluation of the state of the resource was based on results from the VPA for the years 1969 to 2011. 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 and 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 19) were used to calculate beginning of year population biomass (Table 25). A weight of 2.4 kg, which was midway between the age 6 and 8 weight for that cohort, was used for age 7 in 1995 as no data were available for that age group. The 1986-95 average weight at each age was used for 1969-85.

The adult (ages 3+) biomass trend reflects the survey adult biomass trends well (scaled with catchabilities; Figure 35). Adult biomass increased during the late 1970s and early 1980s to 38,000 mt in 1981. The increase was due to recruitment of the strong 1975 and 1978 year-classes whose abundances were estimated to be above 50 million age-1 fish each (Figure 36). However, adult biomass declined rapidly in the early 1980s as these two cohorts were fished intensely at ages 2 and 3 and subsequent recruitment was poor. Improved recruitment in the 1990s and the strong 2000 year-class (82 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 10,300 mt in 1993 to 82,600 mt in 2003. Adult biomass decreased to 59,700 mt in 2005 but subsequently increased to 162,800 mt in 2009, higher than the 1931-1955 maximum adult biomass of about 90,000 mt. The tripling of the biomass after 2005 was due to the exceptional 2003 year-class, estimated at 304 million age-1 fish. In 2011 the adult biomass decreased to 93,400 mt (80% confidence interval: 74,300 mt – 111,300 mt, Figure 37). The 2001, 2002, 2004, 2006, 2008 and 2009 year classes, at less than 7 million fish, are below the average of 9 million age 1 fish for 1990 to 2011 (excludes the 2000,2003 and 2010 year-classes) and the 2007 year class is near the average. The 2005 year-class (23.6 million age 1 fish) is well above this average. The preliminary estimate for the 2010 year class is outstanding at 557 million age-1 fish which would make it the largest in the assessment time series: 1931-1955 and 1969-2010.

From 2003 onwards, the age at full recruitment into the fishery has been at age 5 (rather than age 4 as in previous years) due to a decline in size at age. Comparison of age 4 and 5 fishing mortality (Table 24) and average weights at age from the fishery and survey (Figure 38) indicate that full recruitment to the fishery since 2003 occurs around age 5. Fishery weights are approaching survey (population) weights at age 5, and, when beginning of year to mid-year growth is accounted for, indicate that age 5 fish are fully selected by the fishery. Fully recruited fishing mortality (population weighted average of fully recruited ages) is presented, therefore, for ages 4+ for pre-2003 and ages 5+ for 2003 onwards. Fully recruited fishing mortality fluctuated between 0.25 and 0.5 during the 1980s and early 90s (Table 24, Figure 39). After reaching a high of 0.5 in 1992 and 1993, it decreased to well below F_{ref} = 0.26 after 1994, stayed below F_{ref} until 2003, fluctuated around F_{ref} during 2004 to 2006, then declined and was 0.15 in 2010 (80% confidence interval: 0.13 – 0.19, Figure 31). The determination of F_{ref} was based on analyses that assumed full recruitment to the fishery for ages 4 and older.

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 40). Average partial recruitment for 2006 to 2010 is less variable when weighted by population numbers and is considered more appropriate than the unweighted average.

Gains in fishable biomass may be partitioned into those associated with somatic growth of haddock which have previously recruited to the fishery, and those associated with new recruitment to the fishery (Rivard 1980). We used age 2 as the age of first recruitment to the fishery. This choice facilitated comparisons with historic stock productivity but may be less representative of the current fishery selectivity. Since 1993, except for 1996, 2001, 2003 and

2004, surplus production (biomass gains from growth and from recruitment, decremented by losses due to natural deaths) exceeded fishery harvest yields, resulting in net population biomass increases (Figure 41). In 2009 and 2010, surplus production decreased substantially as growth of the 2003 year class slowed and gains from recruitment remained low. Growth of fish is the dominant component of the biomass gain but recruitment accounts for significant portions when stronger year-classes enter the population, e.g. the 2000 year class in 2002 and the 2003 year class in 2005 (Figure 42). The biomass contributed by the 2003 year class, both when it recruited at age 2 and through growth during that year was greater than that of any other previous cohort since 1969.

PRODUCTIVITY

Recruitment, as well as age structure, spatial distribution and fish growth reflect changes in the productive potential. Data to approximate the age composition of the catch from unit areas 5Zj and 5Zm during 1931 to 1955 were used to reconstruct a population analysis of EGB that was suitable for comparison of productivity to recent years (Gavaris and Van Eeckhaute 1997, Figure 36). Recruitment, while highly variable, has generally been higher when adult biomass has been above 40,000 mt (Figure 43). Since 1969, only the 1975, 1978, 2000, 2003 and 2010 year-classes have been above the average abundance of year-classes observed during the period 1931-55. The recruits per adult biomass ratio was generally low during the 1980s but higher during the 1990s, comparable to that in the 1931-1955 period (Figure 44), when the 3+ biomass was above 40,000 mt. Since 2001, with the exception of 2003, 2005 and 2010, recruits per spawner have again been low. The very high biomass (greater than 100,000 mt) observed since 2006 has produced one exceptional year class but has generally produced below average year classes (Figure 43).

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 2003 year-class, the main component of the 3+ age group, was widely distributed throughout the survey area (Figures 18-20).

DFO survey average weights at length for 9 length groups, used to reflect fish condition, exhibit a declining trend since about 2001 and declined in 2011 to well below each length's average and are at the lowest level for most lengths examined (Figure 45). Poor condition of haddock in 2010 was corroborated by fishermen who noticed a substantial decrease in individual haddock yield. Poor condition is likely associated with low food availability as fishermen related that many haddock had no food in their stomachs and their distribution was more scattered than in recent years which may be an indication that haddock were having to range further to find food.

Both average length and weight at age started declining about the year 2000. Average size at age had seen some improvement for the younger age groups in recent years, however, the declines observed in 2010 continued in 2011 for these younger ages (Figure 38). Average weights in 2011 remain below the 1991 to 2000 average (Table 19). The average size at age for the 2003 year-class is smaller than previous year-classes, but its rate of growth at length has been similar to previous year-classes (Figure 46). The 2010 year class average size at age 1 is less than the 2003 year class and is the second lowest in the time series.

In summary, positive signs of productivity include expanded age structure, broad spatial distribution and large biomass and this stock has produced 2 exceptional year classes in the

last 8 years. On the negative side, condition has decreased, growth has declined and recruitment from the very large biomass has been extremely variable.

PARTIAL RECRUITMENT ON OLDER AGES

In 2012, the 2003 year class will be age 9 and will comprise a large part of the catch. Inclusion in the 9+ group may confound fishing mortality estimation and subsequent estimation of partial recruitment to the fishery. To investigate the fishing mortality and partial recruitment on age 9, the 2010 TRAC recommended a sensitivity run which includes age 9 as a tuning index to calibrate the VPA. This model formulation is detailed in Appendix A. This model has a strong residual pattern for age 9, showing positive residuals in the early part of the time series and negative residuals for the last 8 (DFO survey) to 12 (NMFS spring survey) years (Figure A3) and results in lower population estimates for recent years (Table A2) as well as increased Fs (Table A3). The estimate of partial recruitment for the 2000 year class at age 9 is low at 0.36 (Table A5) and is similar to the benchmark model result of 0.32 for the age 9+ group in 2009 (Table 26), of which the 2000 year class would comprise the major portion.

OUTLOOK

This outlook is provided in terms of consequences with respect to the harvest reference point for alternative catch quotas in 2012. 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, they 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.

Projection inputs for the 2003, 2005 and 2010 year classes were based on year class specific growth patterns. Weights at age for the 2005 year class were derived as described in previous assessments (Van Eeckhaute and Brodziak 2006, Van Eeckhaute et al. 2007, 2008, 2009 and 2010) where year class specific values were estimated using the relationship between length and growth rate (Table 27 and Figure 47) from DFO survey data and the relationship between beginning of year lengths (DFO survey) and average fishery lengths (Table 28 and Figure 48). Beginning of year weights at age for the 2005 year class, derived from a length weight relationship (Waiwood and Neilson 1985), were reduced by 15% to account for the reduction in observed weights relative to those derived from the length weight relationship (Table 29). A partial recruitment of 1 was assigned for this year class. Input values for the 9+ group were based on the 2003 year class as the 9+ group will be comprised primarily of this year class. No growth was assumed for the 2003 year class so the 2010 fishery weight of 1.63 kg and the 2011 survey weight of 1.37 kg were used for subsequent fishery and beginning of year weights, respectively, for the 9+ group (Table 30). A fishery partial recruitment of 1 was used for the 9+ group, higher than the model results indicated (Table 26) but consistent with partial recruitment values used to determine F_{ref}. Weights and partial recruitment for the 2003 year class at ages 2, 3 and 4 were used for the 2010 year class for 2012 onward.

For the other less influential year classes, the 2011 survey and 2010 fishery weights at age were used for inputs, unless it was considered appropriate to use the 3-year averages, i.e, to avoid using the lower weights at age of the 2003 year class and when weights at age had

dropped within a cohort. For these year classes, fishery partial recruitment was based on the most recent five years.

A deterministic projection and risk assessment was conducted to beginning year 2013 incorporating these patterns in growth and partial recruitment (Table 30; Figure 49). Stock size estimates at the beginning of 2011 were used to start the forecasts. Abundance of the 2012 and 2013 year-classes were assumed to be 6.3 million at age 1, the 2002 to 2011 median. Natural mortality was assumed to be 0.2. Assuming a 2011 catch equal to the 22,000 mt total quota, a combined Canada/USA catch of 16,000 mt in 2012 results in a neutral risk (50%) that the 2012 fishing mortality rate would exceed F_{ref} = 0.26 (Table 31, Figure 50). A catch of 13,900 mt in 2012 results in a low risk (25%) that the 2012 fishing mortality rate will exceed F_{ref}. A catch of 17,800 mt in 2012 results in a high risk (75%) that the 2012 fishing mortality rate will exceed F_{ref}. Due to the 2010 year class' entry into the 3+ group in 2013, the estimated probability that the adult biomass will not achieve a 0%, 10% or 20% increase from 2012 to 2013 is virtually 0%. The adult biomass will decline to 64,900 mt at the beginning of 2012 as is expected with the passing of the 2003 year class through the population but it will increase to 124,600 mt at the beginning of 2013 when the 2010 year class will be age 3. The 9+ group, of which the 2003 year class is the main component, is expected to comprise 72% and the 2005 year class 11% of the 2012 catch biomass (Table 31).

A medium term outlook to beginning year 2014 was conducted using the same input values as for the 2012 fishery forecast with the extension to 2014 of the growth assumptions for the 2003 and 2010 year classes. Assuming a 2011 catch equal to the 22,000 mt total quota and an F in 2012 of 0.26, a combined Canada/USA catch of 15,700 mt in 2013 results in a neutral risk (50%) that the 2013 fishing mortality rate would exceed F_{ref} = 0.26. A catch of 13,700 mt in 2013 results in a low risk (25%) that the 2013 fishing mortality rate will exceed F_{ref}. A catch of 18,100 mt in 2013 results in a high risk (75%) that the 2013 fishing mortality rate will exceed F_{ref}. The deterministic result of 15,034 mt (Table 31) is about 4% less than the neutral risk (50%) of exceeding the F_{ref} catch of 15,700 mt, The difference is due to the difference you would expect between a mean or expected value (least-squares estimate) and the median of its confidence distribution when there is greater uncertainty (i.e., on the 2010 year class) with a skewed distribution.

An exploratory projection analysis with constant catch of 22, 20, 18, 16 and 14 thousand mt for 2012 and 2013 indicated that the adult biomass would be expected to increase in 2013 and 2014 compared to the current level (2011), however, the fishing mortality rate would exceed F_{ref} for the higher catch levels (Table 32). The sensitivity of the projections to the size of the 2010 year class was examined by reducing it to half of its estimated size. Biomass then decreased from the 2011 level for all constant catch levels examined and the fishing mortality was higher and usually greater than F_{ref} (Table 33). If the lower partial recruitment for the 9+ age group that the model estimates is aliasing higher natural mortality, emigration of older ages outside the management area or some unknown mechanism which results in the unavailability of older ages to the fishery, Fs would be higher as more of the catch would come from the younger ages.

SPECIAL CONSIDERATIONS

The 2003 year class will enter the 9+ group in 2012. Catch projections for 2012 are highly influenced by the partial recruitment that is used for the 9+ age group. There is no reason to believe that age 9 haddock should be less available to the fishery than age 8 haddock; however, the domed partial recruitment at age 9 that the assessment model produces may be aliasing

increased natural mortality, emigration outside of the management area or to areas inaccessible to the fishery, or some other unknown process. If age 9 availability to the fishery is reduced in 2012, a larger proportion of the catch will come from other, much less abundant year classes with a resulting increase in fully recruited fishing mortality and the 2003 year class could also experience higher than intended fishing mortality. With a domed partial recruitment, less fluctuation in quotas in the next few years could be realized if this year class is not fished at unintentionally high levels, thereby preserving the year class to carry the fishery for a few more years until the 2010 year class can start contributing substantially to the fishery. Analysis of the 2012 fishery will be helpful in determining whether reduced availability of older haddock is real and future catch allocations may need to be adjusted for this lack of availability, whatever the cause.

The medium term outlook for stock biomass is strongly influenced by the outstanding 2003 and 2010 year classes. As the importance of the 2003 year class diminishes, the 3+ stock biomass will decline in 2012 even for relatively low catch, and it will then increase beginning in 2013 as the 2010 year class recruits. While the catch projection indicates that the 2012 TAC should be less than the 2011 TAC to prevent the fishing mortality rate from exceeding the F_{ref}, the adult biomass would be expected to increase in 2013 and 2014 compared to the current level (2011), even if the 2010 TAC of 22,000 mt was maintained. However, if the 2010 year class turns out to be much smaller than currently estimated (i.e., half the size), a catch equal to the current TAC is likely to result in a decrease in adult biomass in 2014 compared to 2011.

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 ratios, 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 B summarizes the performance of the management system. It reports the TRAC advice, 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 by Tom Nies (staff member of the New England Fishery Management Council, NEFMC). The largest differences in expected and actual results occurred when projection inputs for partial recruitment and weights at age for 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 1969-2010. 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		48	76	14532	724	15256	15410	7590
2006	11984	313		62	275	12047	588	12634	14520	7480
2007	11890	256[3]		56	306[3]	11946	562	12508	12730	6270
2008	14781	1138[3]		33	52[3]	14814	1190	16004	14950	8050
2009	17595	2152[3]		54	55[3]	17648	2208	19856	18900	11100
2010	16578	2167		14	34	16592	2201	18794	17612	11988

[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 130 mm square mesh required. Fixed gear required to use large hooks until June
1991	Established overfishing definitions for haddock.	MG < 65 ft similar to 1990 but mesh size increased to 145 mm diamond.
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. 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 by end of year. TAC = 3000 mt.
1995		All OT vessels using square mesh. 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 vessel 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.
1997	May: Additional scheduled Days-at-sea restrictions.	Vessels over 65 ft operated on enterprise allocations, otter trawlers under 65 ft on

Year	USA	Canada
	September: Trip limit raised to 1000 lbs/day, maximum of 10,000 lbs/trip.	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.	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.	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.	TAC = 5,400 mt.
2001-2002	Day and trip limit adjustments. Daily trip limit suspended July 5, 2002.	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.	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. 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.	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.	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.	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.	TAC = 12,730 mt; exploratory winter fishery Jan. to Feb. 15, 2007
2008	TAC[1]=8,050 mt. Minimum size reverts back to 19 in. in August. Prohibitions on yellowtail flounder fishing Jan to April. Trawl fishery opening delayed until Aug. 1. Ruhle trawl (type of separator trawl) approved for use beginning Sept 15. Restrictions on cod catches.	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.	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.

Year	USA	Canada
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 set to 18 inches. All legal size fish must be retained by sector vessels.	TAC = 17,612 mt; winter fishery Jan. 1 to Feb. 7, 2010

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

Table 3. Canadian landings (mt) of haddock from eastern Georges Bank during 1969-2010 by gear category and tonnage class for principal gears.

Year	Otter Trawl							Longline				Scallop Fishery	Other	Total
	Side	Stern												
		1[1]	2	3	4	5	Total[2]	1[1]	2	3	Total			
1969	777		0	1	225	2902	3127		2	21	23	15	0	3941
1970	575		2	0	133	1179	1314		6	72	78	2	1	1970
1971	501		0	0	16	939	955		18	129	151	3	0	1610
1972	148		0	0	2	260	263		23	169	195	1	2	609
1973	633		0	0	60	766	826		23	80	105	0	1	1565
1974	27		0	6	8	332	346		29	59	88	1	0	462
1975	222		0	1	60	963	1024		25	81	107	0	0	1353
1976	217		0	2	59	905	967		48	108	156	0	15	1355
1977	370		92	243	18	2025	2378		43	51	94	1	28	2871
1978	2456		237	812	351	5639	7039		121	47	169	17	287	9968
1979	1622		136	858	627	1564	3185		190	80	271	2	0	5080
1980	1444		354	359	950	6254	7917		129	51	587	4	65	10017
1981	478		448	629	737	2344	4159		331	99	1019	1	1	5658
1982	115		189	318	187	3341	4045		497	187	712	0	0	4872
1983	106		615	431	107	1130	2283		593	195	815	1	3	3208
1984	5		180	269	21	149	620		614	192	835	2	1	1463
1985	72		840	1401	155	348	2745		562	33	626	2	39	3484
1986	51		829	1378	95	432	2734		475	98	594	4	32	3415
1987	48		782	1448	49	1241	3521		854	113	1046	38	50	4703
1988[3]	72		1091	1456	186	398	3183		428	200	695	16	80	4046
1989	0		489	573	376	536	1976		713	175	977	12	95	3060
1990	0		928	890	116	471	2411		623	173	853	7	69	3340
1991	0		1610	1647	81	689	4028		900	271	1309	8	111	5456
1992	0		797	1084	56	645	2583		984	245	1384	4	87	4058
1993	0		535	1179	67	699	2489		794	156	1143	2	93	3727
1994	0		495	911	79	112	1597		498	47	714	9	91	2411
1995	0		523	896	14	214	1647		256	75	390	7	21	2065
1996	1		836	1405	166	270	2689		561	107	947	0	26	3663
1997	0		680	1123	91	96	1991		501	116	722	0	36	2749
1998	0		863	1340	98	71	2422		570	252	921	0	28	3371
1999	0		954	1471	174	145	2761		486	241	887	0	32	3680
2000	0		1313	2269	230	246	4146		619	258	1186	0	70	5402
2001	0		1564	2555	0	757	5112		754	302	1633	0	29	6774
2002	0		1217	2720	0	657	4954		794	151	1521	0	12	6488
2003	0		1186	3246	0	0	4985		806	249	1776	0	14	6775
2004	0		2152	4651	0	67	7744		716	223	2000	0	1	9745
2005	0	1467	2929	7393	326	0	12115	1645	646	78	2368	0	1	14484
2006	0	1605	1805	6076	601	0	10088	1321	491	84	1896	0	1	11984
2007	0	1782	1982	6112	159	0	10034	1463	363	28	1854	0	1	11890
2008	0	2308	2413	7894	0	0	12615	1632	532	0	2164	0	2	14781
2009	0	2384	3112	9884	27	0	15407	1600	585	0	2185	0	3	17595
2010	0	1872	2645	8921	661	0	14100	1932	544	0	2476	0	2	16578

[1] Tonnage class 1 landings included in 'Total' if not specified. Historically, tonnage class 1 accounted for a low proportion of total otter trawl landings but the proportion has increased in recent years..

[2] Total includes catches for tonnage classes which are not listed, only tonnage classes with substantial catches listed

[3] 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.

Table 4. Monthly landings (mt) of haddock by Canada from eastern Georges Bank during 1969-2010.

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

[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. Monthly landings (mt) of haddock by the United States from eastern Georges Bank during 1969-2010. An allocation algorithm was applied to landings from 1994 to 2010 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

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

Table 6. United States landings (mt) of haddock from eastern Georges Bank during 1969-2010 by gear category and tonnage class. An allocation algorithm was applied to landings from 1994 to 2010 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

Table 7. United States landings and discards of haddock in 2010 by quarter and market category from eastern Georges Bank and National Marine Fisheries Service sampling intensity 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.

Market Category	Large	Scrod	Unclassified	Total
		Landings (mt)		
Quarter 1	69	355	0	424
Quarter 2	87	590	2	678
Quarter 3	80	495	0	576
Quarter 4	80	408	0	489
Total	317	1848	2	2167
		Number measured		
Quarter 1	208	242	0	450
Quarter 2	214	254	0	468
Quarter 3	617	357	0	974
Quarter 4	839	253	0	1092
Total	1878	1106	0	2984
		Number aged		
Quarter 1	100	125	0	225
Quarter 2	100	125	0	225
Quarter 3	301	175	0	476
Quarter 4	403	126	0	529
Total	904	551	0	1455
		Discards (mt)		
Quarter 1	N/A	N/A	N/A	
Quarter 2	N/A	N/A	N/A	13
Quarter 3	N/A	N/A	N/A	
Quarter 4	N/A	N/A	N/A	21
Total	N/A	N/A	N/A	34

Table 8. Inter- and intra-reader testing for Georges Bank haddock ageing. (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 (%)	Bowker's test
DFO/NMFS Exchange:							
2011 DFO Spring Survey (NED2011002)	Exchange	Spring 2011	DK vs. SJS	61	0.98	95.1	
2010 Canadian Commercial (Q2-4)	Exchange	Spring 2011	DK vs. SJS	51	3.22	86.3	n/s[1]
2010 US Commercial (Q1-2)	Exchange	Spring 2011	DK vs. SJS	50	1.49	88.0	n/s[1]
2010 NMFS Autumn Survey (201004)	Exchange	Spring 2011	DK vs. SJS	50	4.03	86.0	n/s[1]
NMFS testing:							
2010 US Commercial (Q4)	Precision	3/2011	SJS	104	0.15	99.0	
2010 US Commercial (Q3)	Precision	3/2011	SJS	104	0.45	95.2	
2010 NFMS Autumn Survey (201004)	Precision	1/2011	SJS	110	1.29	99.1	
2010 US Commercial (Q2)	Precision	1/2011	SJS	105	0.51	94.3	
2010 US Commercial (Q1)	Precision	12/2010	SJS	110	0.18	98.2	
Haddock Reference Collection	Accuracy	10/2010	SJS	57	4.12	87.7	n/s[1]
DFO testing:							
2010 Canadian Commercial Port (Q1)	Precision	10/2010	DK	102	2.4	91.2	
2010 Canadian Commercial Obs. (Q1)	Precision	10/2010	DK	99	0.36	96.0	
2010 Canadian Commercial Port (Q2)	Precision	10/2010	DK	116	1.66	90.5	
2010 Canadian Commercial Obs. (Q2)	Precision	10/2010	DK	114	1.43	92.1	
2010 Canadian Commercial Port (Q3)	Precision	11/2010	DK	132	1.65	88.6	n/s[1]
2010 Canadian Commercial Port (Q4)	Precision	2/2011	DK	101	0.42	97.0	
2010 DFO Survey (NED2010001)	Precision	2/2011	DK	120	1.09	90.0	
2011 DFO Survey (NED2011002)	Precision	5/2011	DK	110	0.86	96.4	
DFO combined results:							
2010 Canadian Commercial Port	Precision		DK	451	1.54	91.6	
2010 DFO Survey, 2010 Canadian Commercial (Port & Obs.)	Precision		DK	784	1.31	92.0	

Table 9. Haddock age and length samples for landings from the Canadian groundfish fishery and for discards from the scallop dredge fishery in 2010 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[4]
				At Sea		Port		
				Trips	Measured	Samples	Measured	
1	OTB	Jan	2,390,921	19	13,900	7	1,662	Survey = 735
		Feb	574,390	5	3,049	1	240	Port/AtSea = 400
	DR[1]		3,592	6	244			Total = 1135[5]
2	OTB	June	1,854,338	21	19,573	13	3,323	Port = 251
	LL	June	6,294	Used July samples				At Sea = 136
	GN[2]	June	257	1	4			Total = 387[6]
	DR[1]		4,354	5	68			
3	OTB	July	2,336,340	16	16,605	7	1,705	
		Aug	2,668,949	16	16,023	10	2,460	
		Sept	1,768,582	5	6,050	3	750	
	LL	July	555,924	2	4,641	3	751	
		Aug	1,138,514	11	14,571	6	1,443	Port = 654
		Sept	488,186	3	3,236	4	927	At Sea = 42
	GN[2]	July	454					Total = 696[7]
		Aug	804					
		Sept	351			2	336	
	HL[3]	Aug	531					
	DR[1]		3,149	6	112			
4	OTB	Oct	1,338,944	5	6,722	7	1,676	
		Nov	637,300	7	11,172	5	1,155	
		Dec	530,115	6	8,993	5	1,148	Port = 376
	LL	Oct	232,672			1	238	At Sea = 17
		Nov	54,396	1	1,337	1	245	Total = 393[8]
	DR[1]		3,097		99			
Totals			16,592,454	135	126,399	75	18,059	1,611

[1]Scallop fishery samples were combined by quarter.
[2]Gillnet landings combined with Q3.
[3]Handline landings added to August LL landings.
[4]When otoliths were not available for a length grouping, ages were estimated.
[5]Ages for 1 length grouping were estimated and are not included in total.
[6] Ages for 6 length groupings were estimated and are not included in total.
[7] Ages for 11 length groupings were estimated and are not included in total.
[8] Ages for 6 length groupings were estimated and are not included in total.

Table 10. Components of the 2010 catch at age in numbers of haddock from eastern Georges Bank by quarter or half year.

	Age Group										
	0	1	2	3	4	5	6	7	8	9+	Total
Canadian Landings											
2010 Q1	0	0	1015	22258	32171	106673	47305	1531055	9384	43882	1793743
2010 Q2	0	0	5507	89223	36806	127118	50927	960447	7988	12501	1290516
2010 Q3	0	43	31155	179096	167916	374697	167510	4665978	26029	100811	5713235
2010 Q4	0	2208	11687	85026	54031	131334	96265	1442218	0	15662	1838430
Year total	0	2251	49364	375603	290924	739821	362006	8599698	43401	172856	10635924
United States Landings[1]											
2010 H1	0	0	0	3471	8264	48523	13037	635878	2407	18539	730119
2010 H2	0	0	836	5012	12156	50829	5712	591530	4296	18326	688697
Year total	0	0	836	8483	20420	99352	18749	1227408	6703	36865	1418816
Canadian Discards											
2010 Q1	0	35	38	223	125	219	83	1842	7	35	2606
2010 Q2	0	0	207	662	120	378	91	1964	13	15	3451
2010 Q3	8051	1395	255	252	124	150	52	1184	6	21	11490
2010 Q4	776	377	208	283	95	225	103	1382	0	12	3461
Year total	8828	1807	708	1420	464	972	329	6372	25	83	21008
United States Discards											
2010 H1	0	700	3362	4132	1222	1572	233	5660	0	130	17011
2010 H2	5931	26537	1689	1282	840	1996	355	9680	0	77	48388
Year total	5931	27237	5051	5413	2062	3569	588	15340	0	207	65398
Total Catch											
2010	14759	31295	55958	390919	313870	843714	381672	9848819	50129	210011	12141146

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

Table 11. Total annual commercial catch at age numbers (000's) of haddock from eastern Georges Bank during 1969-2010. 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	6890	526	823	128	157	9033
2006	1	20	16	2519	44	289	4544	234	551	154	8372
2007	0	2	39	181	7344	148	168	1431	136	187	9635
2008	0	4	30	273	268	9721	102	85	708	95	11288
2009	3	17	125	192	741	261	11223	73	58	379	13075
2010	15	31	56	391	314	844	382	9849	50	210	12141

Table 12. Average weight at age (kg) of haddock from the combined Canadian and USA commercial groundfish fishery landings on eastern Georges Bank during 1969-2010. From 1969 to 1973 only USA fishery sampling for lengths and ages was available. Between 1974 and 1984 a mix of USA and Canadian samples were used. No USA fishery weights were available for 1997, 1998. For age 1 missing weights (**bold)** an average of 0.600 kg was used. Missing weights for older haddock were extrapolated within year class.

	Age Group								
Year	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	3.709
1998	0.568	1.131	1.573	1.697	1.983	2.312	2.864	3.395	3.276
1999	0.678	1.094	1.568	1.907	1.893	2.216	2.577	2.816	2.161
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	0.056	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	2.245
2010	0.436	0.739	1.063	1.231	1.338	1.503	1.594	1.728	2.220
Low	0.335[2]	0.514	0.812	0.977	1.338	1.503	1.572	1.671	2.122
High	0.797	1.216	1.724	2.244	2.662	3.760	4.107	4.086	4.455
Median	0.560[2]	0.974	1.359	1.755	2.110	2.475	2.840	3.012	3.418
Average	0.552[2]	0.950	1.324	1.713	2.046	2.348	2.672	2.920	3.301
2008-10 Avg	0.482	0.798	1.017	1.239	1.383	1.548	1.635	1.962	2.300

[1]One haddock measured. [2]Excludes 2005 value.

Table 13. Average lengths at age (cm) of haddock from the combined Canadian and USA commercial groundfish fishery landings on eastern Georges Bank during 1969-2010.

Year	Age Group								
	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	16.5[1]	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
Low	30.4[2]	35.2	43.4	43.9	49.1	50.9	51.3	52.3	57.1
High	40.6[2]	47.2	53.3	59.7	63.5	72.5	75.8	75.5	76.7
Median	36.1[2]	44.3	49.8	54.3	58.3	61.3	63.9	66.1	68.7
Average	35.8[2]	43.5	49.1	53.7	57.3	60.1	63.0	65.0	67.9
Avg. 2008-10	34.1	40.9	44.6	47.7	49.5	51.4	52.1	55.3	58.6

[1]One haddock measured. [2]Excludes 16.5 cm value in 2005.

Table 14. Conversion factors used to adjust for changes in door type and survey vessel in the National Marine Fisheries Service surveys during 1968-2011.

Year	Door	Spring		Fall	
		Vessel	Conversion	Vessel	Conversion
1968	BMV	Albatross IV	1.49	Albatross IV	1.49
1969	BMV	Albatross IV	1.49	Albatross IV	1.49
1970	BMV	Albatross IV	1.49	Albatross IV	1.49
1971	BMV	Albatross IV	1.49	Albatross IV	1.49
1972	BMV	Albatross IV	1.49	Albatross IV	1.49
1973	BMV	Albatross IV	1.49	Albatross IV	1.49
1974	BMV	Albatross IV	1.49	Albatross IV	1.49
1975	BMV	Albatross IV	1.49	Albatross IV	1.49
1976	BMV	Albatross IV	1.49	Albatross IV	1.49
1977	BMV	Albatross IV	1.49	Delaware II	1.2218
1978	BMV	Albatross IV	1.49	Delaware II	1.2218
1979	BMV	Albatross IV	1.49	Delaware II	1.2218
1980	BMV	Albatross IV	1.49	Delaware II	1.2218
1981	BMV	Delaware II	1.2218	Delaware II	1.2218
1982	BMV	Delaware II	1.2218	Albatross IV	1.49
1983	BMV	Albatross IV	1.49	Albatross IV	1.49
1984	BMV	Albatross IV	1.49	Albatross IV	1.49
1985	Polyvalent	Albatross IV	1	Albatross IV	1
1986	Polyvalent	Albatross IV	1	Albatross IV	1
1987	Polyvalent	Albatross IV	1	Albatross IV	1
1988	Polyvalent	Albatross IV	1	Albatross IV	1
1989	Polyvalent	Delaware II	0.82	Delaware II	0.82
1990	Polyvalent	Delaware II	0.82	Delaware II	0.82
1991	Polyvalent	Delaware II	0.82	Delaware II	0.82
1992	Polyvalent	Albatross IV	1	Albatross IV	1
1993	Polyvalent	Albatross IV	1	Delaware II	0.82
1994	Polyvalent	Delaware II	0.82	Albatross IV	1
1995	Polyvalent	Albatross IV	1	Albatross IV	1
1996	Polyvalent	Albatross IV	1	Albatross IV	1
1997	Polyvalent	Albatross IV	1	Albatross IV	1
1998	Polyvalent	Albatross IV	1	Albatross IV	1
1999	Polyvalent	Albatross IV	1	Albatross IV	1
2000	Polyvalent	Albatross IV	1	Albatross IV	1
2001	Polyvalent	Albatross IV	1	Albatross IV	1
2002	Polyvalent	Albatross IV	1	Albatross IV	1
2003	Polyvalent	Delaware II	0.82	Delaware II	0.82
2004	Polyvalent	Albatross IV	1	Albatross IV	1
2005	Polyvalent	Albatross IV	1	Albatross IV	1
2006	Polyvalent	Albatross IV	1	Albatross IV	1
2007	Polyvalent	Albatross IV	1	Albatross IV	1
2008	Polyvalent	Albatross IV	1	Albatross IV	1
2009	3 bridle, 4 seam	Henry B Bigelow	See Table 15	Henry B Bigelow	See Table 15
2010	3 bridle, 4 seam	Henry B Bigelow	See Table 15	Henry B Bigelow	See Table 15
2011	3 bridle, 4 seam	Henry B Bigelow	See Table 15		

Table 15. Conversion factors for Georges Bank haddock used to adjust for changes in net, doors, survey vessel and protocols for the National Marine Fisheries Service surveys during 2009 and 2010 when the *Henry B. Bigelow* was the research vessel used. *Bigelow* catches are divided by the conversion factor to equate to *Albatross IV* catches.

Length (cm)	Conversion factor
1 – 18	2.626169
19	2.580551
20	2.534933
21	2.489315
22	2.443697
23	2.398079
24	2.352462
25	2.306844
26	2.261226
27	2.215608
28	2.169990
29	2.124372
30	2.078754
31	2.033136
32	1.987518
33	1.941900
34	1.896283
35	1.850665
36	1.805047
37	1.759429
38	1.713811
39	1.668193
40	1.622575
41	1.576957
42	1.531339
43	1.485721
44	1.440104
45	1.394486
46	1.348868
47	1.303250
48	1.257632
49	1.212014
50	1.166396
51 and greater	1.163990

Table 16. 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 1986-2011.

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

Table 17. 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 1968-2011. From 1973-81, 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

Table 18. Total swept area estimated abundance at age (numbers in 000's) of eastern Georges Bank haddock from National Marine Fisheries Service fall surveys during 1963-2010. Since 2009 a new net, vessel and protocols were used and conversion factors to equate to *Albatros 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	344780	2309	1170	2138	786	2332	1179	19819	344	374857

Table 19. Average weight at age (kg) of eastern Georges Bank haddock from the Canadian Department of Fisheries and Oceans surveys during 1986-2011. These weights are used to represent beginning of year population weights. The NMFS spring survey lengths for 2011 are included for comparison. Highlighted values indicate that weights in 2011 were less than or equal to weights in 2010 for the same year class.

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
2011 NMFS	0.051	0.338	0.670	0.873	0.874	1.024	1.247	1.185	1.370
Low	0.028	0.171	0.389	0.657	0.870	1.018	1.120	1.371	1.721
High	0.150	0.685	1.227	1.803	3.044	2.848	3.598	3.559	3.918
Median	0.107	0.471	0.823	1.193	1.617	1.959	2.208	2.602	3.038
Average	0.100	0.434	0.821	1.228	1.591	1.934	2.218	2.483	2.902
Avg. 2009-11	0.075	0.365	0.712	0.953	1.020	1.161	1.311	1.941	2.005
Avg. 1991-2000	0.118	0.528	0.975	1.401	1.749	2.187	2.523	2.780	3.252

[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 20. Average lengths at age (cm) of eastern Georges Bank haddock from the Canadian Department of Fisheries and Oceans surveys during 1986-2011. The NMFS spring survey lengths for 2011 are included for comparison. Highlighted values indicate that lengths in 2011 were less than or equal to lengths in 2010 for the same year class.

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
2011 NMFS	17.7	33.0	42.1	46.8	46.3	48.8	51.8	50.9	52.7
Low	15.1	27.0	34.0	40.2	42.6	47.6	49.3	52.3	55.4
High	24.7	40.7	49.7	55.7	63.7	62.7	67.8	69.3	71.5
Median	22.3	35.9	43.2	48.5	52.9	58.1	59.3	62.2	65.8
Average	21.6	35.0	42.7	48.6	52.8	56.8	59.1	61.3	64.7

Table 21. Data and model changes to the eastern Georges Bank haddock assessment framework from 1998 to 2010.

Assessment Year	Change
1998	Framework: Random error in catch at age negligible. Errors 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 (Appendix A). Largest change for 1994 discards from 258 mt to 1279 mt.

Table 22. Statistical properties of estimates of population abundance (numbers in 000's) at beginning of year 2011 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	655880	396762	0.605	98740	0.151
2	5043	1954	0.387	277	0.055
3	3472	1080	0.311	108	0.031
4	5096	1377	0.270	173	0.034
5	2517	662	0.263	73	0.029
6	7270	1709	0.235	100	0.014
7	1075	319	0.297	41	0.038
8	47958	9061	0.189	674	0.014
Survey Calibration Constants					
Canadian Department of Fisheries and Oceans Survey					
1	0.235	0.042	0.177	0.003	0.011
2	0.400	0.068	0.171	0.001	0.002
3	0.773	0.131	0.170	0.020	0.026
4	0.825	0.145	0.176	0.005	0.006
5	0.865	0.147	0.170	0.010	0.011
6	0.742	0.129	0.174	0.009	0.012
7	0.846	0.159	0.188	0.007	0.009
8	0.786	0.133	0.169	0.006	0.008
National Marine Fisheries Service (NMFS) Spring Survey – Yankee 36 – 1969-72/1982-2011					
1	0.128	0.020	0.158	0.001	0.010
2	0.321	0.051	0.160	0.002	0.006
3	0.418	0.061	0.147	0.003	0.007
4	0.388	0.058	0.149	0.005	0.013
5	0.444	0.067	0.152	0.006	0.013
6	0.383	0.058	0.152	0.002	0.005
7	0.383	0.059	0.154	0.002	0.006
8	0.405	0.065	0.161	0.006	0.015
NMFS Spring Survey – Yankee 41 – 1973-81					
1	0.228	0.071	0.313	0.008	0.035
2	0.534	0.160	0.300	0.024	0.045
3	0.652	0.198	0.304	0.031	0.048
4	0.806	0.260	0.323	0.033	0.041
5	0.895	0.292	0.326	0.063	0.071
6	0.811	0.309	0.381	0.051	0.063
7	1.488	0.519	0.349	0.066	0.044
8	0.724	0.252	0.348	0.030	0.042
NMFS Fall Survey					
0	0.137	0.019	0.139	0.002	0.014
1	0.301	0.043	0.141	0.004	0.012
2	0.244	0.035	0.141	0.003	0.010
3	0.240	0.035	0.145	0.000	0.001
4	0.199	0.029	0.144	0.000	0.002
5	0.166	0.023	0.136	0.001	0.003

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

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	3082	8519	1728	123	251	18	17	327	454	14518	11436	2917
1975	3448	2490	4948	1166	100	176	12	14	557	12910	9462	6973
1976	54076	2807	1787	2701	761	78	112	8	437	62766	8691	5884
1977	6039	43910	2157	1307	1463	501	64	74	348	55864	49825	5914
1978	4058	4943	28726	1706	906	922	263	52	319	41895	37838	32895
1979	52346	3317	3784	14596	1249	587	480	144	287	76790	24443	21126
1980	6239	42666	2700	2911	8084	696	300	199	301	64095	57856	15190
1981	4616	5079	19101	1901	2111	4443	396	130	352	38128	33512	28433
1982	2097	3730	3534	9570	1197	1281	2522	217	358	24506	22409	18679
1983	2555	1715	2397	1944	5280	796	709	1409	356	17160	14605	12890
1984	16105	2083	1269	1367	1094	2839	465	487	1047	26756	10651	8568
1985	1640	13120	1615	806	805	653	1312	214	822	20987	19347	6226
1986	13919	1335	8809	975	497	480	420	732	695	27862	13943	12608
1987	2201	11315	1058	4892	641	278	282	237	974	21877	19676	8361
1988	16073	1801	7391	748	2627	435	176	156	829	30236	14163	12362
1989	1023	13112	1428	4078	501	1349	256	109	674	22530	21507	8395
1990	2389	835	9587	1091	2640	281	793	179	579	18374	15986	15150
1991	2076	1928	677	6637	773	1470	165	498	543	14768	12691	10763
1992	8231	1680	1160	472	3571	553	853	71	667	17257	9026	7346
1993	12379	6695	1151	659	271	1612	372	412	498	24048	11669	4975
1994	11724	10062	5225	623	279	140	724	267	535	29580	17855	7793
1995	5908	9566	7857	3495	343	163	26	422	534	28313	22406	12840
1996	5829	4830	7761	5951	2489	233	111	19	721	27942	22113	17284
1997	17484	4769	3925	5913	4094	1661	137	74	538	38594	21110	16342
1998	8468	14289	3819	3148	4358	2916	1184	100	464	38746	30278	15988
1999	28771	6917	11523	2864	2342	3081	1984	866	420	58768	29997	23080
2000	9655	23531	5624	8756	2057	1694	2210	1394	941	55861	46206	22675
2001	83961	7899	18976	4199	6027	1446	1195	1614	1683	127002	43040	35141
2002	4121	68722	6408	13974	2958	4171	948	795	2306	104402	100281	31560
2003	2577	3373	55964	5050	9737	2080	2811	673	2179	84443	81866	78493
2004	304414	2103	2752	44166	3875	6633	1319	1870	2024	369158	64744	62640
2005	6081	248933	1699	2186	32872	2628	4084	616	2573	301671	295590	46657
2006	23558	4966	203591	1365	1587	20716	1678	2604	2353	262419	238860	233894
2007	6427	19270	4052	164411	1077	1040	12875	1163	3424	213738	207311	188041
2008	9785	5260	15742	3154	127991	749	700	9254	3465	176101	166316	161056
2009	5114	8007	4279	12643	2340	96028	521	497	9689	139118	134005	125997
2010	5856	4172	6443	3331	9687	1682	68589	361	7950	108071	102215	98044
2011	557140	4766	3365	4923	2444	7170	1034	47284	6570	634696	77556	72789

Table 24. Fishing mortality rates for eastern Georges Bank haddock during 1969-2010 from a virtual population analysis using the bootstrap bias adjusted population abundance at the beginning of 2011. The aggregated rates are weighted by population numbers. The rates for ages 4+ and 5+ are also shown as exploitation rate (%). Highlighted cells follow two recent large year classes, the 2000 and 2003.

Year	Age Group												
	1	2	3	4	5	6	7	8	9+	4+	4+(%)	5+	5+(%)
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	36.8
1970	0.021	0.152	0.057	0.261	0.425	0.383	0.424	0.377	0.538	0.387	29.3	0.421	31.3
1971	0.000	0.608	0.892	0.369	0.302	1.114	1.202	0.564	0.623	0.577	40.1	0.582	40.4
1972	0.075	0.005	0.404	0.705	0.468	0.175	0.973	0.342	0.460	0.410	30.7	0.389	29.4
1973	0.112	0.647	0.045	0.830	1.056	0.410	0.101	0.571	0.294	0.470	34.2	0.272	21.7
1974	0.013	0.343	0.193	0.000	0.154	0.181	0.015	0.103	0.164	0.126	10.8	0.141	11.9
1975	0.006	0.132	0.405	0.227	0.051	0.255	0.218	0.218	0.063	0.176	14.6	0.105	9.1
1976	0.008	0.064	0.113	0.413	0.217	0.000	0.208	0.000	0.046	0.323	25.2	0.149	12.6
1977	0.000	0.224	0.035	0.166	0.262	0.444	0.000	0.247	0.048	0.228	18.6	0.261	20.9
1978	0.002	0.067	0.477	0.112	0.235	0.452	0.405	0.244	0.033	0.228	18.5	0.308	24.2
1979	0.004	0.006	0.062	0.391	0.385	0.470	0.679	0.401	0.056	0.396	29.8	0.421	31.4
1980	0.006	0.604	0.151	0.121	0.399	0.363	0.639	0.335	0.046	0.328	25.5	0.391	29.5
1981	0.013	0.163	0.491	0.263	0.299	0.366	0.401	0.330	0.024	0.318	24.8	0.332	25.8
1982	0.001	0.242	0.398	0.395	0.208	0.392	0.382	0.377	0.224	0.373	28.4	0.337	26.1
1983	0.005	0.101	0.361	0.375	0.420	0.338	0.176	0.383	0.114	0.374	28.4	0.373	28.4
1984	0.005	0.054	0.254	0.330	0.317	0.572	0.577	0.466	0.405	0.458	33.5	0.487	35.2
1985	0.006	0.198	0.304	0.284	0.316	0.242	0.384	0.320	0.170	0.293	23.2	0.295	23.3
1986	0.007	0.033	0.388	0.220	0.379	0.333	0.371	0.303	0.068	0.260	20.9	0.274	21.8
1987	0.000	0.226	0.147	0.422	0.188	0.259	0.391	0.388	0.134	0.354	27.2	0.218	17.8
1988	0.004	0.033	0.395	0.201	0.466	0.330	0.277	0.393	0.143	0.351	27.0	0.378	28.7
1989	0.002	0.113	0.069	0.235	0.377	0.331	0.158	0.264	0.079	0.246	19.9	0.262	21.0
1990	0.014	0.010	0.168	0.144	0.385	0.334	0.265	0.308	0.085	0.285	22.5	0.319	24.9
1991	0.012	0.308	0.161	0.420	0.136	0.345	0.644	0.387	0.132	0.374	28.4	0.285	22.6
1992	0.007	0.178	0.365	0.355	0.595	0.196	0.528	0.523	0.164	0.485	35.1	0.495	35.7
1993	0.007	0.048	0.415	0.659	0.460	0.601	0.130	0.541	0.184	0.494	35.6	0.460	33.7
1994	0.003	0.047	0.202	0.396	0.339	1.493	0.340	0.451	0.104	0.379	28.8	0.373	28.4
1995	0.001	0.009	0.078	0.140	0.187	0.187	0.117	0.145	0.034	0.134	11.4	0.119	10.2
1996	0.001	0.007	0.072	0.174	0.205	0.334	0.196	0.187	0.117	0.182	15.1	0.195	16.1
1997	0.002	0.022	0.021	0.105	0.139	0.138	0.108	0.122	0.072	0.120	10.2	0.133	11.3
1998	0.002	0.015	0.088	0.095	0.147	0.185	0.112	0.139	0.086	0.137	11.6	0.151	12.8
1999	0.001	0.007	0.075	0.131	0.124	0.132	0.153	0.134	0.069	0.132	11.2	0.132	11.2
2000	0.001	0.015	0.092	0.173	0.152	0.149	0.114	0.159	0.082	0.154	13.0	0.134	11.4
2001	0.000	0.009	0.106	0.150	0.168	0.222	0.208	0.172	0.143	0.169	14.1	0.176	14.6
2002	0.000	0.005	0.038	0.161	0.152	0.194	0.143	0.165	0.148	0.164	13.7	0.167	14.0
2003	0.003	0.003	0.037	0.065	0.183	0.255	0.207	0.198	0.126	0.161	13.5	0.189	15.7
2004	0.001	0.013	0.030	0.095	0.188	0.284	0.560	0.283	0.154	0.140	11.9	0.267	21.3
2005	0.002	0.001	0.019	0.119	0.260	0.247	0.249	0.258	0.070	0.241	19.5	0.247	19.9
2006	0.001	0.003	0.014	0.036	0.221	0.273	0.165	0.262	0.075	0.237	19.2	0.247	19.9
2007	0.000	0.002	0.049	0.050	0.162	0.193	0.128	0.135	0.061	0.057	5.1	0.122	10.5
2008	0.000	0.006	0.018	0.095	0.086	0.161	0.142	0.087	0.030	0.085	7.4	0.085	7.4
2009	0.003	0.016	0.048	0.064	0.125	0.133	0.163	0.134	0.043	0.119	10.2	0.125	10.7
2010	0.005	0.014	0.065	0.103	0.096	0.268	0.167	0.162	0.029	0.147	12.4	0.148	12.5

Table 25. Beginning of year biomass (mt) for eastern Georges Bank haddock during 1969-2011. 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 2011 to determine biomass. Highlighted cells follow two recent large year classes, the 2000 and 2003.

Year	Age Group											
	1	2	3	4	5	6	7	8	9+	1+	2+	3+
1969	92	99	3403	1311	1816	17938	6702	733	2674	34768	34676	34577
1970	413	339	132	2528	954	1048	9823	3805	1743	20784	20371	20033
1971	27	1483	433	164	2113	600	670	5745	3346	14580	14553	13071
1972	610	99	1201	234	123	1506	185	180	4616	8752	8143	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	4909
1975	396	1281	4626	1754	200	412	33	41	1918	10661	10264	8983
1976	6216	1444	1671	4062	1516	183	299	24	1507	16922	10706	9261
1977	694	22593	2017	1965	2915	1175	171	217	1200	32948	32254	9661
1978	466	2543	26857	2565	1805	2162	706	153	1100	38359	37893	35350
1979	6017	1707	3538	21950	2489	1375	1289	421	987	39774	33756	32050
1980	717	21953	2524	4377	16108	1631	805	584	1036	49735	49018	27065
1981	531	2613	17858	2859	4206	10418	1063	380	1212	41140	40609	37996
1982	241	1919	3304	14392	2385	3005	6769	636	1232	33884	33643	31723
1983	294	882	2241	2924	10520	1866	1902	4128	1226	25982	25689	24806
1984	1851	1072	1187	2056	2180	6657	1248	1425	3607	21283	19431	18360
1985	189	6751	1510	1212	1603	1531	3523	626	2831	19775	19587	12836
1986	1874	603	8583	1409	1512	1368	1510	2471	2721	22051	20177	19574
1987	330	5653	757	8181	1289	710	887	747	3533	22087	21757	16104
1988	1563	837	6878	1342	4772	834	479	509	3207	20421	18858	18021
1989	63	6217	927	5678	999	3410	552	312	2118	20278	20214	13997
1990	356	438	8860	1288	4917	583	1989	504	2009	20944	20589	20150
1991	248	1320	542	10031	1311	3579	347	1555	1864	20797	20549	19229
1992	1007	1012	1296	501	7422	1196	2309	162	2293	17199	16192	15180
1993	1510	3221	1413	1188	345	3761	871	1127	1632	15069	13559	10338
1994	1251	4721	5470	1009	538	302	2283	718	1650	17942	16691	11970
1995	509	4720	7567	5440	762	398	62	1262	1700	22420	21911	17191
1996	808	2390	7132	7856	4807	595	321	49	2587	26546	25738	23348
1997	2311	2415	3068	7127	6813	3614	335	192	1699	27573	25262	22847
1998	909	7649	3954	3656	6841	5698	3089	358	1605	33758	32849	25200
1999	3730	3276	10495	3693	2949	5758	4227	2358	1256	37742	34012	30736
2000	1117	12785	5335	12945	3848	3031	5079	3495	2730	50367	49249	36464
2001	7838	4136	19077	5756	10834	3132	2689	4186	4928	62577	54739	50603
2002	394	22786	4986	15898	4419	8195	2063	1753	6245	66739	66345	43558
2003	207	1246	47349	5368	14382	3421	6207	1500	5419	85099	84891	83646
2004	19451	652	2151	50845	5061	10336	2140	3657	4485	98779	79328	78676
2005	169	54206	837	1522	40304	3471	6252	986	6289	114037	113867	59662
2006	1381	850	79169	897	1381	28298	2669	4535	5543	124725	123343	122493
2007	492	4731	1641	116575	1068	1815	20077	1943	6374	154714	154223	149492
2008	1047	1730	9024	2506	118686	940	1211	13654	6573	155371	154324	152594
2009	583	3098	3317	12628	2310	120815	772	1331	21586	166440	165857	162758
2010	424	1606	4825	3197	10852	2031	91408	640	16428	131411	130987	129381
2011	21416	1534	2060	4428	2330	7300	1158	64817	11307	116350	94934	93400

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 2010 from the eastern Georges Bank Canadian commercial fishery. Average F's used to normalize the partial recruitment were weighted by population numbers.

	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	0.76	1.20	1.00	0.53
1986	0.02	0.11	1.28	0.73	1.25	1.10	1.23	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	0.55	0.47	1.25	1.09	0.86	1.00	0.28
1991	0.03	0.80	0.42	1.08	0.35	0.89	1.66	1.00	0.34
1992	0.01	0.34	0.70	0.68	1.14	0.38	1.01	1.00	0.31
1993	0.01	0.09	0.77	1.22	0.85	1.11	0.24	1.00	0.34
1994	0.01	0.11	0.45	0.88	0.75	3.31	0.75	1.00	0.23
1995	0.01	0.06	0.53	0.96	1.29	1.29	0.80	1.00	0.24
1996	0.00	0.04	0.38	0.93	1.09	1.78	1.05	1.00	0.63
1997	0.01	0.18	0.17	0.86	1.15	1.14	0.89	1.00	0.59
1998	0.02	0.11	0.63	0.69	1.06	1.33	0.81	1.00	0.62
1999	0.01	0.05	0.56	0.98	0.93	0.99	1.14	1.00	0.52
2000	0.00	0.10	0.58	1.09	0.96	0.94	0.72	1.00	0.52
2001	0.00	0.05	0.62	0.87	0.98	1.29	1.21	1.00	0.83
2002	0.00	0.03	0.23	0.97	0.92	1.18	0.86	1.00	0.90
2003	0.01	0.02	0.18	0.33	0.93	1.29	1.04	1.00	0.64
2004	0.00	0.05	0.11	0.34	0.66	1.00	1.98	1.00	0.54
2005	0.01	0.00	0.07	0.46	1.01	0.96	0.96	1.00	0.27
2006	0.00	0.01	0.05	0.14	0.84	1.04	0.63	1.00	0.28
2007	0.00	0.02	0.36	0.37	1.20	1.43	0.95	1.00	0.45
2008	0.01	0.07	0.21	1.10	0.99	1.86	1.64	1.00	0.35
2009	0.02	0.12	0.36	0.48	0.94	1.00	1.22	1.00	0.32
2010	0.03	0.08	0.40	0.64	0.60	1.67	1.04	1.01	0.18
Avg 1998-02[1]	0.00	0.06	0.53	0.97	0.94	1.11	0.94	1.01	0.75
Avg 2003-10[1]	0.01	0.01	0.10	0.38	0.96	1.03	1.04	1.00	0.33
Avg 2006-10[1]	0.01	0.05	0.08	0.39	0.96	1.03	1.02	1.00	0.30
Avg 2008-10[1]	0.02	0.10	0.28	0.61	0.96	1.02	1.05	1.00	0.27

[1]Average partial recruitments are weighted by population numbers.

Table 27. Lengths estimated for the eastern Georges Bank haddock 2005 year class based on growth rates from the 1998, 1999 and 2000 year classes (unless indicated otherwise) for input into the catch projection and risk assessment for 2012 and 2013.

Age	Beginning year length (cm)	Growth rate	Calculated length for following year[1]
2005 Year Class			
6	47.6[2]	0.062	50.7
7	50.7	0.036	52.5
8	52.5		

[1] $length_{a+1} = length_a \times e^{growth\ rate}$
[2]Observed 2011 beginning year length for 2005 year class from the Canadian Department of Fisheries and Oceans survey

Table 28. Beginning year and fishery lengths and weights estimated for the eastern Georges Bank haddock 2005 year class for input into the risk assessment for 2012 and 2013.

Age	Beginning of year			Fishery	
	Length	Weight[1]	- 15%[2]	Length	Weight[1]
2005 Year Class					
6	47.6[3]	1.018[3]	N/A	52.4[4]	1.631
7	50.7[5]	1.481	1.259	54.0[4]	1.780
8	52.5[5]	1.640	1.394		

[1]*weight = 0.0000158 x length$^{2.91612}$ (Waiwood and Neilson 1985)*.
[2]Weight reduced by 15% to reflect lower values for survey weights versus fishery weights.
[3]Observed 2011 beginning year length or weight for the 2005 year class from the 2011 Canadian Department of Fisheries and Oceans (DFO) survey.
[4]Estimated from relationship between beginning of year lengths (DFO survey) and fishery lengths the same year.
[5]Calculated length estimated from growth rates (Table 28).

Table 29. Lengths and weights for eastern Georges Bank haddock from the 2011 Canadian Department of Fisheries and Oceans survey compared to weights estimated by the relationship between length and weight (LW) derived by Waiwood and Nielson (1985).

Age	2011 Survey Lengths	Observed (kg)	LW equation (kg)	% difference
1	16.6	0.038	0.057	68
2	32.5	0.322	0.406	79
3	40.1	0.612	0.745	82
4	45.8	0.900	1.099	82
5	47.5	0.953	1.225	78
6	47.6	1.018	1.229	83
7	49.3	1.120	1.366	82
8	52.3	1.371	1.625	84

Table 30. Input for projections and risk analyses of eastern Georges Bank haddock for the 2011 fishery. A catch of 22,000 mt in 2011 and natural mortality = 0.2 were assumed for the forecasts. Shaded values indicate the 2003 (yellow), 2005 (grey) and the 2010 (blue) year classes for which year class specific growth patterns were used to determine input values.

Year	Age Group								
	1	2	3	4	5	6	7	8	9+
Population Numbers (000s)									
2011	557140	4766	3365	4923	2444	7170	1034	47284	6570
Partial Recruitment to the Fishery[1]									
2011	0.004[2]	0.06	0.3	0.5	1	1	1	1	1
2012	0.01	0.004[2]	0.3	0.5	1	1	1	1	1
2013	0.01	0.06	0.051[2]	0.5	1	1	1	1	1
Weight at beginning of year for population (kg)[3]									
2011	0.04	0.32	0.61	0.9	0.95	1.02	1.120	1.37	1.721
2012	0.04	0.06[2]	0.61	0.9	0.95	1.02	1.48[4]	1.37	1.37[5]
2013	0.04	0.32	0.22[2]	0.9	0.95	1.02	1.31[6]	1.64[4]	1.37[5]
2014	0.04	0.32	0.61	0.39[2]	0.95	1.02	1.31[6]	1.37	1.37[5]
Weight at age for catch (kg)[7]									
2011	0.39[2]	0.74	1.06	1.23	1.34	1.63[8]	1.64[9]	1.6	2.3[10]
2012	0.44	0.63[2]	1.06	1.23	1.34	1.5	1.78[8]	1.96[11]	1.6[5]
2013	0.44	0.74	0.98[2]	1.23	1.34	1.5	1.64[9]	1.96[11]	1.6[5]
Maturity									
2011	0	0	1	1	1	1	1	1	1
2012	0	0	1	1	1	1	1	1	1
2013	0	0	1	1	1	1	1	1	1

[1]Based on 2006 to 2010 average except where indicated and ages 5 to 9+ assumed fully recruited.
[2]Based on observed values from 2003 year class.
[3]2011 Canadian Department of Fisheries and Oceans (DFO) survey average weights at age except where indicated.
[4]Based on a length based growth model (see Table 30). Lengths were converted to weights using a length-weight relationship for commercially caught fish (Waiwood and Nielson 1985) and reduced by 15% to reflect lower population weights at age (Table 30).
[5]The 9+ group weights are based on the 2003 year class. No growth was assumed for the 2003 year class (in the 9+ group at age 9, 10 and 11).
[6]Based on the 2009 to 2011 age 7 survey average as the 2011 DFO survey value indicated a reduction in weight at age from age 6 to age 7 within the year class (Table 19).
[7]2010 Canadian fishery weights at age except where indicated.
[8]Based on a length based growth model. Lengths were converted to weights using a length-weight relationship for commercially caught fish (Waiwood and Nielson 1985) (Table 30).
[9]Average of 2008 to 2010 Canadian fishery weights at age (rather than using the 2003 year class weight at age 7 which is growing more slowly than other year classes).
[10]Average of 2008 to 2010 Canadian fishery weights at age.
[11]Average of 2008 to 2010 Canadian fishery weights at age instead of the 2010 age 8 weight which was a drop in weight from age 7 for this year class .

Table 31. Bias adjusted deterministic projection results for eastern Georges Bank haddock for the 2012 and 2013 fishery using 10 million age 1 recruits for the 2011 year class and 6.3 million age 1 recruits (the 2002 to 20011 median) for the 2012 and 2013 year classes and assuming that the 2011 quota of 22,000 mt is caught. Shaded values indicate the 2003 (yellow), 2005 (grey) and the 2010 (blue) year classes.

Year	Age Group											
	1	2	3	4	5	6	7	8	9+	1+	2+	3+
Population Numbers (000s)												
2011	557140	4766	3365	4923	2444	7170	1034	47284	6570	634696	77556	72790
2012	10000	455709	3846	2563	3573	1573	4614	665	34658	517201	507201	51492
2013	6300	8166	372715	2913	1843	2256	993	2913	22299	420398	414098	405932
2014	6300	5145	6582	301134	2094	1163	1424	627	15916	340385	334085	328940
Population Biomass (mt)												
2011	21171	1535	2059	4430	2329	7299	1158	64826	11307	116115	94944	93409
2012	400	29165	2346	2307	3395	1604	6829	911	47481	94439	94039	64874
2013	252	2613	81252	2621	1750	2301	1301	4777	30550	127417	127165	124552
2014	252	1646	4015	117141	1989	1186	1865	859	21805	150759	150507	148861
Fishing mortality												
2011	0.001	0.014	0.072	0.12	0.241	0.241	0.241	0.241	0.241			
2012	0.003	0.001	0.078	0.13	0.26	0.26	0.26	0.26	0.26			
2013	0.003	0.016	0.013	0.13	0.26	0.26	0.26	0.26	0.26			
Projected Catch Numbers (000s)												
2011	486	62	213	507	476	1396	201	9206	1279	13826	13340	13278
2012	24	429	262	284	745	328	962	139	7223	10396	10372	9943
2013	15	115	4451	323	384	470	207	607	4647	11219	11204	11089
Catch Biomass (mt)												
2011	190	46	226	624	638	2276	330	14730	2942	22000	21810	21765
2012	10	301	278	349	998	492	1712	272	11557	15967	15957	15656
2013	7	85	4362	397	515	705	339	1190	7436	15034	15028	14943

Table 32. Bias adjusted deterministic projection results for eastern Georges Bank haddock to beginning of year 2014 for constant quota scenarios of 22, 20, 18, 16 and 14 thousand mt for 2012 and 2013. Partial recruitment to the fishery for the 9+ group was set at 1. F is for fully recruited ages. Highlighted cells (yellow and green) indicate the 2010 year class at ages 1 to 4 and the 2003 year class at age 8 and in the 9+ group. Highlighted F values indicate values greater than the F_{ref}. Biomass at the beginning of 2014 is highlighted to facilitate comparison between scenarios.

				Age Group										
Quota	Year	F		1	2	3	4	5	6	7	8	9+	1+	3+
22 K	2011		Biomass	21171	1535	2059	4430	2329	7299	1158	64826	11307	116115	93409
	2012			400	29165	2346	2307	3395	1604	6829	911	47481	94439	64874
	2013			206	2610	81214	2531	1651	2047	1157	4250	27175	122840	120024
	2014			206	1346	3969	116055	1761	941	1395	642	16308	142623	141071
	2011	0.241	Catch	190	46	226	624	638	2276	330	14730	2942	22000	21765
	2012	0.377		15	436	396	492	1372	676	2353	374	15887	22000	21549
	2013	0.433		9	140	7237	613	748	966	465	1631	10190	22000	21851
20K	2011		Biomass	21171	1535	2059	4430	2329	7299	1158	64826	11307	116115	93409
	2012			400	29165	2346	2307	3395	1604	6829	911	47481	94439	64874
	2013			206	2611	81227	2562	1684	2131	1205	4424	28290	124340	121522
	2014			206	1346	3984	116405	1833	1015	1536	707	17951	144983	143430
	2011	0.241	Catch	190	46	226	624	638	2276	330	14730	2942	22000	21765
	2012	0.337		13	389	356	444	1248	615	2141	340	14454	20000	19597
	2013	0.378		8	123	6315	548	682	899	433	1517	9477	20000	19870
18K	2011		Biomass	21171	1535	2059	4430	2329	7299	1158	64826	11307	116115	93409
	2012			400	29165	2346	2307	3395	1604	6829	911	47481	94439	64874
	2013			206	2612	81239	2592	1717	2215	1252	4599	29409	125842	123023
	2014			206	1347	3998	116729	1903	1090	1681	774	19647	147374	145821
	2011	0.241	Catch	190	46	226	624	638	2276	330	14730	2942	22000	21765
	2012	0.298		12	345	317	397	1124	554	1928	306	13018	18000	17644
	2013	0.326		7	106	5461	484	614	826	398	1394	8710	18000	17887
16K	2011		Biomass	21171	1535	2059	4430	2329	7299	1158	64826	11307	116115	93409
	2012			400	29165	2346	2307	3395	1604	6829	911	47481	94439	64874
	2013			206	2613	81252	2621	1750	2299	1300	4774	30531	127347	124528
	2014			206	1348	4011	117030	1971	1164	1830	843	21392	149794	148241
	2011	0.241	Catch	190	46	226	624	638	2276	330	14730	2942	22000	21765
	2012	0.261		10	301	278	350	1000	493	1715	272	11580	16000	15688
	2013	0.279		6	91	4670	423	546	748	360	1263	7892	16000	15903
14K	2011		Biomass	21171	1535	2059	4430	2329	7299	1158	64826	11307	116115	93409
	2012			400	29165	2346	2307	3395	1604	6829	911	47481	94439	64874
	2013			206	2614	81263	2650	1782	2384	1348	4950	31657	128855	126034
	2014			206	1348	4023	117311	2037	1239	1983	913	23181	152241	150686
	2011	0.241	Catch	190	46	226	624	638	2276	330	14730	2942	22000	21765
	2012	0.224		9	259	241	304	876	431	1502	238	10140	14000	13732
	2013	0.234		5	77	3935	364	478	667	321	1125	7029	14000	13919

Table 33. Bias adjusted deterministic projection results for eastern Georges Bank haddock to beginning of year 2014 for constant quota scenarios of 22, 20, 18, 16 and 14 thousand mt. The 2010 year class was reduced to half of its estimated size. Partial recruitment to the fishery for the 9+ group was set at 1. Highlighted cells (yellow and green) indicate the 2010 year class at ages 1 to 4 and the 2003 year class at age 8 and in the 9+ group. Highlighted F values indicate values greater than the F_{ref}. Biomass at the beginning of 2014 is highlighted to facilitate comparison between scenarios.

				Age Group										
Quota	Year	F		1	2	3	4	5	6	7	8	9+	1+	3+
22K	2011		Biomass	10586	1464	1995	4426	2317	7176	1169	64388	11249	104770	92720
	2012			400	14582	2237	2232	3386	1591	6693	917	47019	79057	64075
	2013			206	2610	40605	2406	1590	2022	1136	4125	26659	81358	78542
	2014			206	1344	3941	57681	1580	807	1227	561	14224	81572	80021
	2011	0.244	Catch	96	44	221	631	642	2264	337	14803	2962	22000	21860
	2012	0.387		15	223	387	488	1397	684	2355	384	16066	22000	21761
	2013	0.550		11	178	4576	720	867	1150	550	1907	12042	22000	21811
20K	2011		Biomass	10586	1464	1995	4426	2317	7176	1169	64388	11249	104770	92720
	2012			400	14582	2237	2232	3386	1591	6693	917	47019	79057	64075
	2013			206	2611	40612	2436	1623	2107	1184	4299	27788	82867	80050
	2014			206	1345	3961	57922	1663	890	1383	633	16033	84037	82485
	2011	0.244	Catch	96	44	221	631	642	2264	337	14803	2962	22000	21860
	2012	0.345		14	200	347	440	1271	623	2142	349	14615	20000	19787
	2013	0.471		10	153	3933	636	786	1064	509	1764	11144	20000	19838
18K	2011		Biomass	10586	1464	1995	4426	2317	7176	1169	64388	11249	104770	92720
	2012			400	14582	2237	2232	3386	1591	6693	917	47019	79057	64075
	2013			206	2612	40618	2466	1656	2193	1233	4475	28921	84379	81561
	2014			206	1346	3979	58138	1743	974	1544	706	17896	86533	84981
	2011	0.244	Catch	96	44	221	631	642	2264	337	14803	2962	22000	21860
	2012	0.305		12	176	309	392	1145	561	1929	314	13161	18000	17811
	2013	0.402		8	130	3356	557	705	973	466	1614	10191	18000	17861
16K	2011		Biomass	10586	1464	1995	4426	2317	7176	1169	64388	11249	104770	92720
	2012			400	14582	2237	2232	3386	1591	6693	917	47019	79057	64075
	2013			206	2613	40624	2494	1688	2279	1281	4650	30057	85894	83075
	2014			206	1347	3996	58334	1820	1058	1708	782	19807	89058	87505
	2011	0.244	Catch	96	44	221	631	642	2264	337	14803	2962	22000	21860
	2012	0.267		11	154	271	346	1018	499	1716	280	11706	16000	15835
	2013	0.339		7	110	2835	483	623	878	420	1455	9190	16000	15883
14K	2011		Biomass	10586	1464	1995	4426	2317	7176	1169	64388	11249	104770	92720
	2012			400	14582	2237	2232	3386	1591	6693	917	47019	79057	64075
	2013			206	2614	40630	2522	1720	2366	1330	4827	31196	87411	84591
	2014			206	1348	4011	58512	1893	1141	1877	859	21760	91607	90053
	2011	0.244	Catch	96	44	221	631	642	2264	337	14803	2962	22000	21860
	2012	0.230		9	133	235	300	891	437	1502	245	10248	14000	13858
	2013	0.282		6	92	2362	412	542	778	372	1290	8146	14000	13902

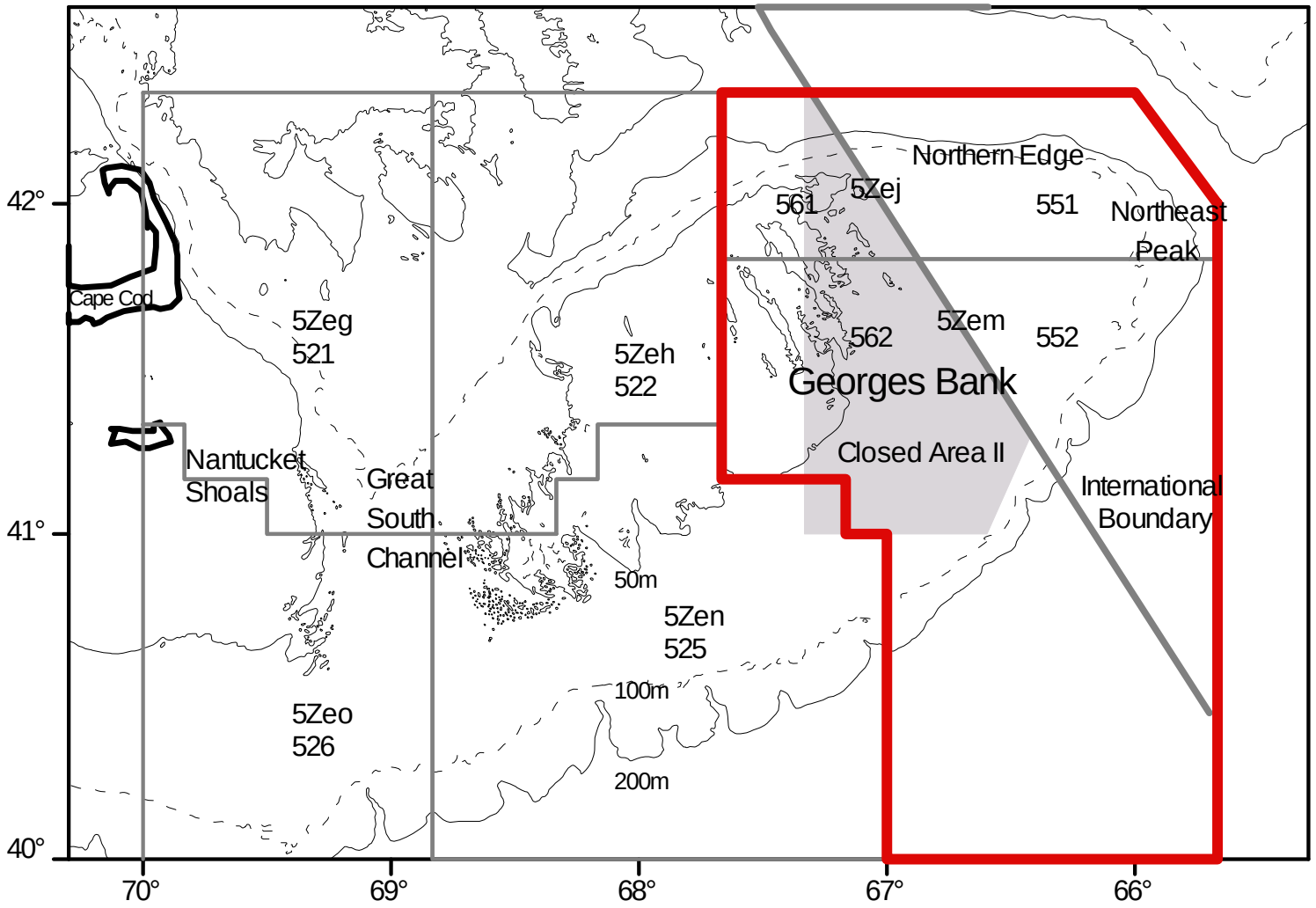

Figure 1. Fisheries statistical unit areas in North Atlantic Fisheries Organization Subdivision 5Ze. Alpha-numeric codes, e.g. 5Zej, are the Canadian Department of Fisheries and Oceans designations and numeric codes, e.g. 561, are National Marine Fisheries Service designations. The eastern Georges Bank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

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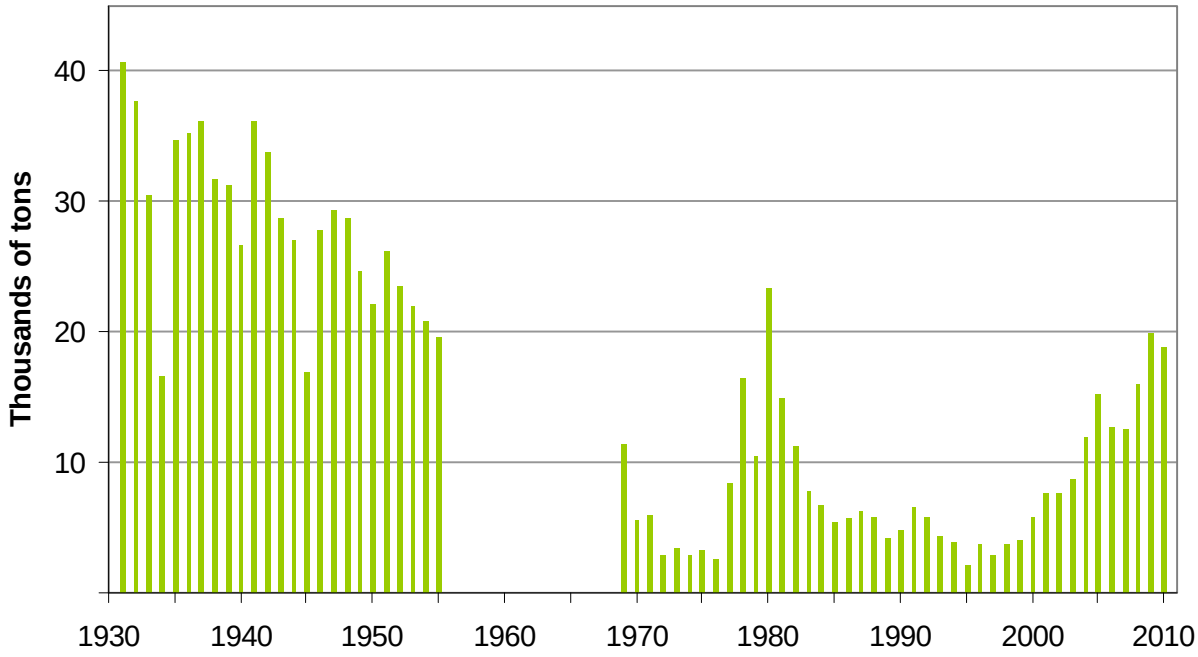


Figure 2. Historical catch of eastern Georges Bank haddock during 1931-1955 (Gavaris and Van Eeckhaute 1997) compared to recent catches during 1969-2010. Catch data for 1956 to 1968 were not available by unit area.

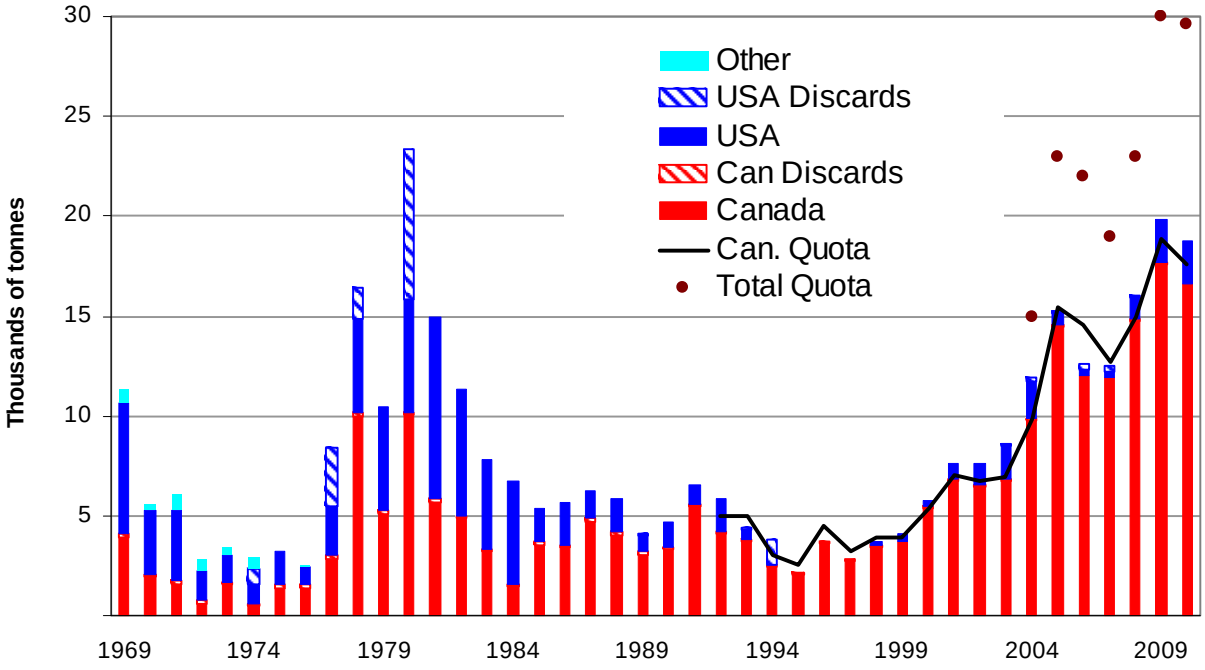


Figure 3. Nominal catches of eastern Georges Bank haddock during 1969-2010.

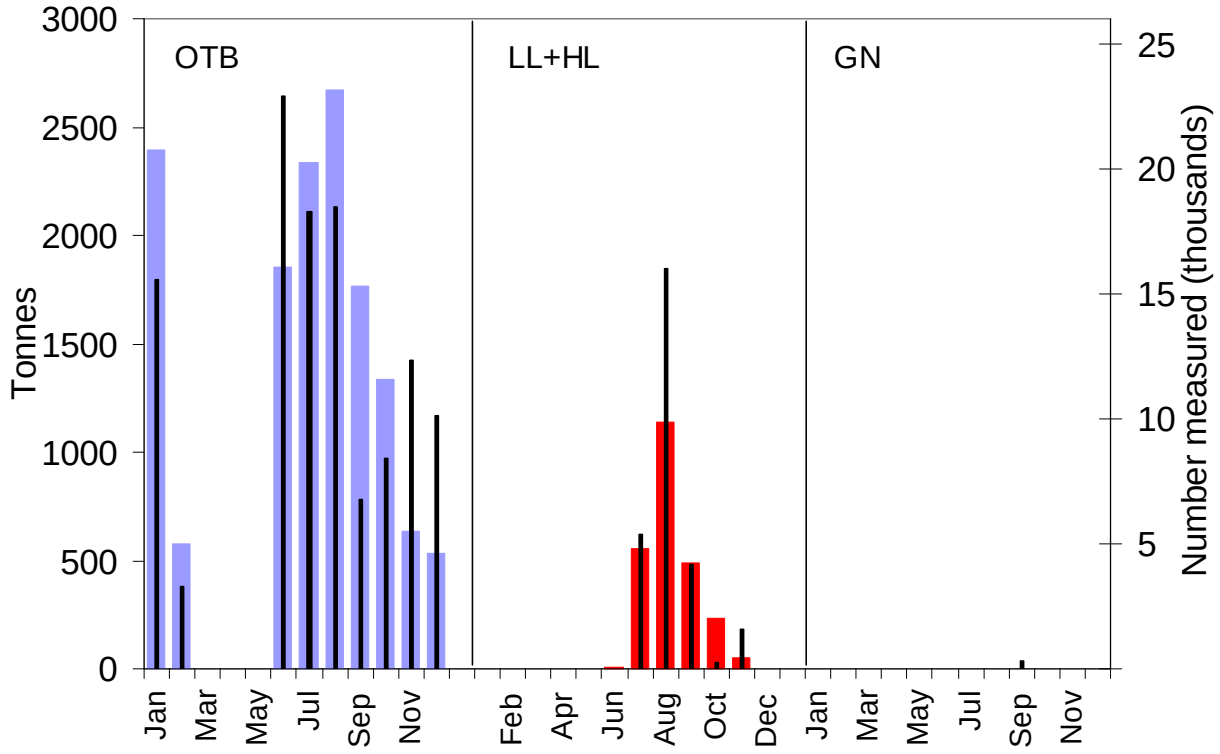
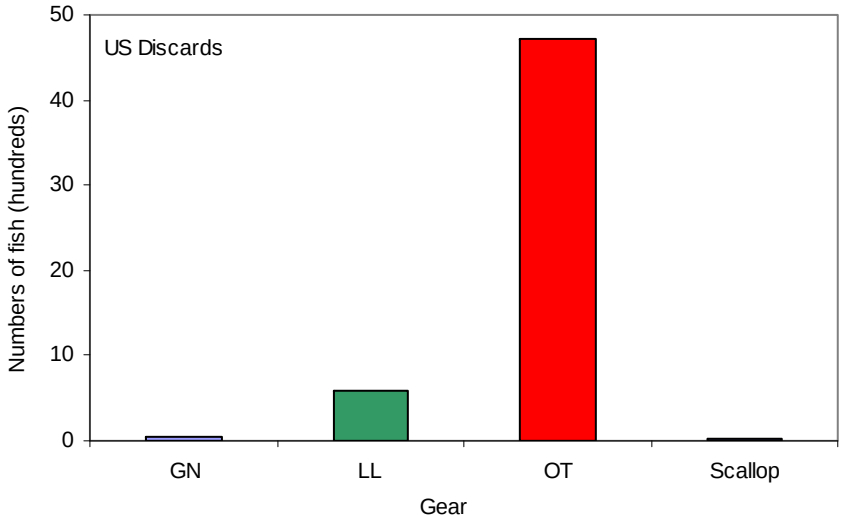
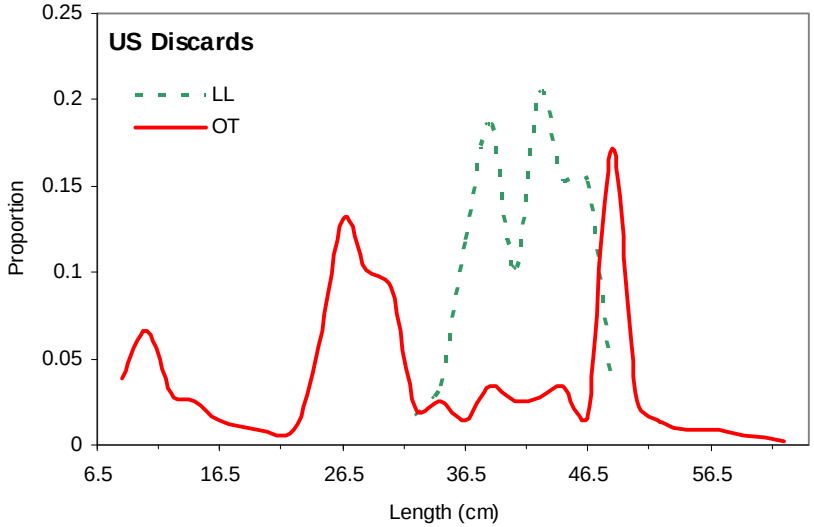


Figure 4. Haddock landings in eastern Georges Bank by month and gear for the Canadian commercial groundfish fishery in 2010 (wide bars) with sampling levels (narrow bars).





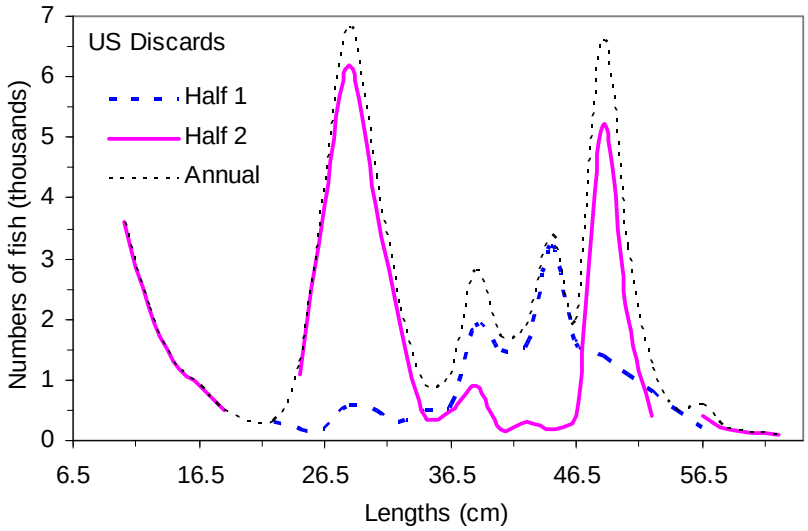


Figure 5. US haddock discards by gear in numbers, proportion at length for longline and otter trawl gear and numbers at length by half year and total.

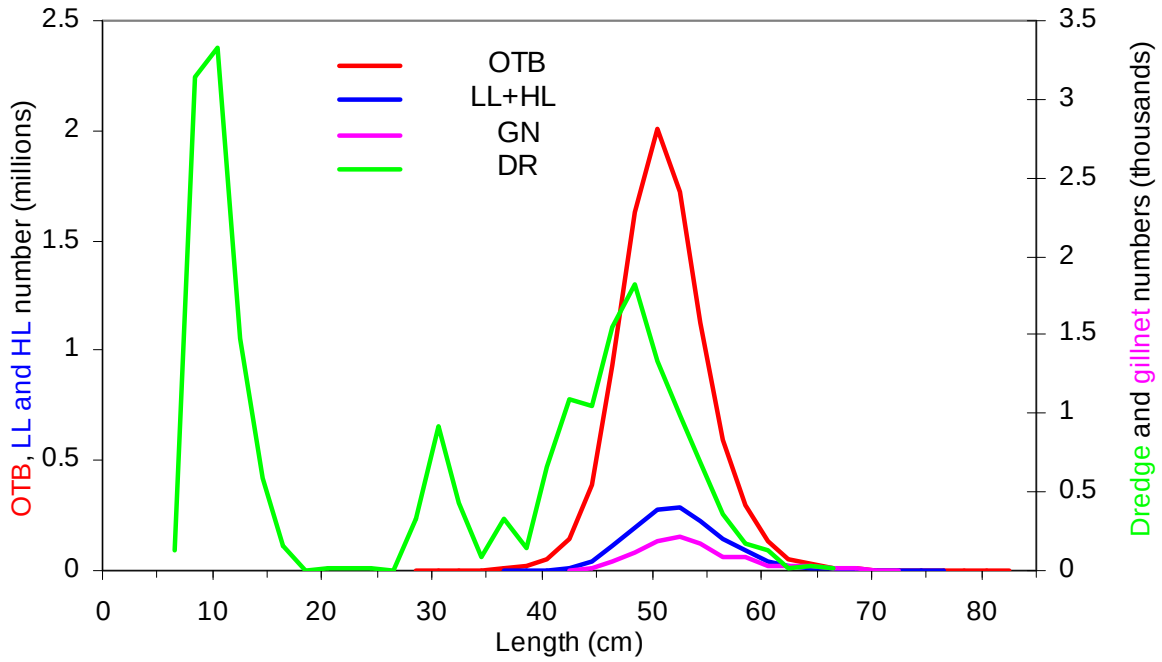


Figure 6. Haddock numbers at length landed by components of the Canadian commercial groundfish fisheries and haddock discards at length from the Canadian scallop fishery on eastern Georges Bank in 2010. The scallop dredge and gillnet length frequencies are expanded according to the axis on the right. OTB=otter trawl bottom, LL+HL=longline and handline, GN=gillnet, DR=scallop dredge.

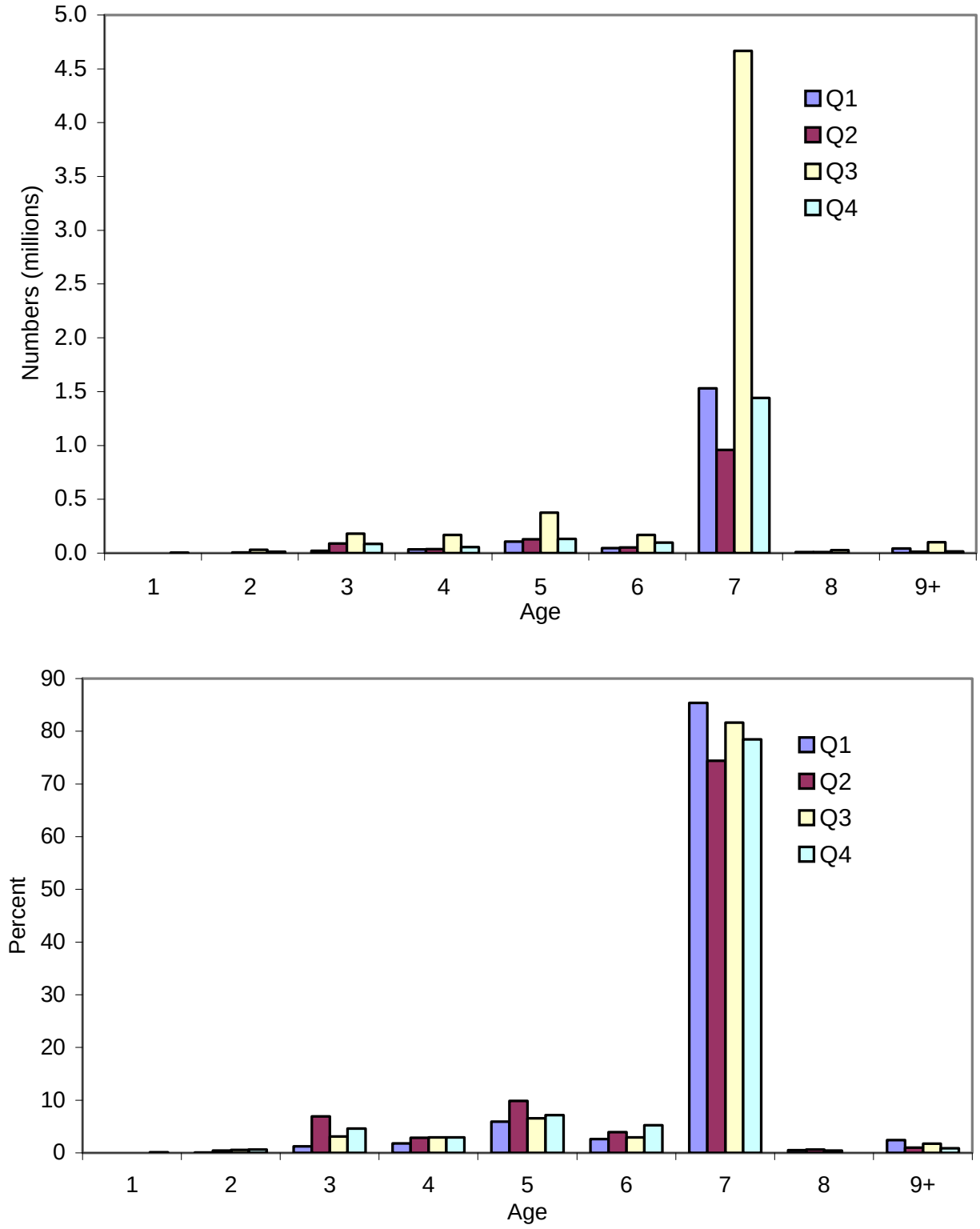


Figure 7. Numbers (top panel) and percent (bottom panel) of haddock landings at age by quarter by the Canadian groundfish fishery on eastern Georges Bank in 2010.

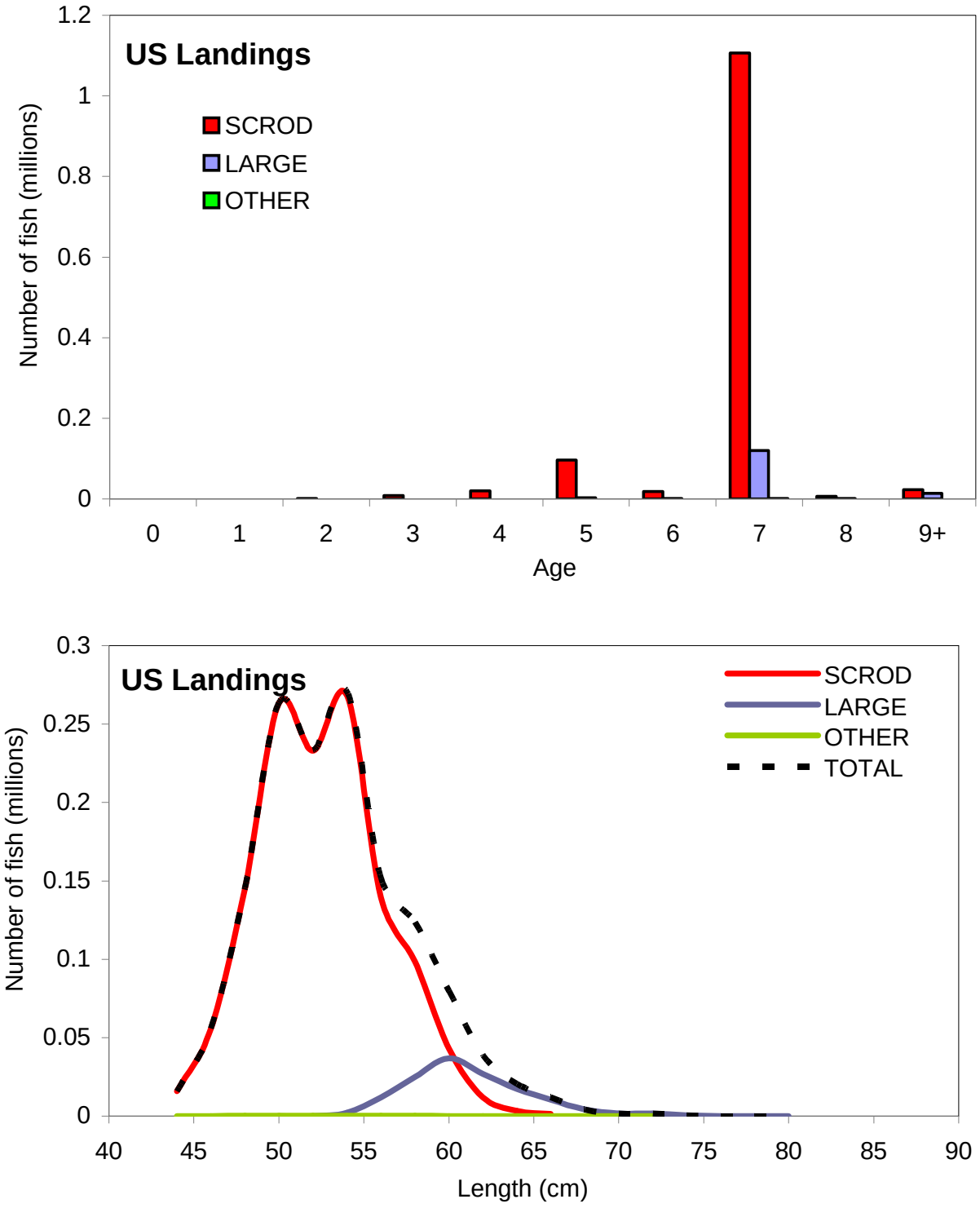


Figure 8. Haddock landings at age (top panel) and length (bottom panel) by market category in numbers in the USA eastern Georges Bank groundfish fisheries in 2010.

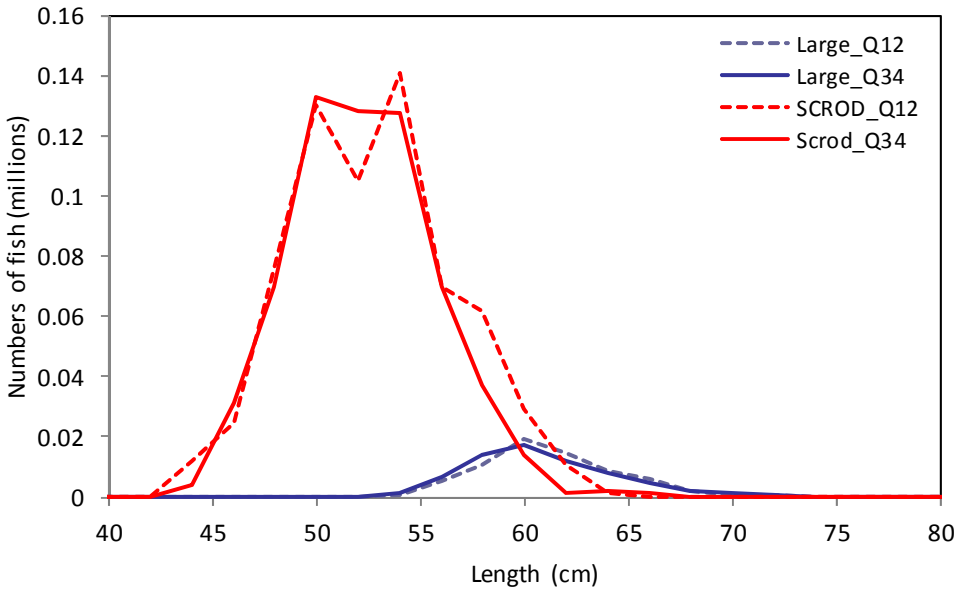


Figure 9. Length composition of haddock by market category and half year landed by the United States eastern Georges Bank groundfish fisheries in 2010.

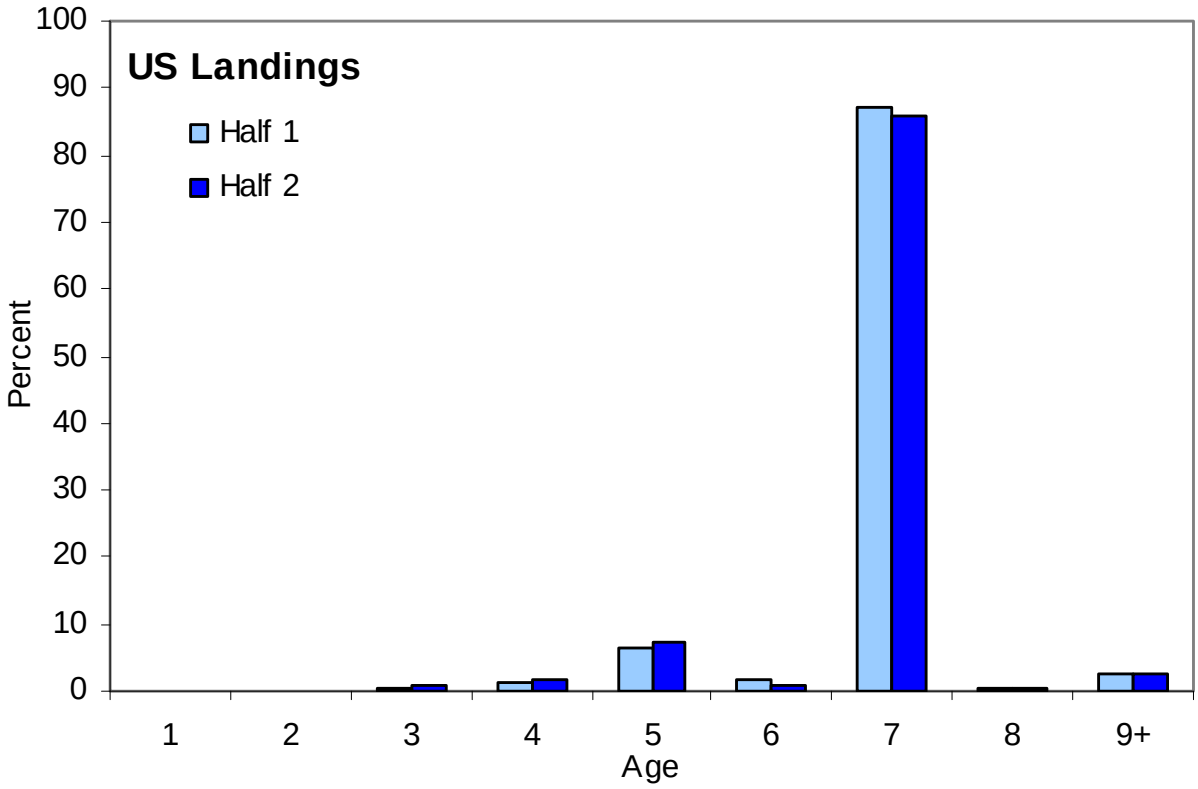


Figure 10. Percent catch at age of haddock landed by the United States eastern Georges Bank groundfish fisheries in 2010.

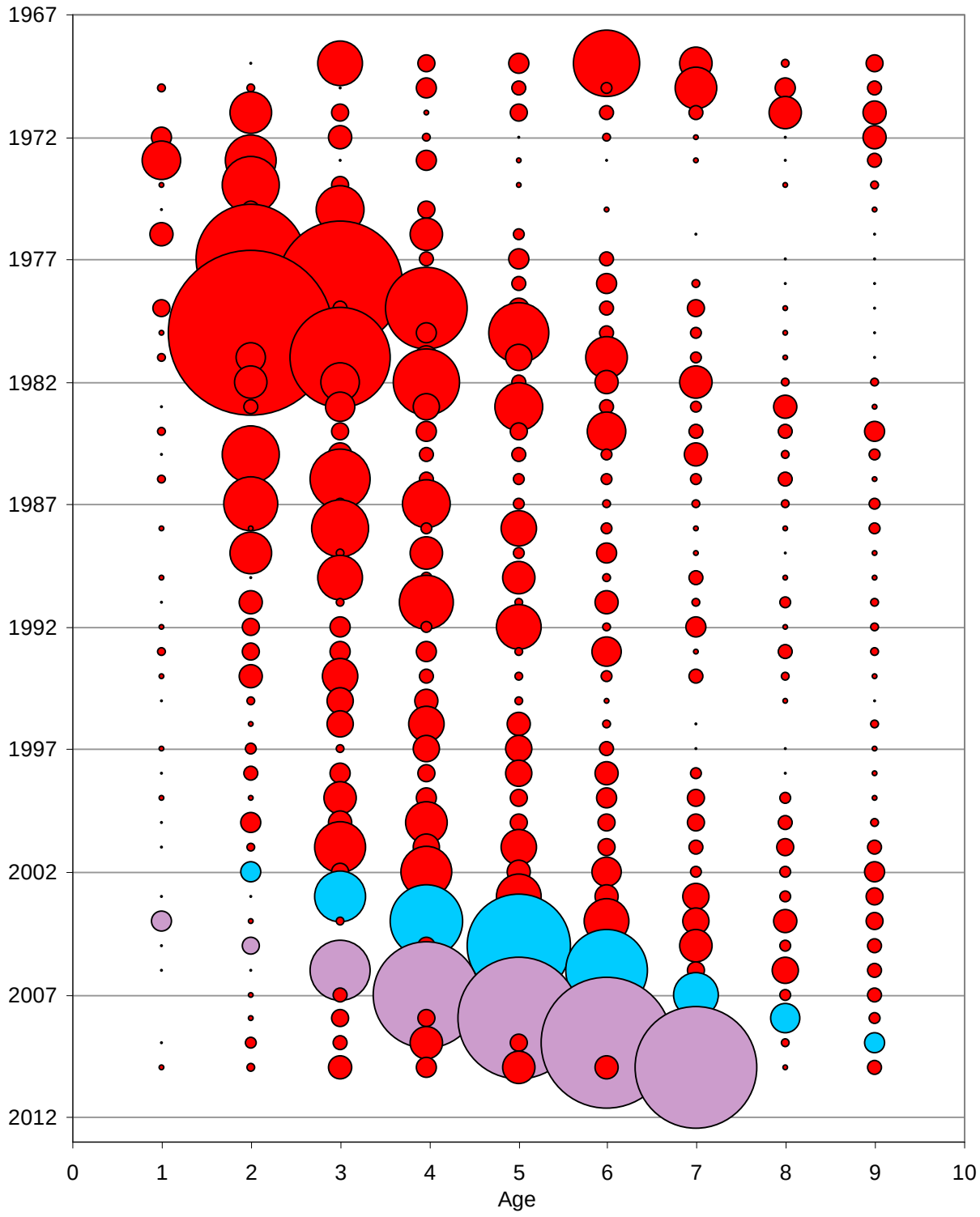


Figure 11. Total commercial catch at age (numbers) of eastern Georges Bank haddock during 1969-2010. The 2000 and 2003 year classes are indicated in blue and purple, respectiviely. The bubble area is proportional to catch magnitude.

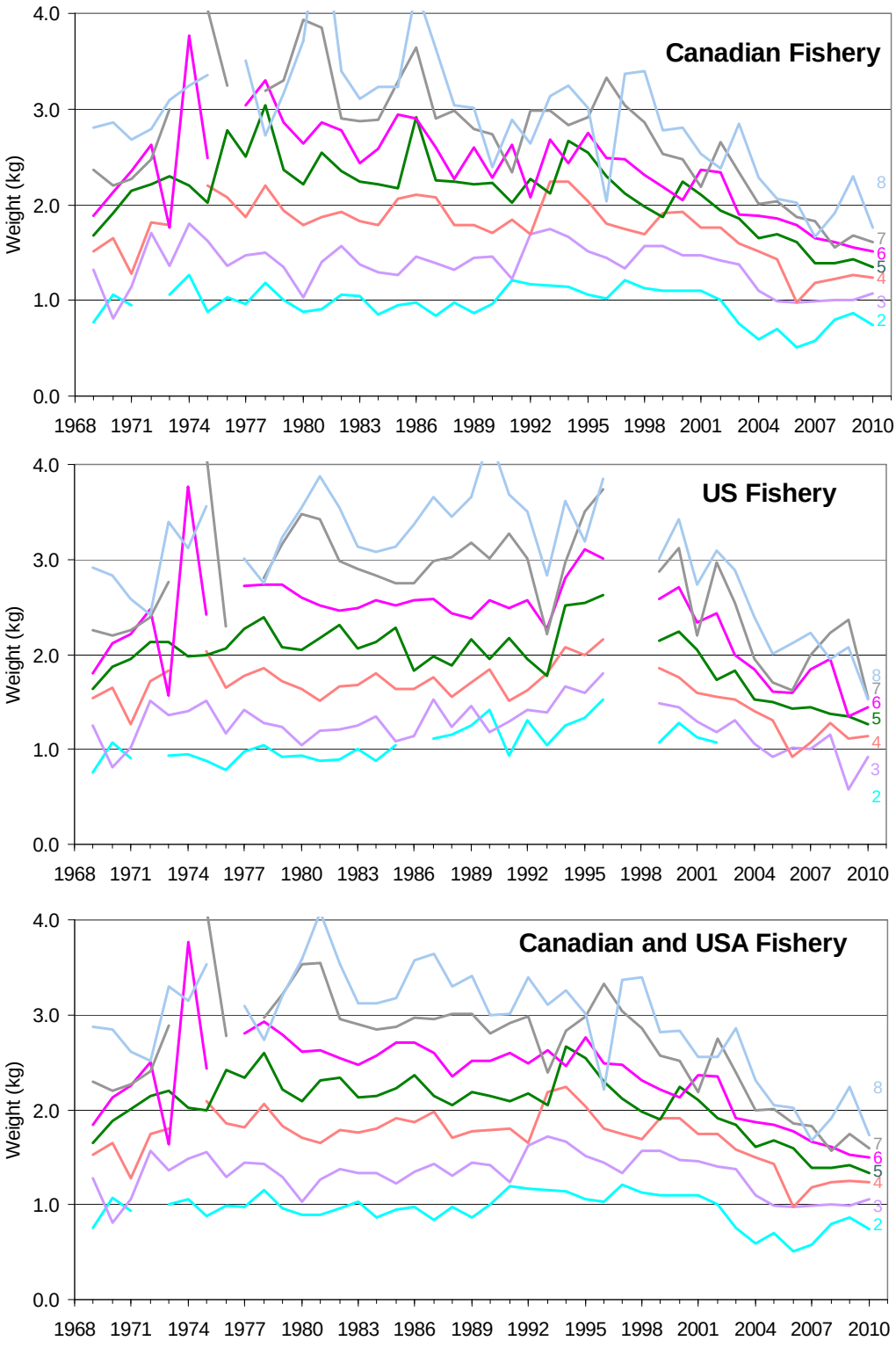


Figure 12. Average weights at age for eastern Georges Bank haddock from the Canadian, USA and combined commercial groundfish fishery during 1969-2010. From 1969 to 1973 only USA fishery sampling for lengths and ages was available. Between 1974 and 1984 a mix of USA and Canadian samples were used (Gavaris and Van Eeckhaute 1990).

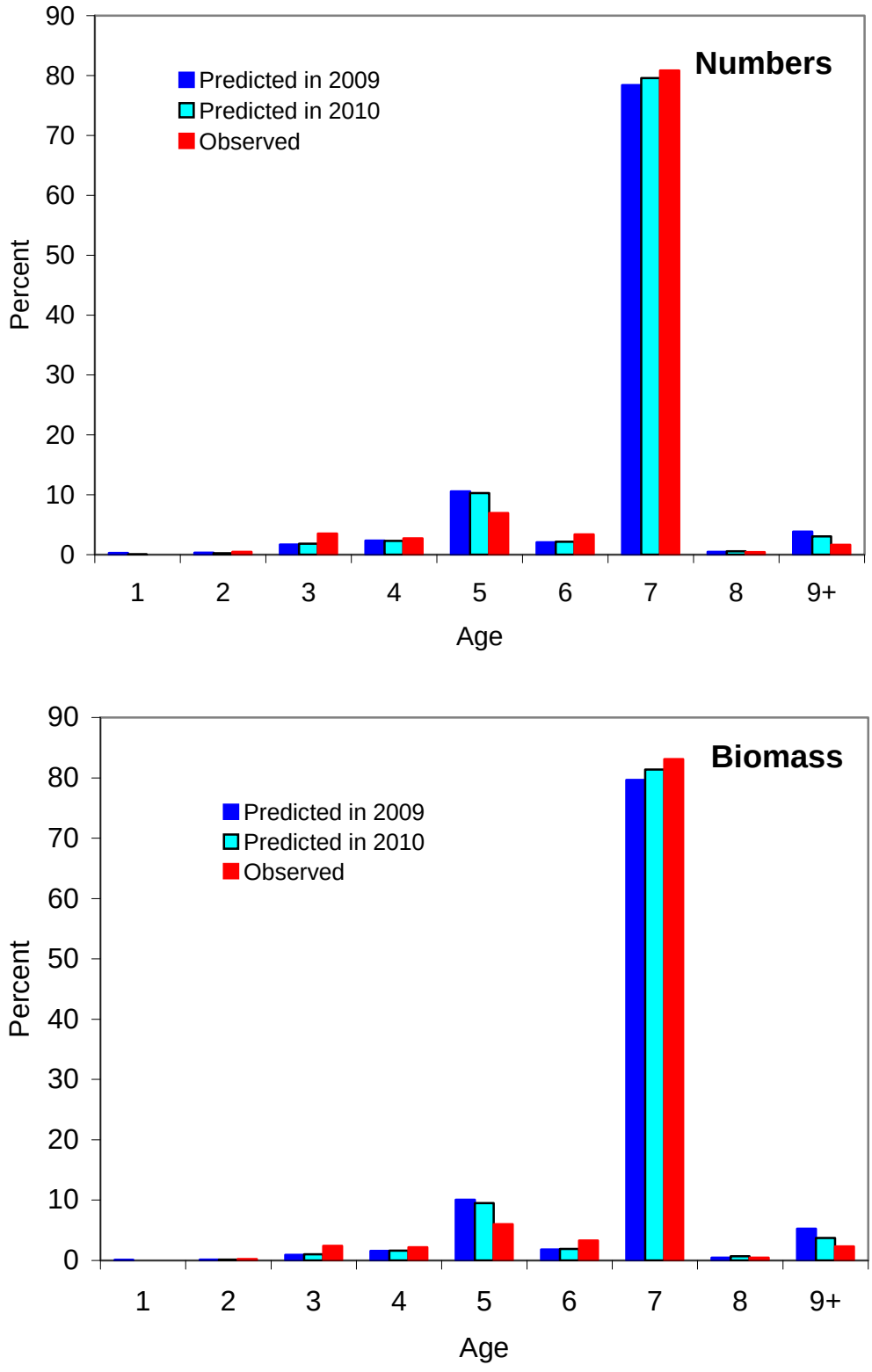


Figure 13. Percent composition of numbers and biomass of 2010 eastern Georges Bank haddock catch projected in 2009 and 2010 compared to the observed 2010 catch.

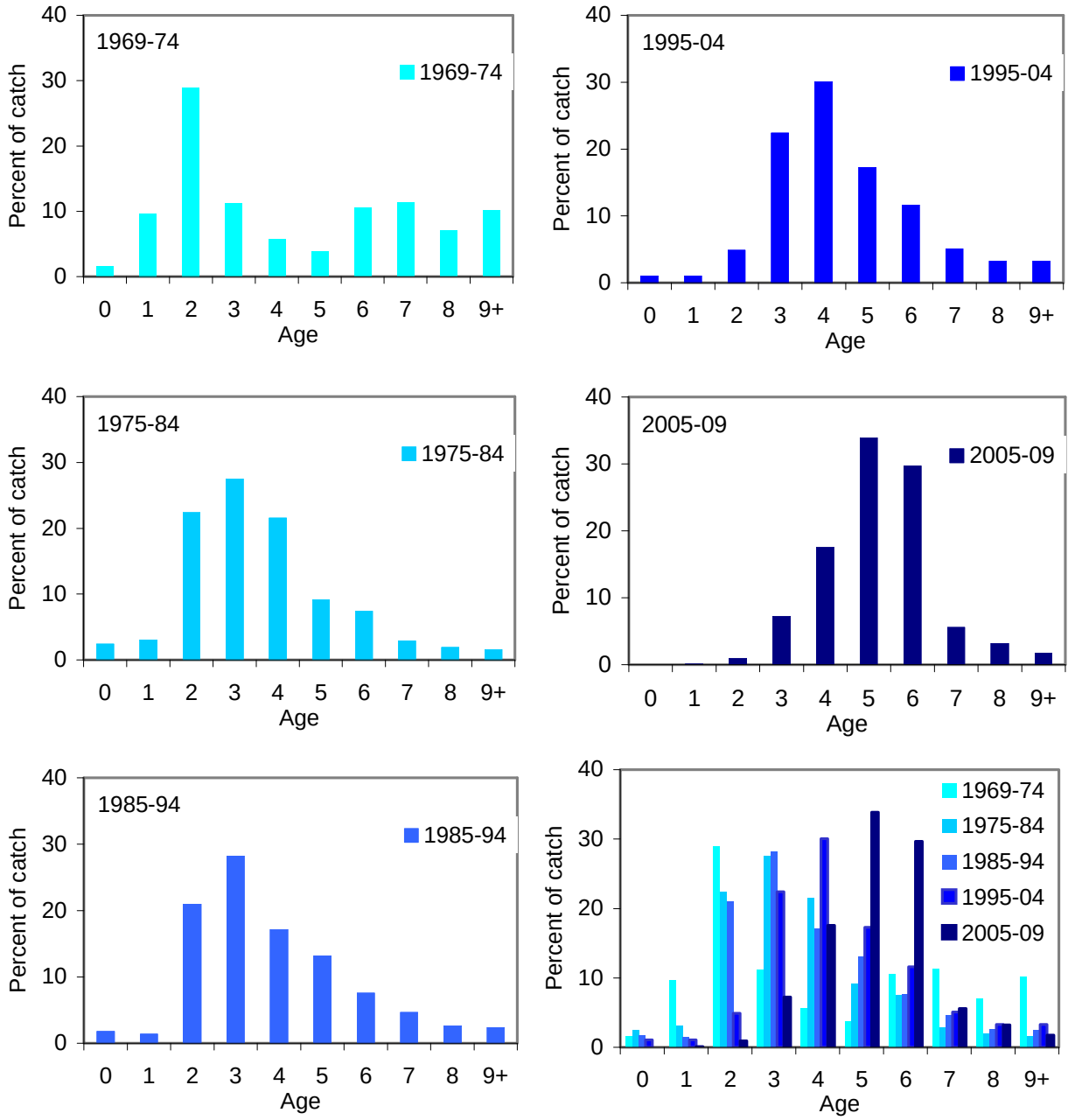


Figure 14. Age composition of the haddock catch for the eastern Georges Bank commercial fishery during 1969-1974, 1975-1984, 1985-1994, 1995-2004, and 2005-2009.

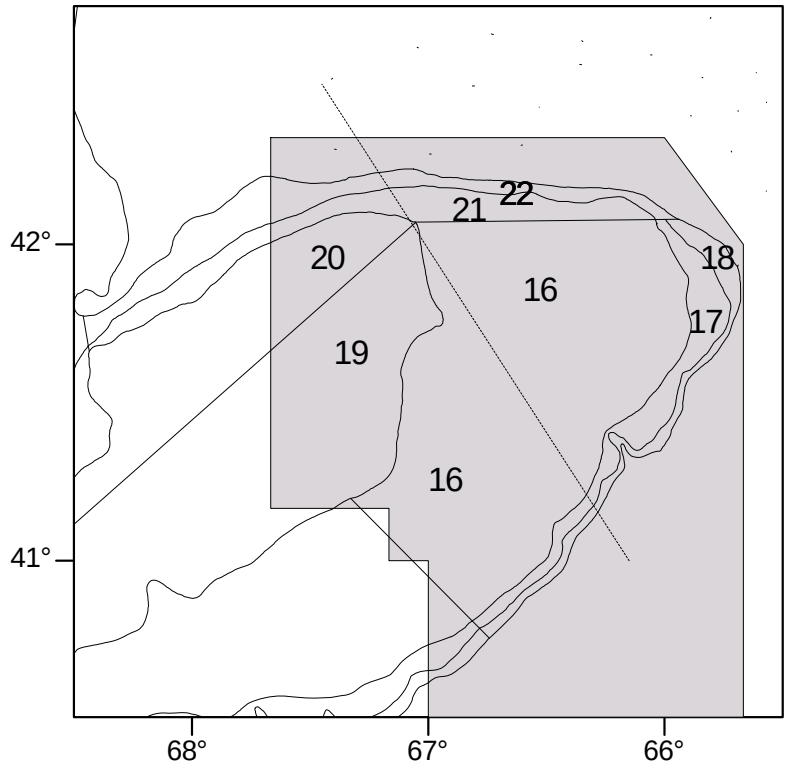


Figure 15. Stratification scheme used for Naional Marine Fisheries Service surveys. The eastern Georges Bank management area is indicated by shading.

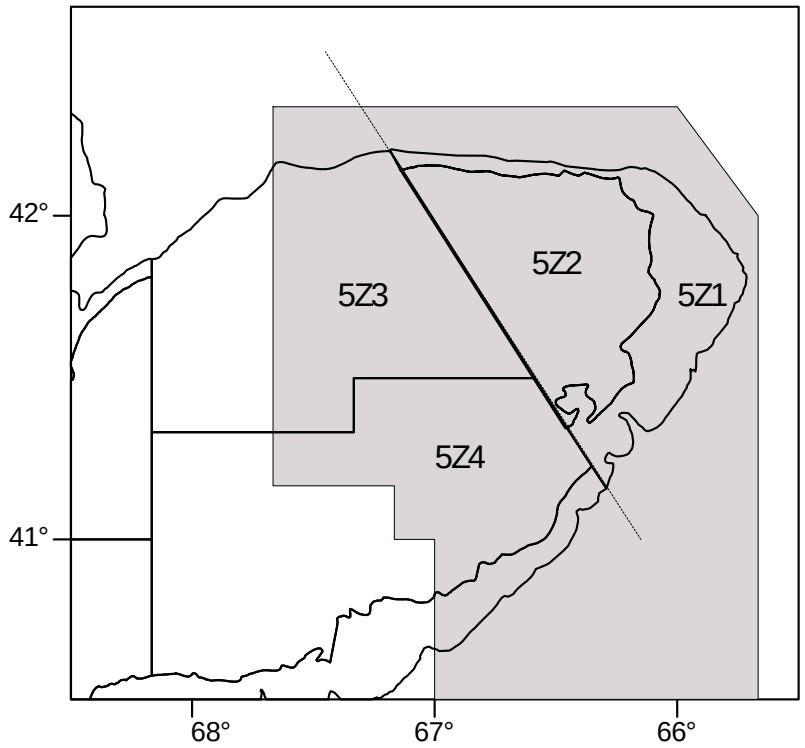


Figure 16. Stratification scheme used for the Caadian Department of Fisheries and Oceans survey. The eastern Georges Bank management area is indicated by shading.

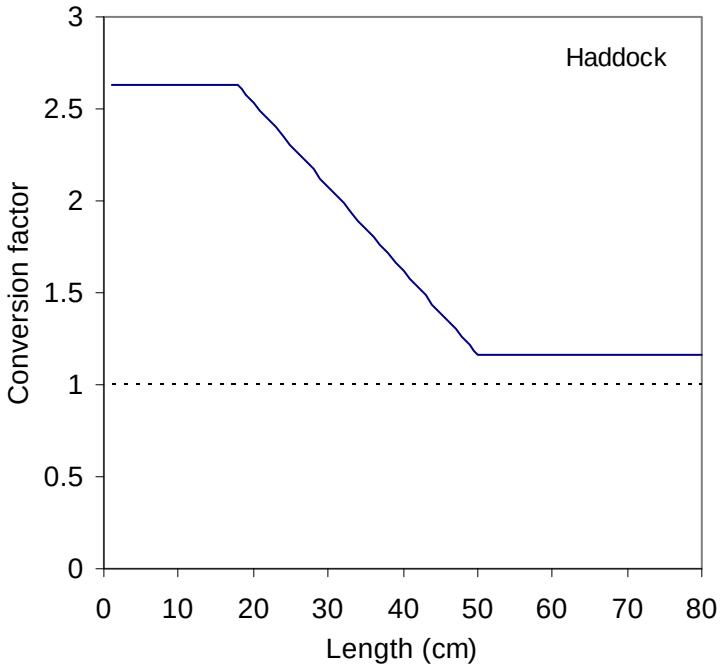


Figure 17. Conversion factors for NMFS surveys conducted by the *Henry B. Bigelow* in 2009 and 2010. Factors are applied by dividing the *Bigelow* catch at length by the length specific conversion factor to make them equivalent to *Albatross IV* catches.

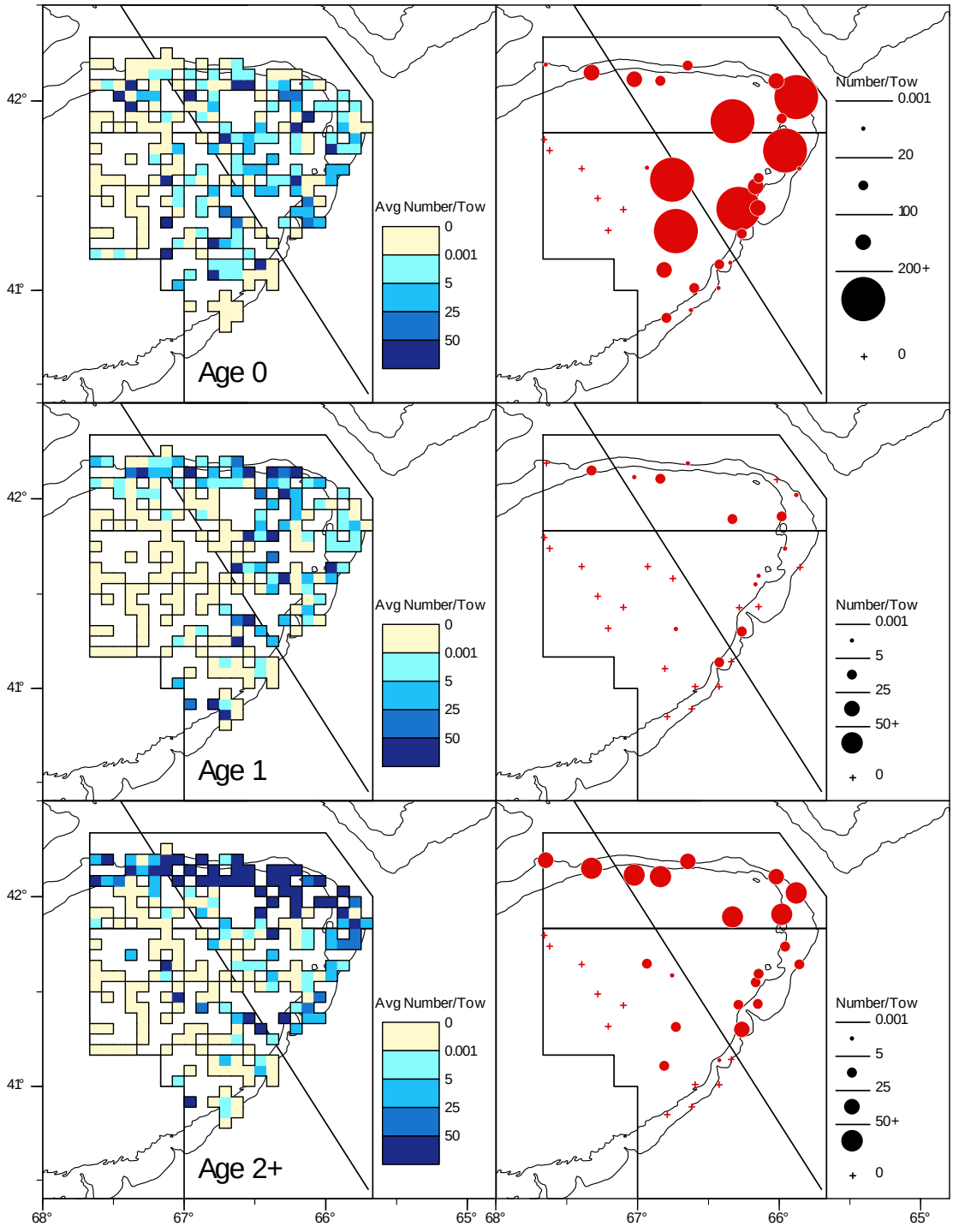


Figure 18. Distribution of eastern Georges Bank haddock abundance (number/tow) as observed from the National Marine Fisheries Service **fall** survey. The squares (left panels) are shaded relative to the average survey catch for 2000 to 2009. The expanding symbols (right panels) represent the **2010** survey catches. Length based conversion coefficients have been applied to the 2009 and 2010 survey to make them comparable to surveys undertaken by the *Albatross IV*.

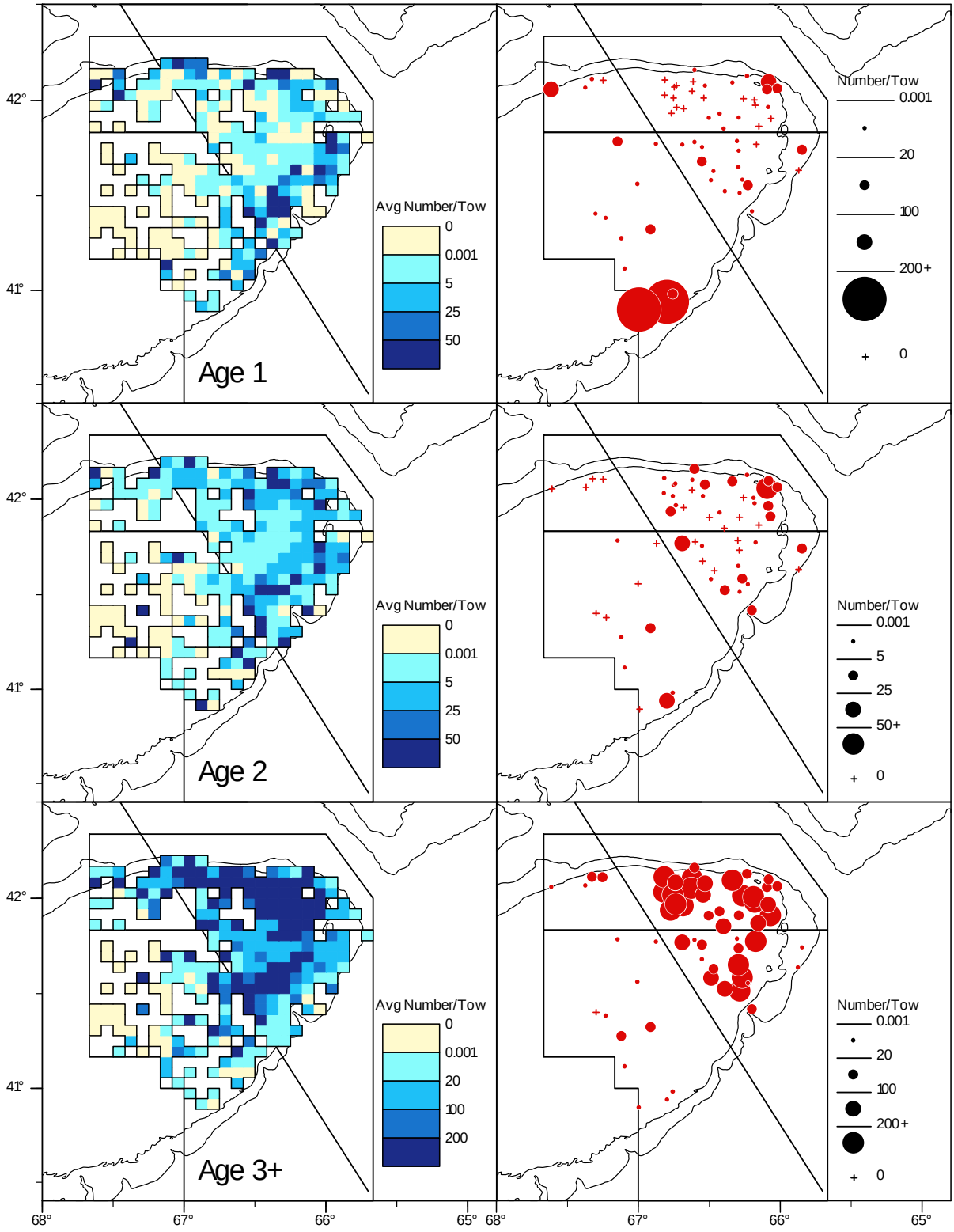


Figure 19. Distribution of eastern Georges Bank haddock abundance (number/tow) as observed from the Canadian Department of Fisheries and Oceans survey. The squares (left panels) are shaded relative to the average survey catch for 2001 to 2010. The expanding symbols (right panels) represent the **2011** survey catches.

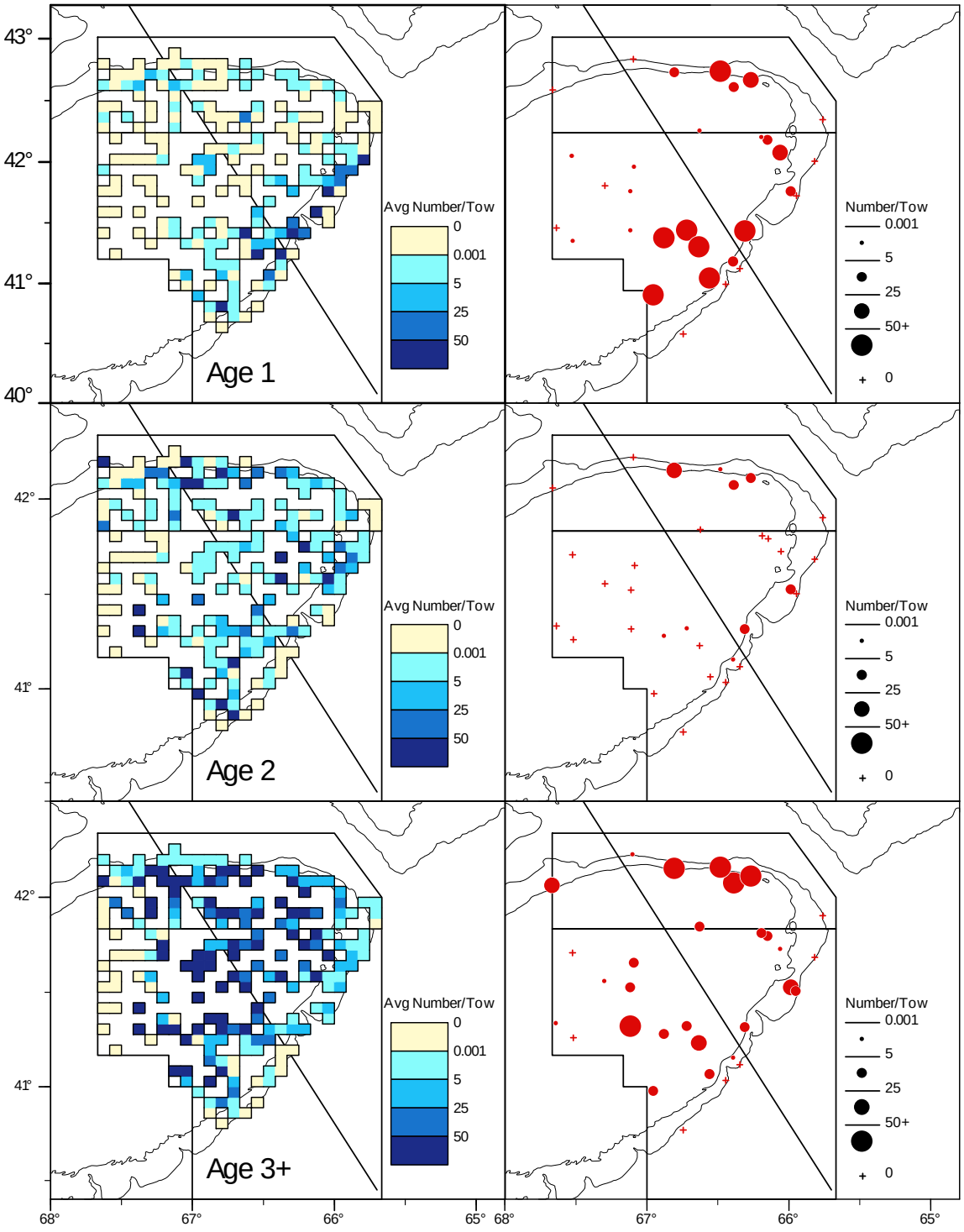


Figure 20. Distribution of eastern Georges Bank haddock abundance (number/tow) as observed from the National Marine Fisheries Service **spring** survey. The squares (left panels) are shaded relative to the average survey catch for 2001 to 2010. The expanding symbols (right panels) represent the **2011** survey catches. Length based conversion coefficients have been applied to the 2009 and 2010 survey to make them comparable to surveys undertaken by the *Albatross IV*.

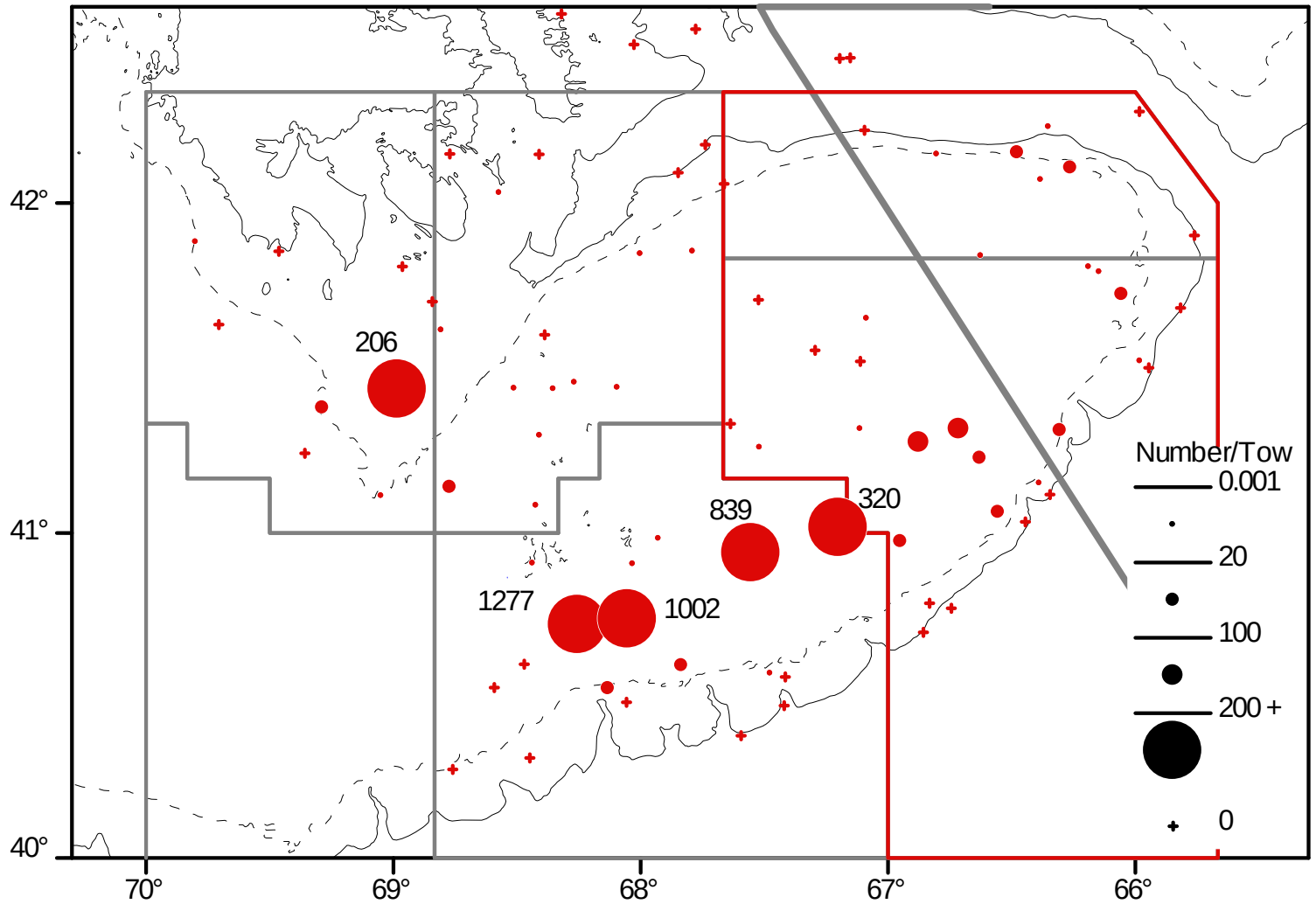


Figure 21. Distribution of the 2010 haddock year class on Georges Bank at age 1 (number/tow) as observed from the 2011 National Marine Fisheries Service **spring** survey. Length based conversion coefficients have been applied to make numbers/tow comparable to surveys undertaken by the *Albatross IV*. The numbers per tow are indicated beside five large sets west of the eastern Georges Bank management area (indicated in red).

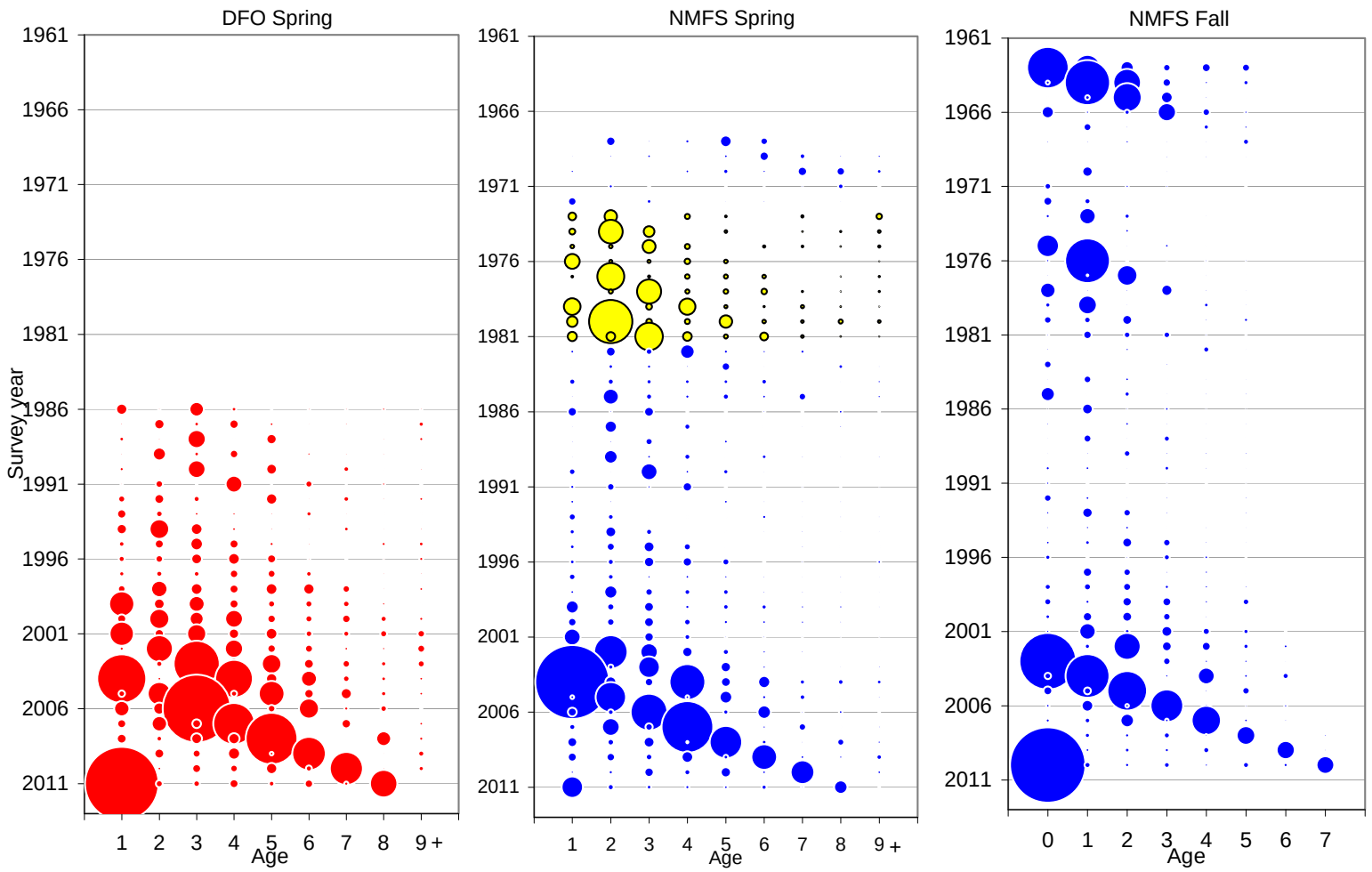


Figure 22. Estimated abundance at age (numbers in 000's) of eastern Georges Bank haddock for the Canadian Department of Fisheries and Oceans (DFO) for 1986 to 2011, the National Marine Fisheries Service (NMFS) spring survey for 1968 to 2011 and the NMFS fall survey for 1963 to 2010. Bubble area is proportional to magnitude (see Tables 14-16). 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. Symbol size has not been adjusted between surveys for the catchability of the survey.

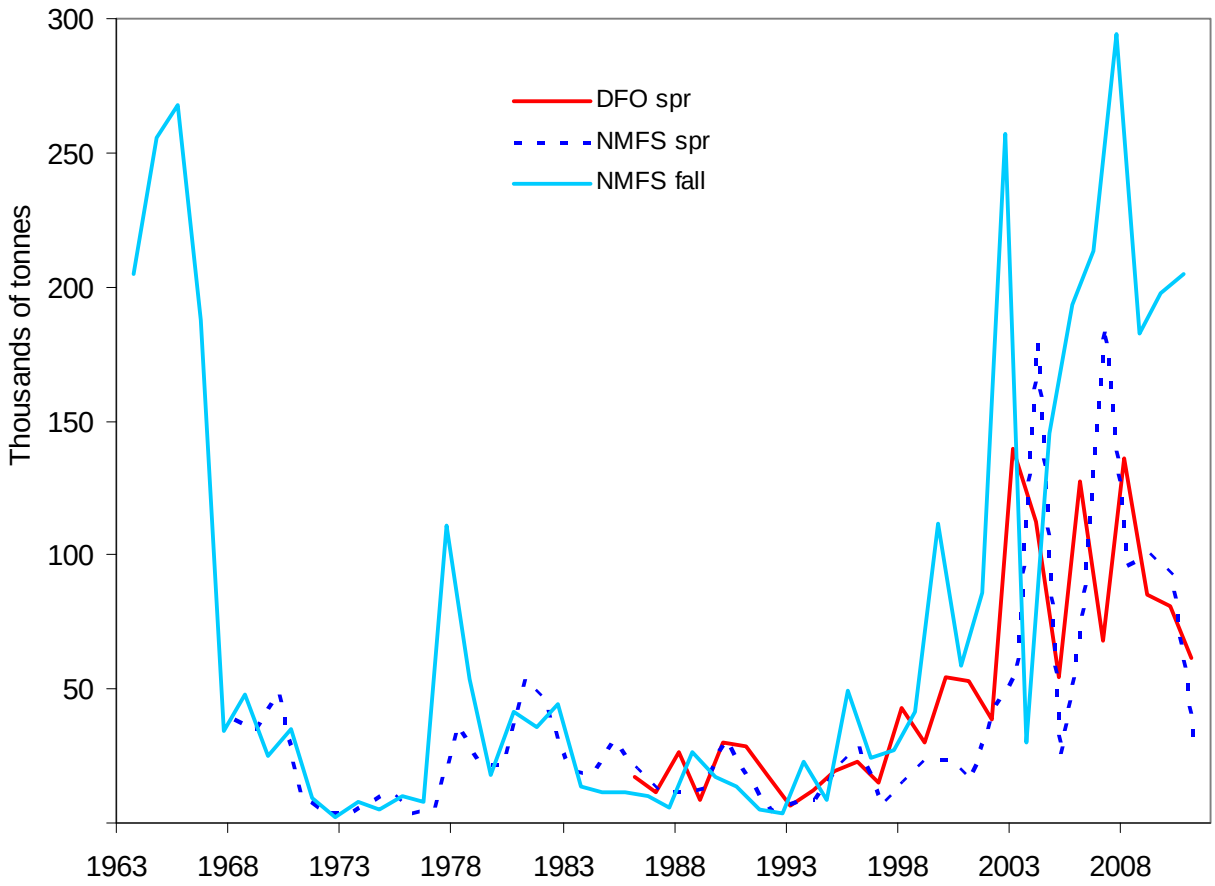


Figure 23. Biomass from National Marine Fisheries Service (NMFS) fall (ages 2-8), NMFS spring (ages 3-8) and Canadian Department of Fisheries and Oceans (DFO) (ages 3-8) research surveys for eastern Georges Bank haddock during 1963-2010, 1968-2011, 1986-2011, respectively (scaled by calibration constants).

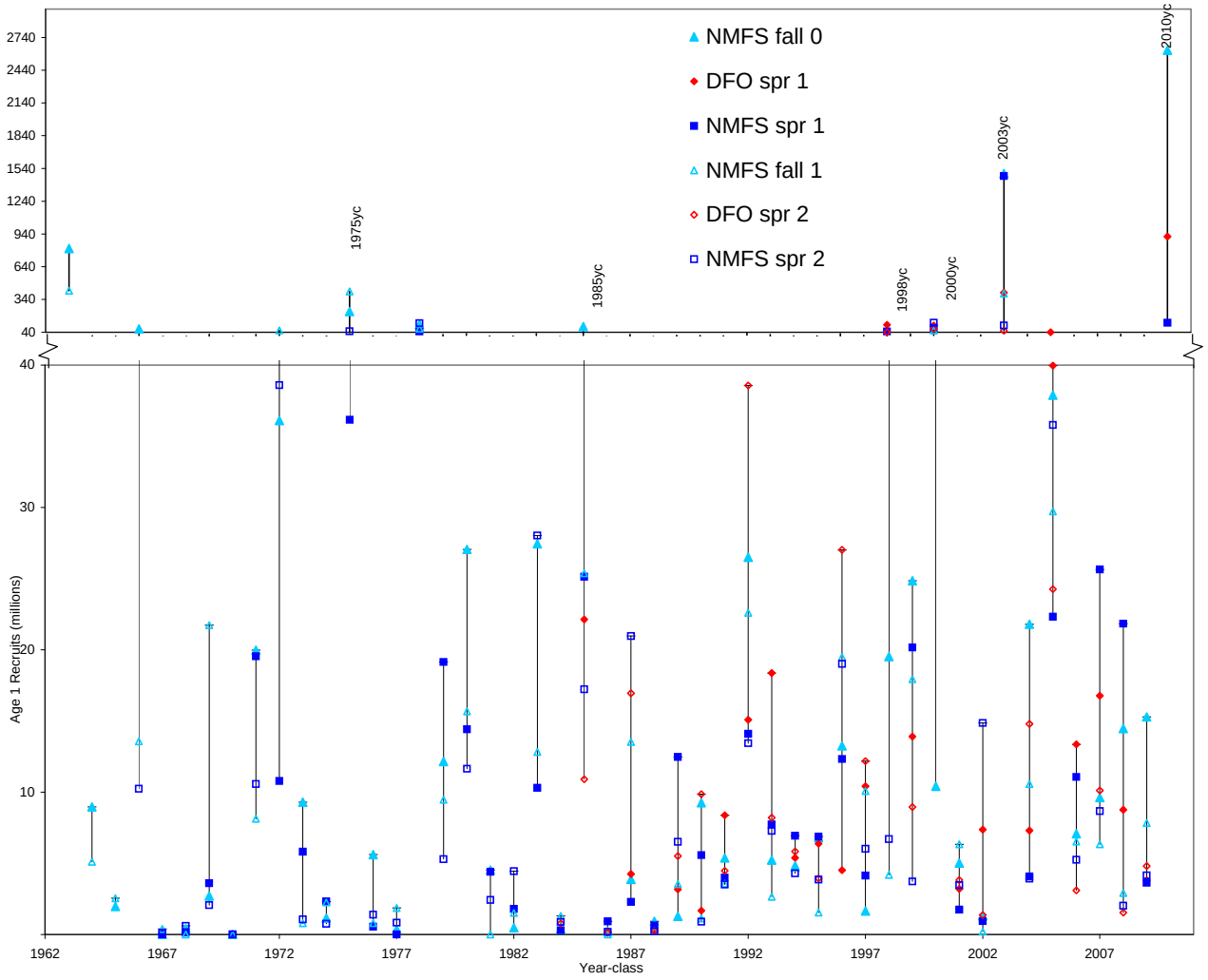


Figure 24. Year-class abundance for ages 0 and 1 from the National Marine Fisheries Service (NMFS) fall survey for 1963-2010 and ages 1 and 2 from the NMFS spring survey for 1968-2011 and the Canadian Department of Fisheries and Oceans (DFO) research survey for 1986-2011 (scaled by calibration constants) for eastern Georges Bank haddock.

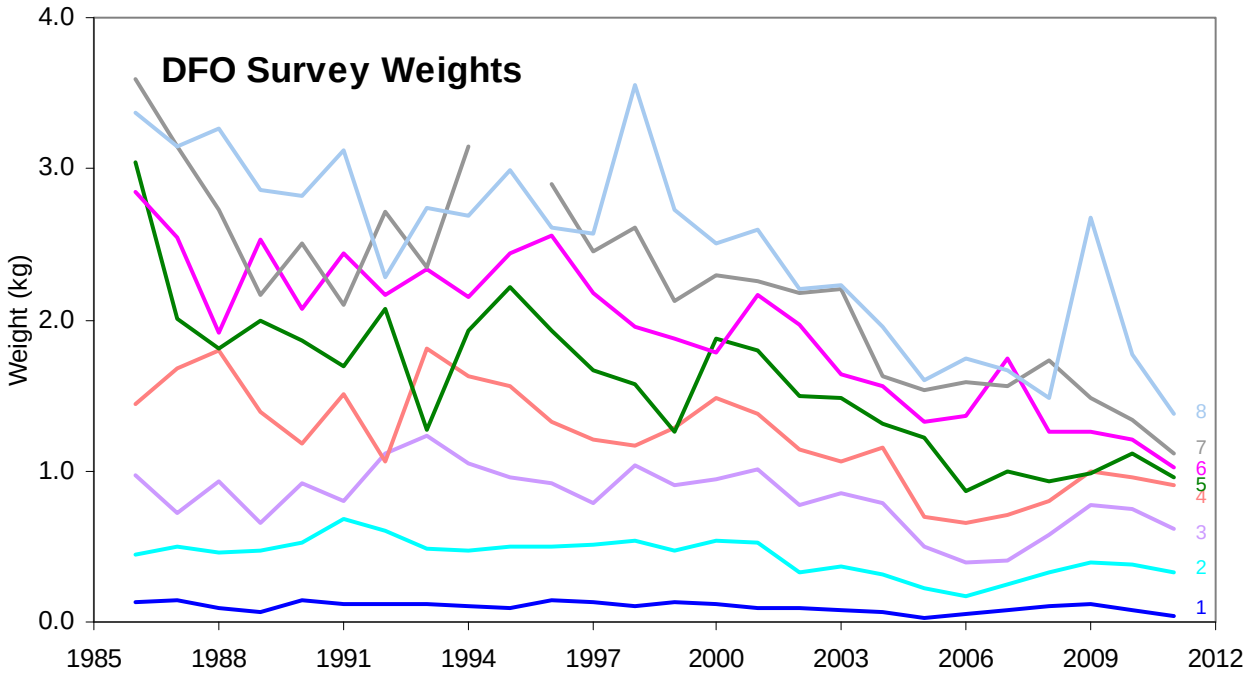


Figure 25. Average weights at age for eastern Georges Bank haddock derived from the Canadian Department of Fisheries and Oceans survey during 1986-2011.

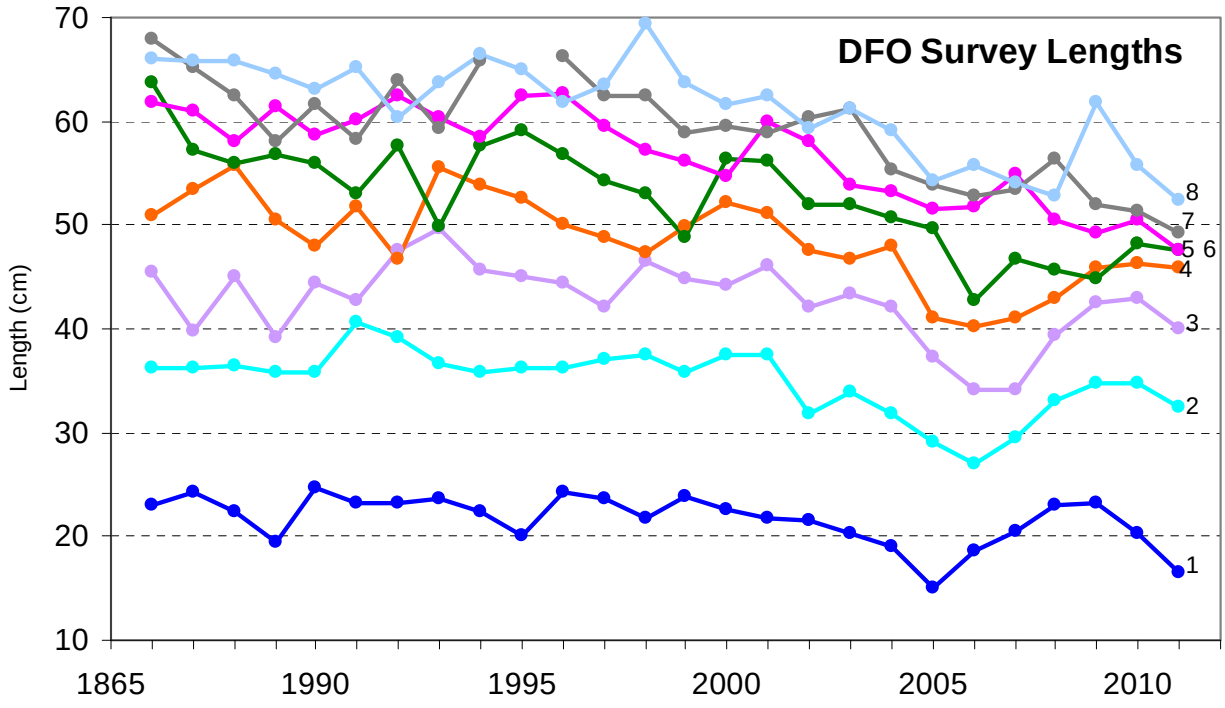


Figure 26. Average lengths at age for eastern Georges Bank haddock derived from Canadian Department of Fisheries and Oceans surveys during 1986-2011.

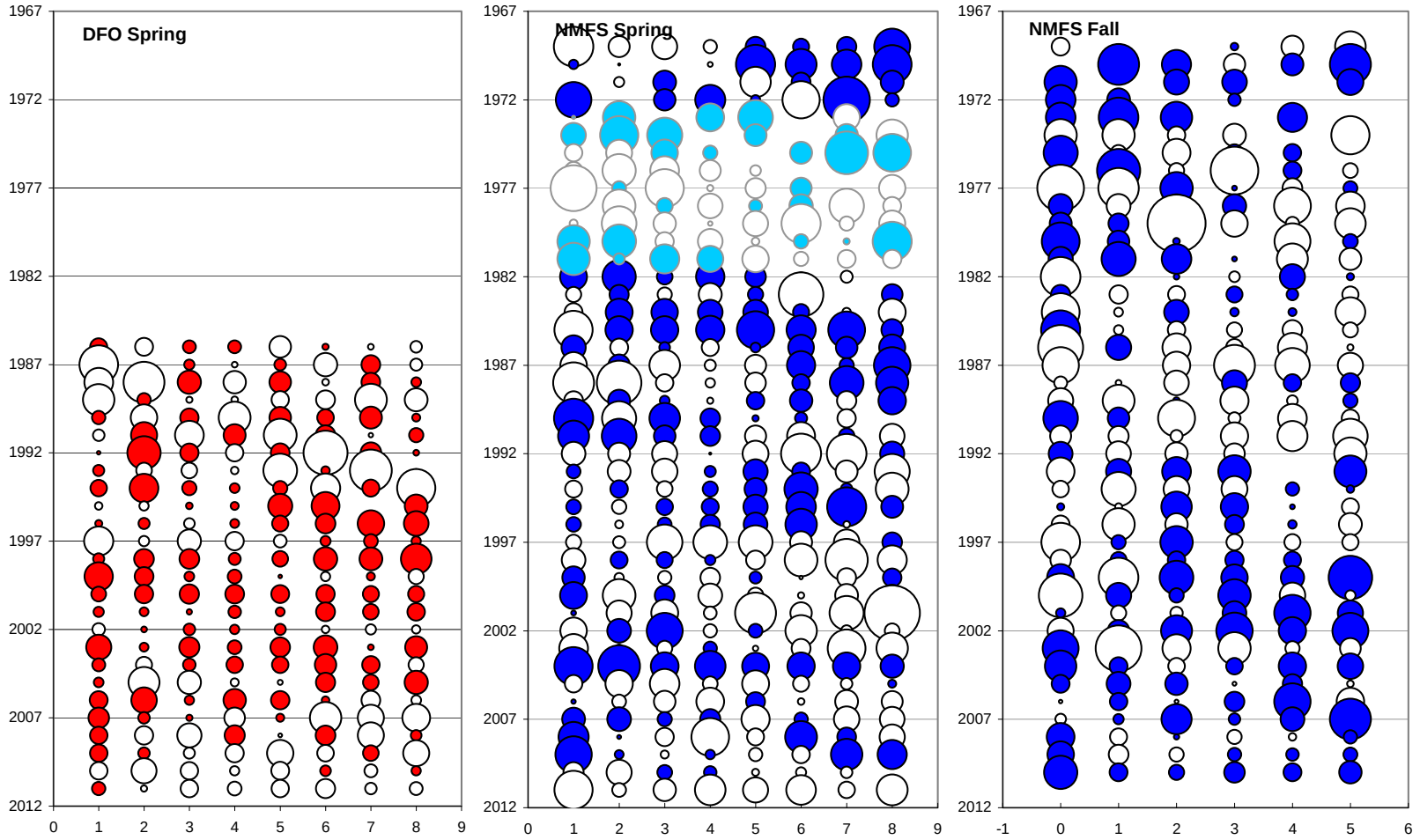


Figure 27. Residuals of survey abundance indices by year and age group from the Canadian Department of Fisheries and Oceans (DFO) research survey 1986 to 2011 and the National Marine Fisheries Service (NMFS) spring and autumn research surveys during 1969-2010 for eastern Georges Bank haddock. Solid symbols indicate positive values, open symbols indicate negative values. Bubble area is proportional to magnitude. From 1973-81 (light blue circles), a 41 Yankee trawl was used for the NMFS spring survey while a 36 Yankee was used in the other years.

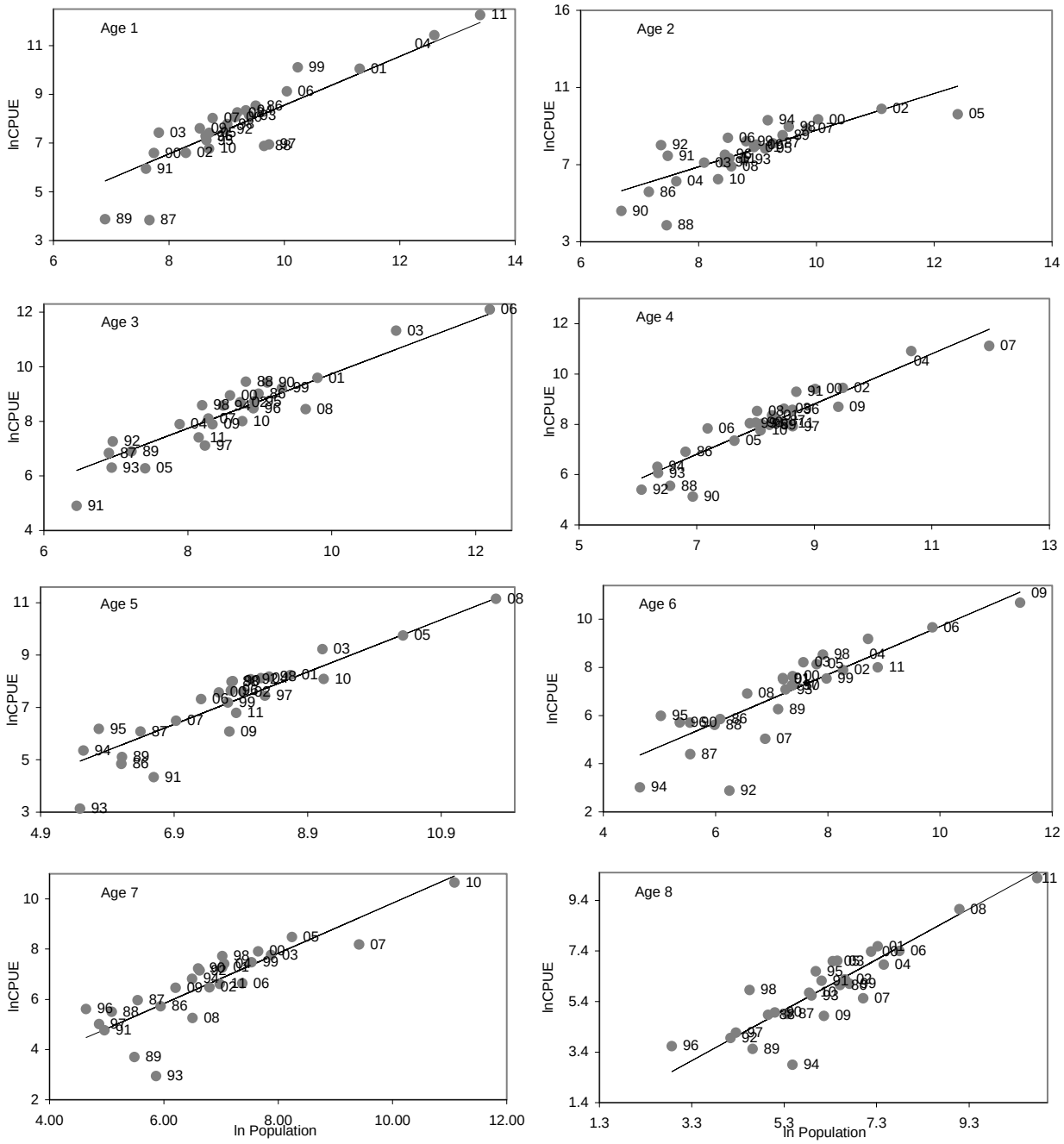


Figure 28. Age by age plots of the observed and predicted ln abundance index versus ln population numbers for eastern Georges Bank haddock from the Department of Fisheries and Oceans survey during 1986-2011.

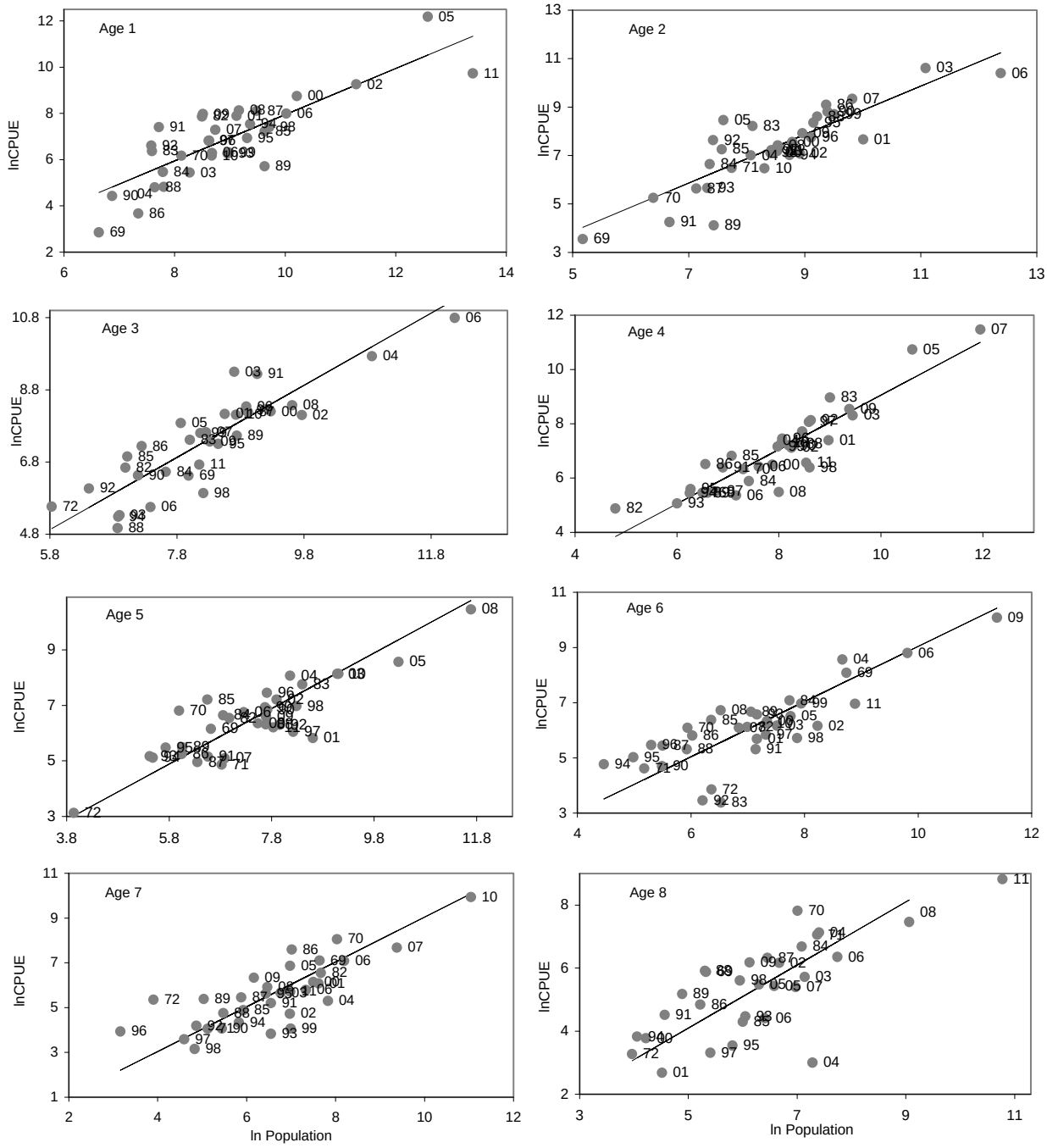


Figure 29. Age by age plots of the observed and predicted ln abundance index versus ln population numbers for eastern Georges Bank haddock from the National Marine Fisheries Service **spring** survey with a Yankee 36 net during 1969-1972 and 1982-2011.

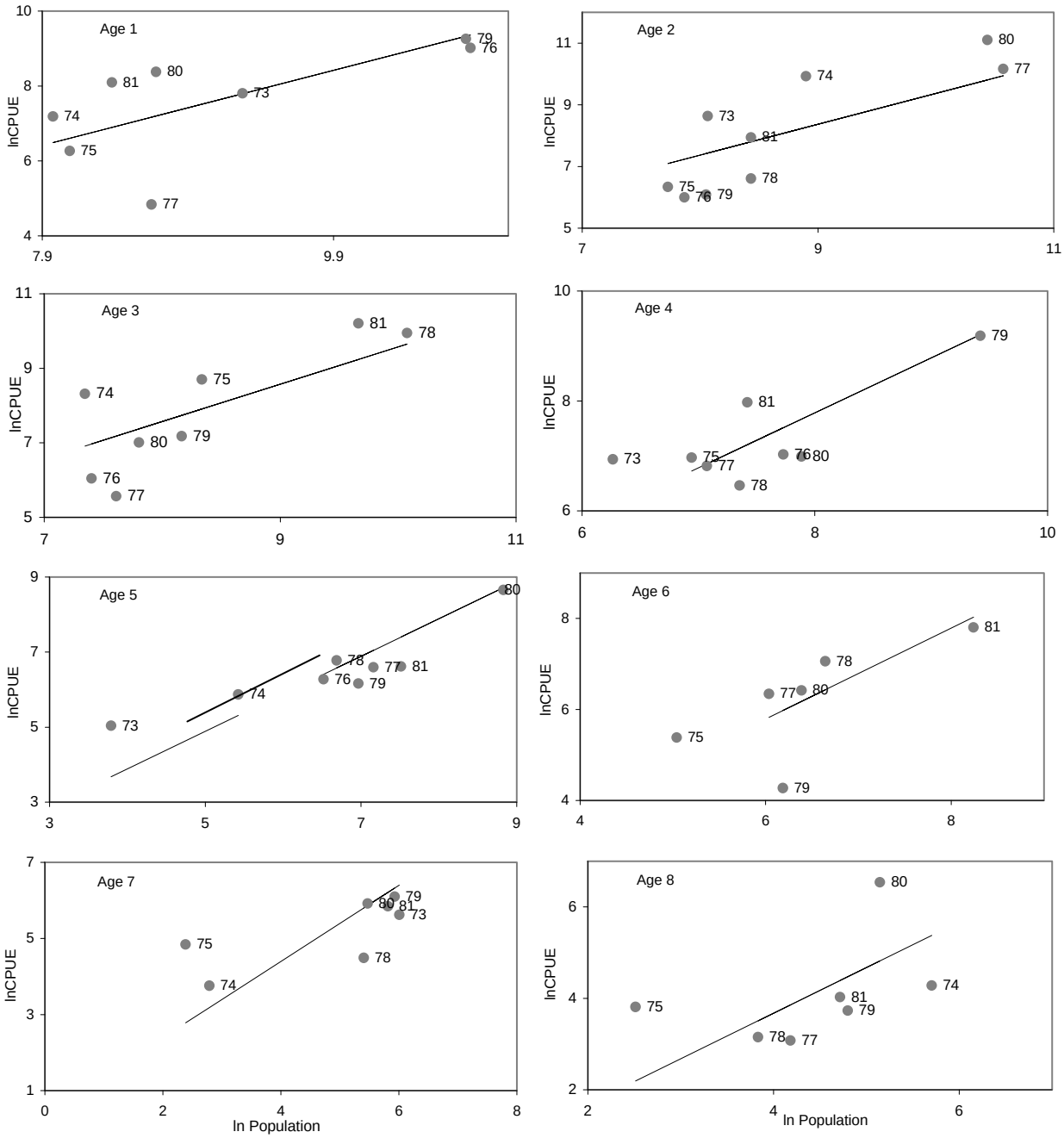


Figure 30. Age by age plots of the observed and predicted ln abundance index versus ln population numbers for eastern Georges Bank haddock from the National Marine Fisheries Service **spring** survey with a Yankee 41 net during 1973-1981.

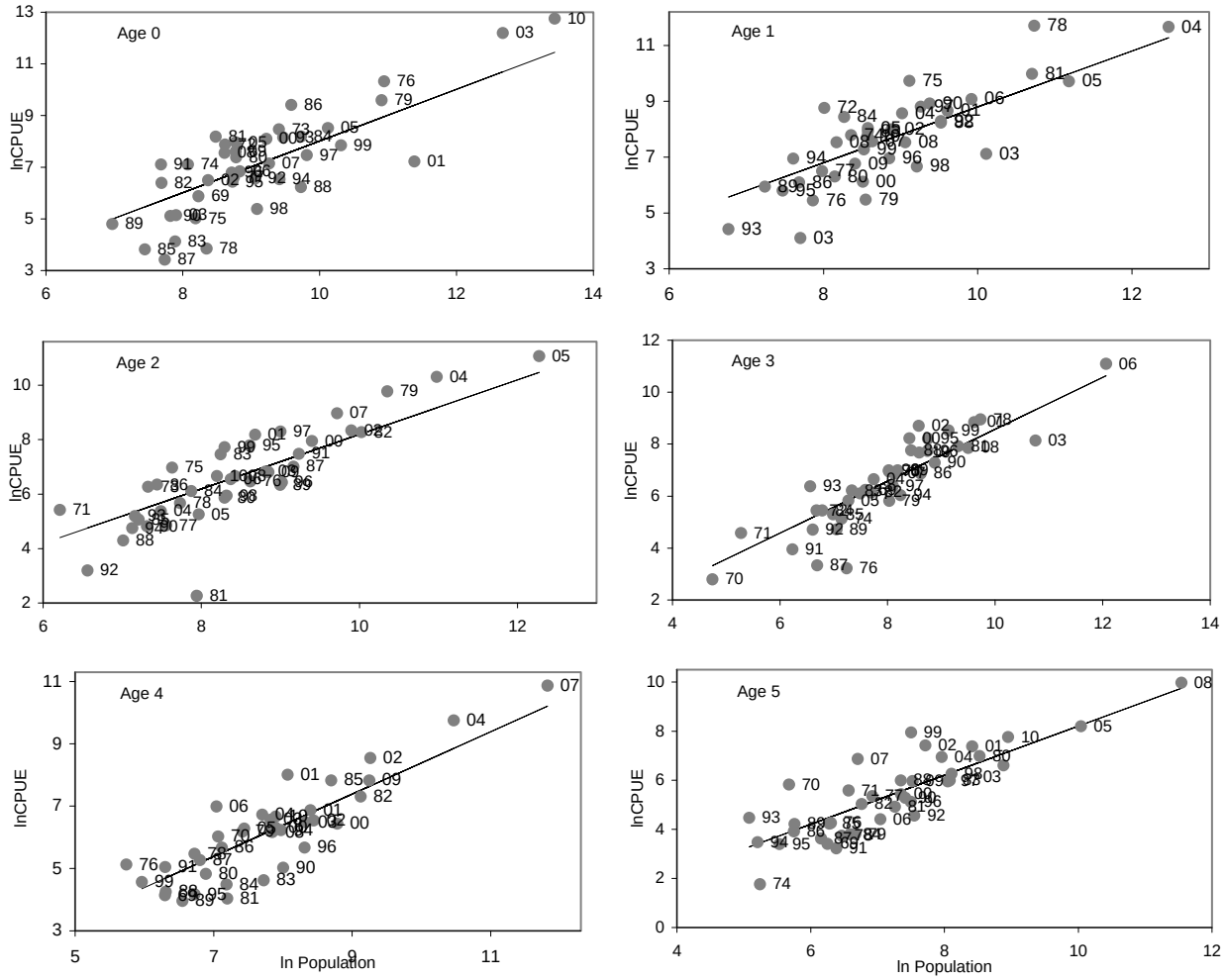


Figure 31. Age by age plots of the observed and predicted ln abundance index versus ln population numbers for eastern Georges Bank haddock from the National Marine Fisheries Service **fall** survey 1969-2010.

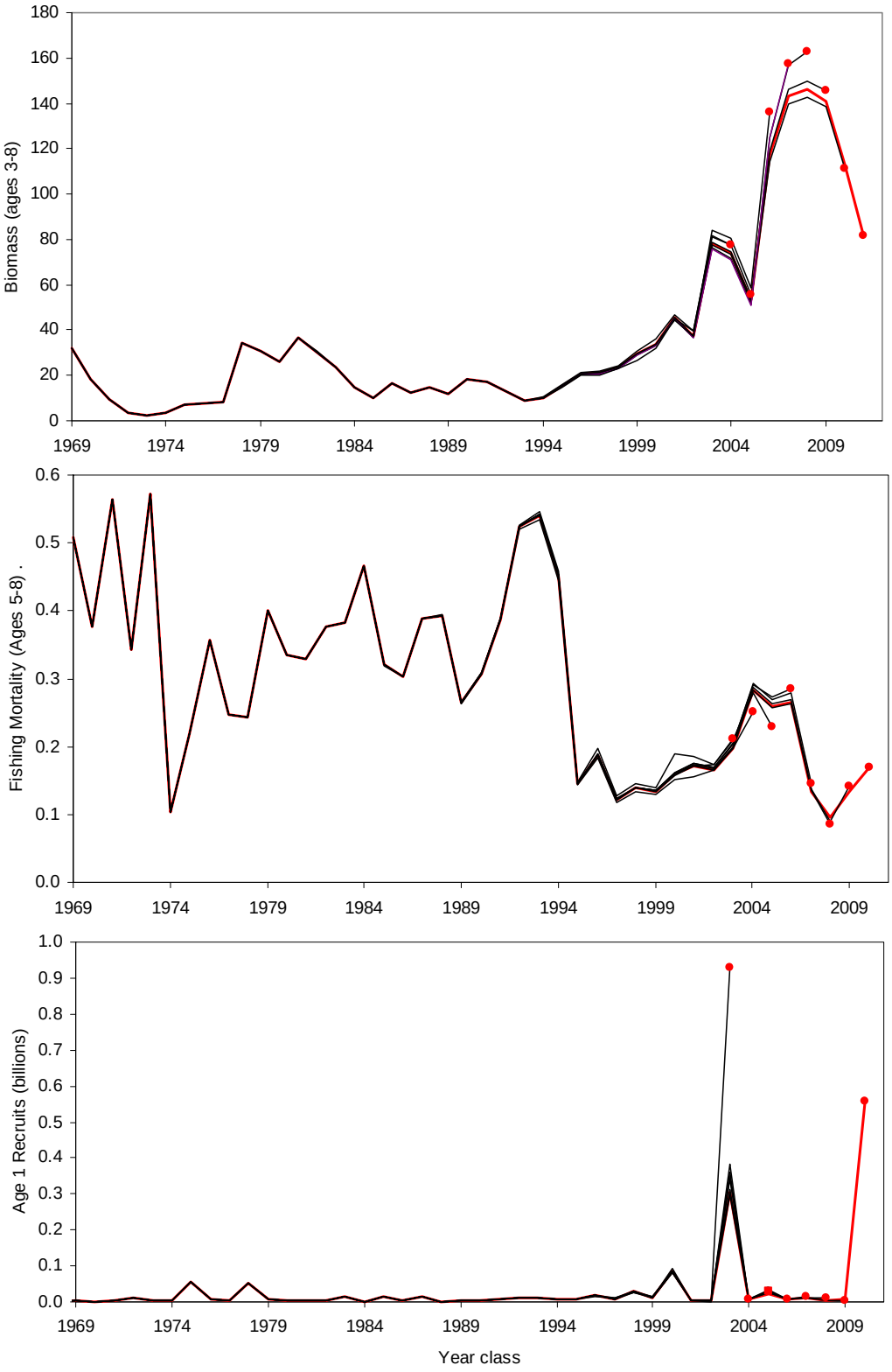


Figure 32. Retrospective results from virtual population analysis of eastern Georges Bank haddock for biomass (ages 3-8), fishing mortality (ages 5-8) and recruits (age 1) as successive years of data are excluded in the assessment.

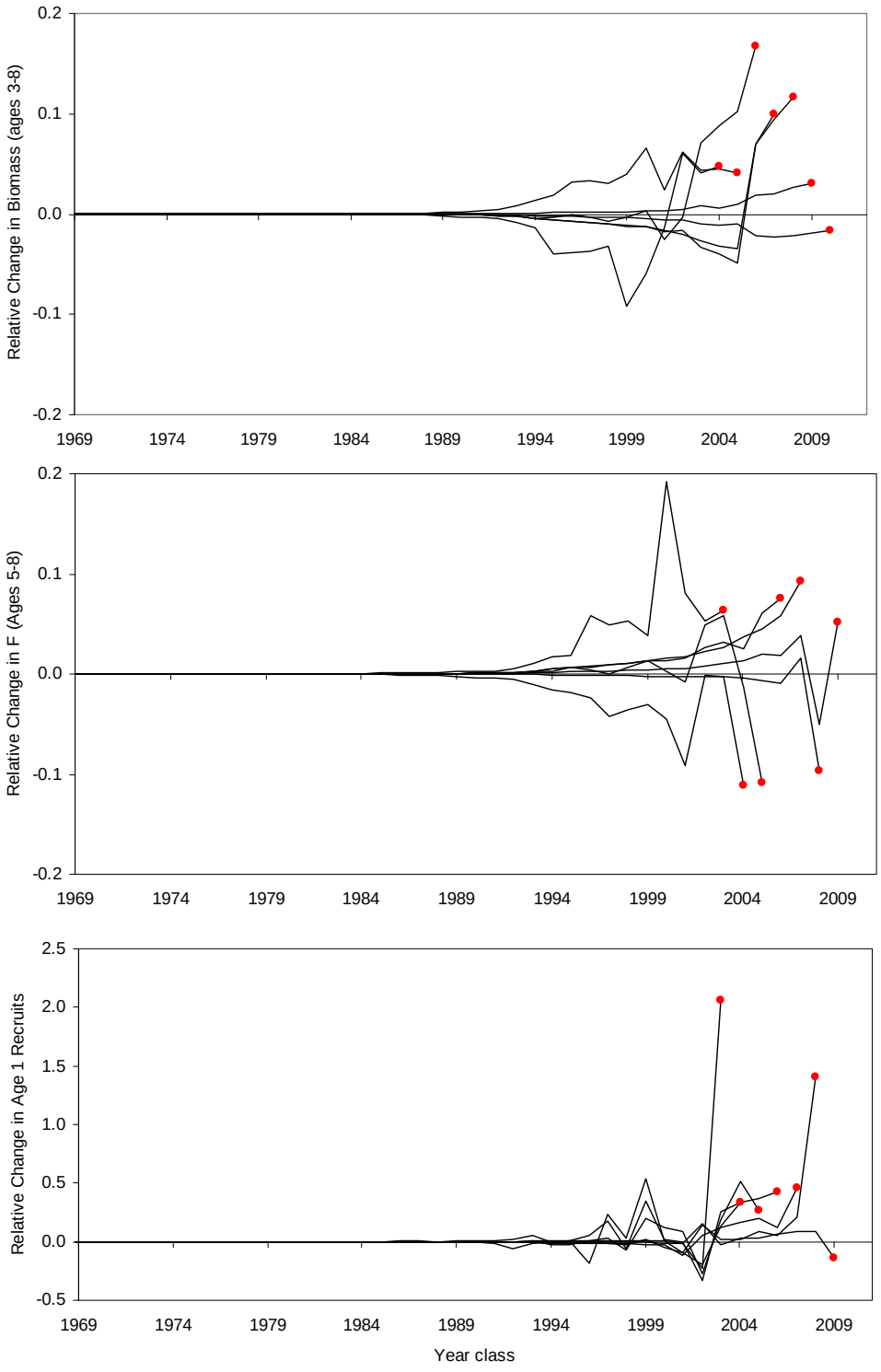


Figure 33. Relative retrospective results from virtual population analysis of eastern Georges Bank haddock for biomass (ages 3-8), fishing mortality (ages 5-8) and recruits (age 1) as successive years of data are excluded in the assessment.

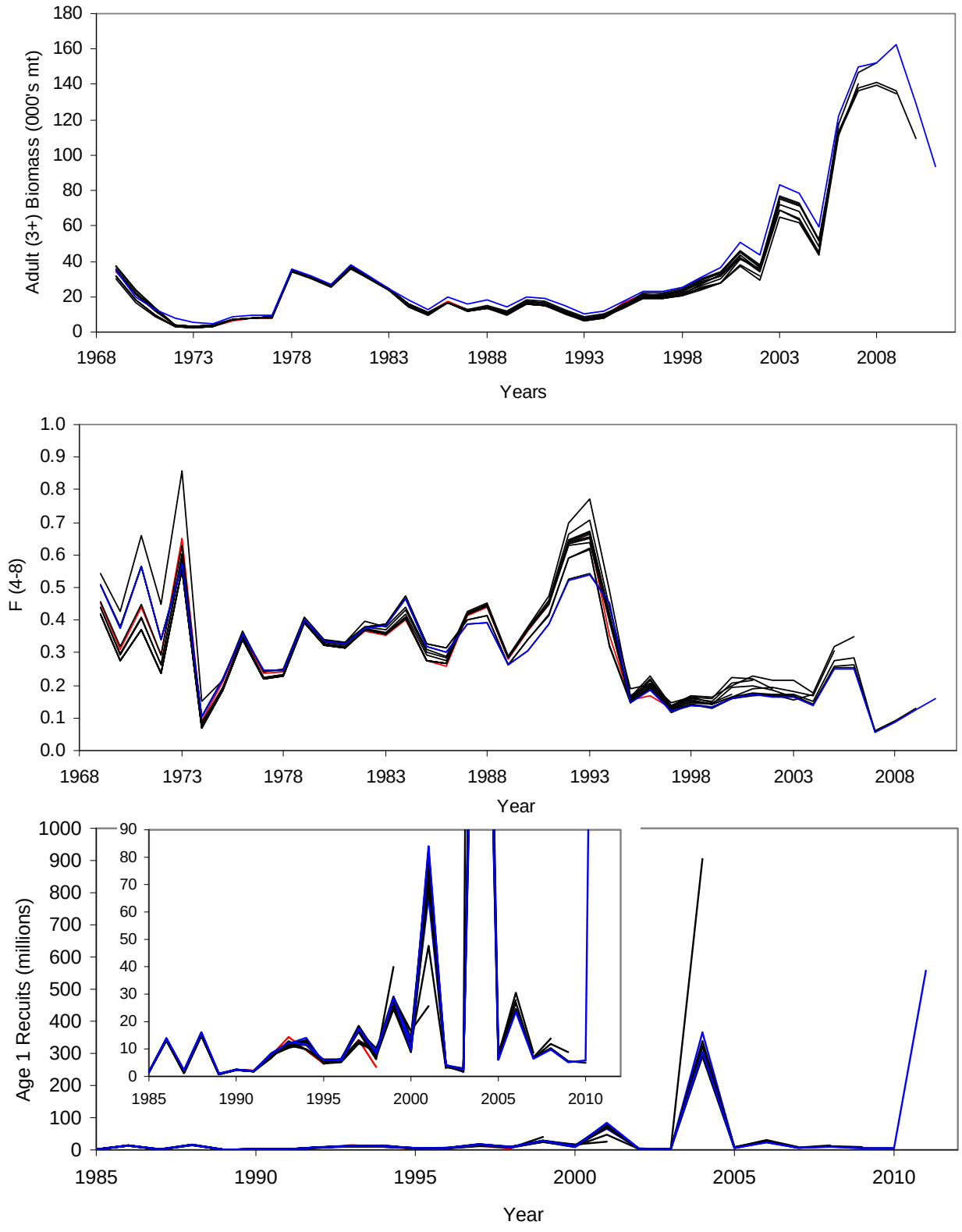


Figure 34. Historical retrospective analysis of the 1998 to 2011 eastern Georges Bank haddock assessments for 1969 to 2011 3+ biomass (top panel) and age 4-8 fishing mortality (middle panel) and 1985 to 2011 age 1 recruitment (lower panel). The insert in the lower panel expands the lower recruitment axis. The 1998 benchmark assessment is indicated in red.

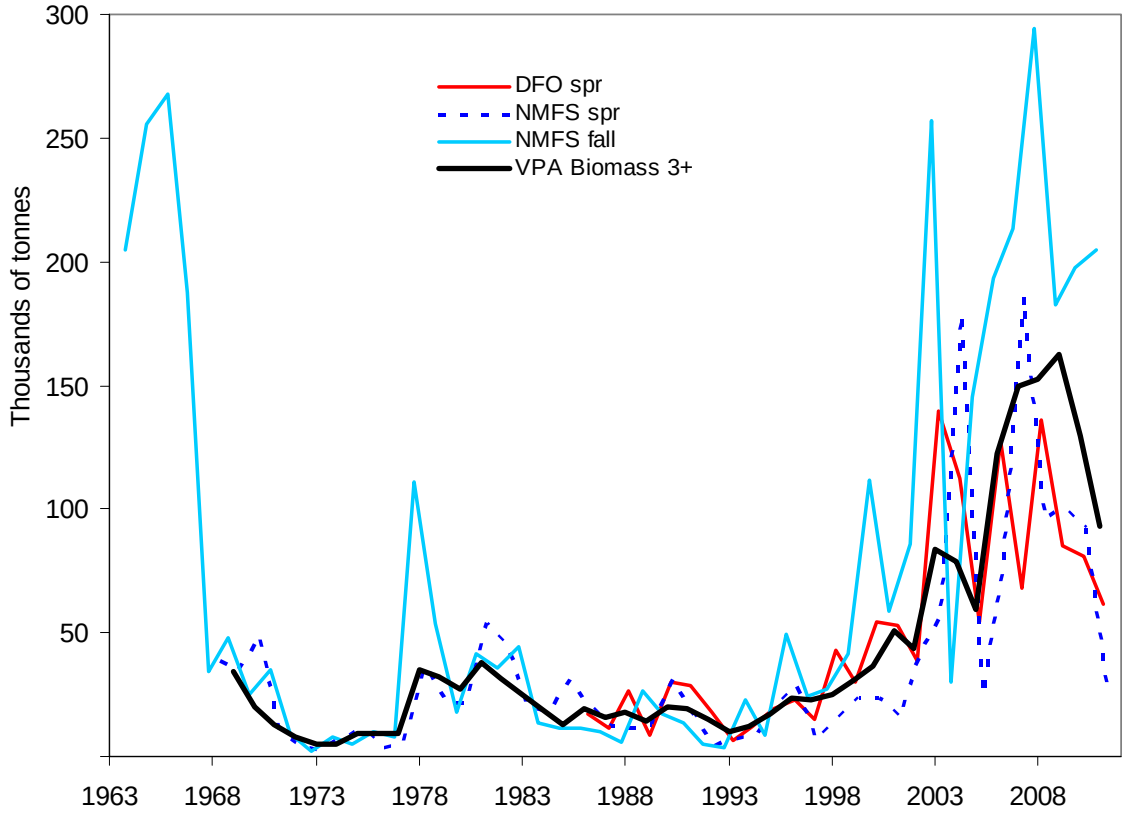


Figure 35. The eastern Georges Bank adult haddock (ages 3+) biomass trend from virtual population analysis compared with the survey adult biomass (scaled with catchabilities) trends.

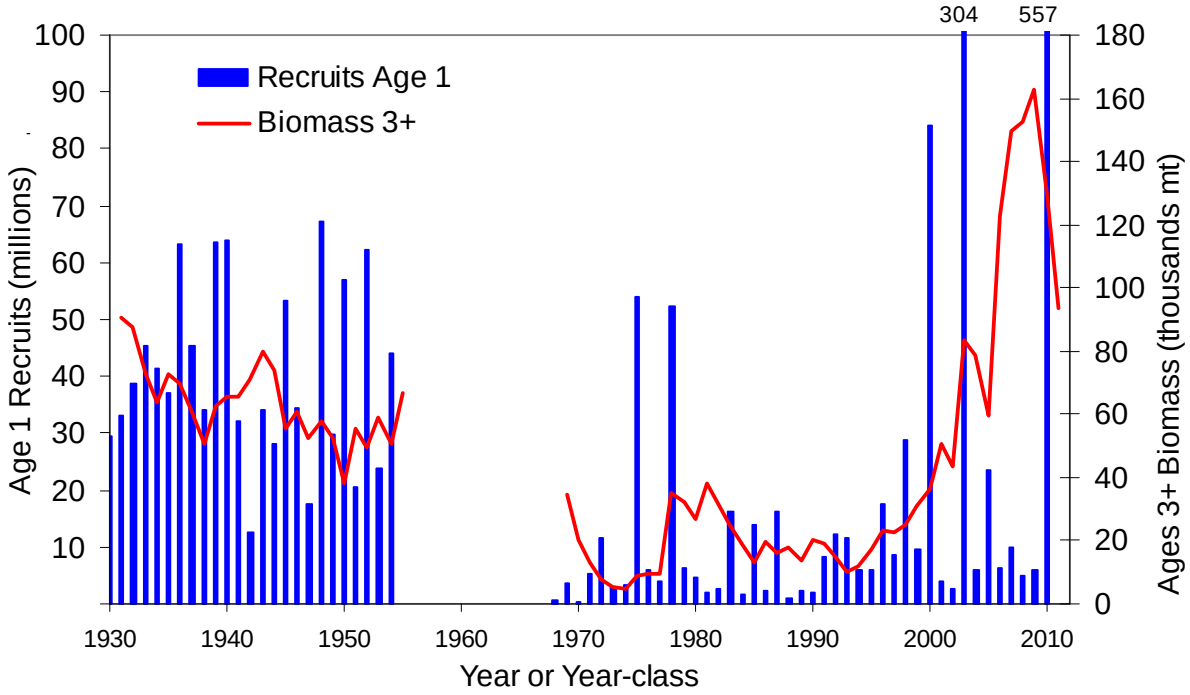


Figure 36. Beginning of year adult (3+) biomass and number of age 1 recruits for eastern Georges Bank haddock during 1931-1955 and 1969-2011.

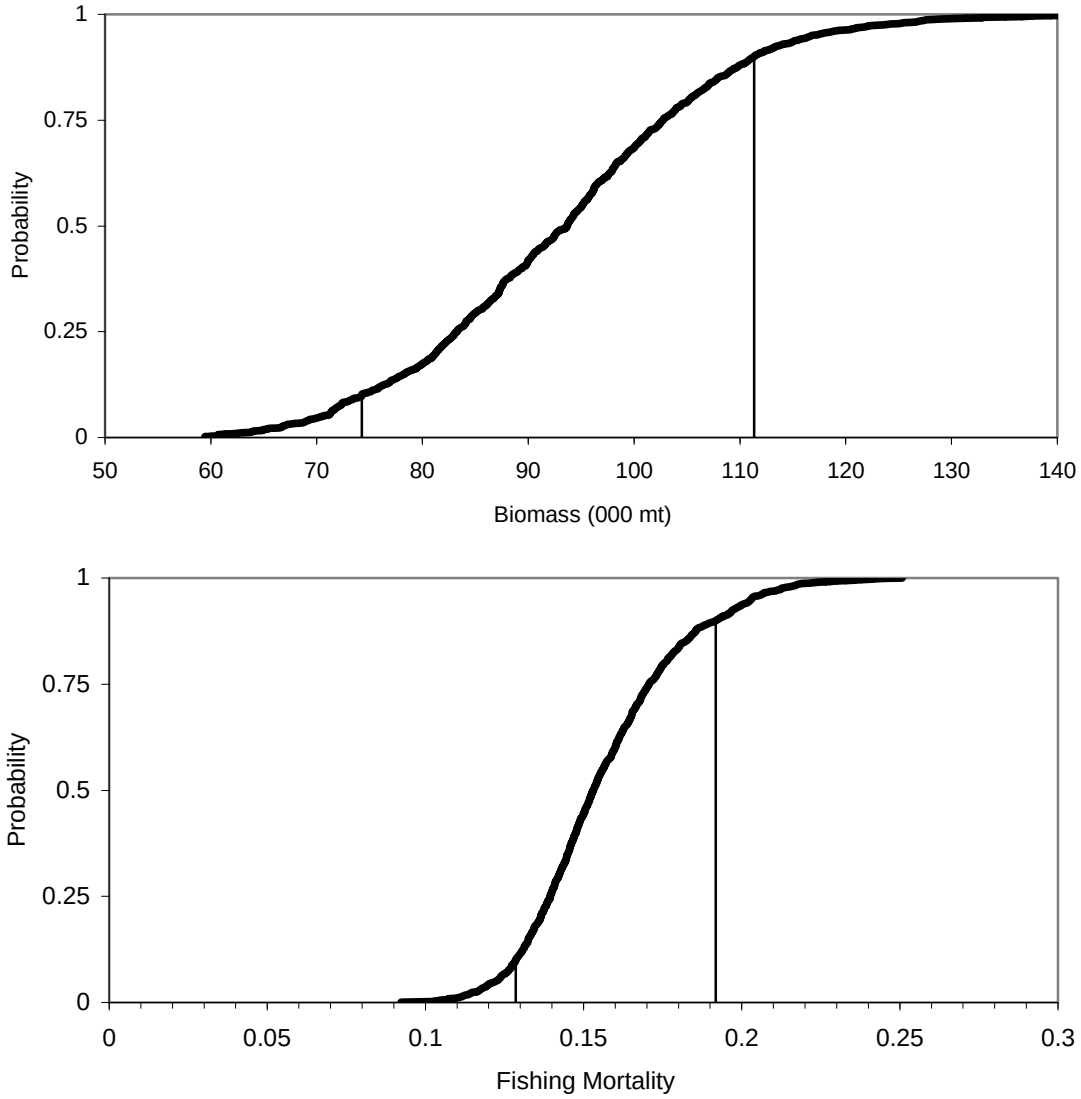


Figure 37. Cumulative probability distribution with 80% confidence intervals for 2011 age 3+ biomass (000 mt) and 2010 age 5+ fishing mortality for eastern Georges Bank haddock.

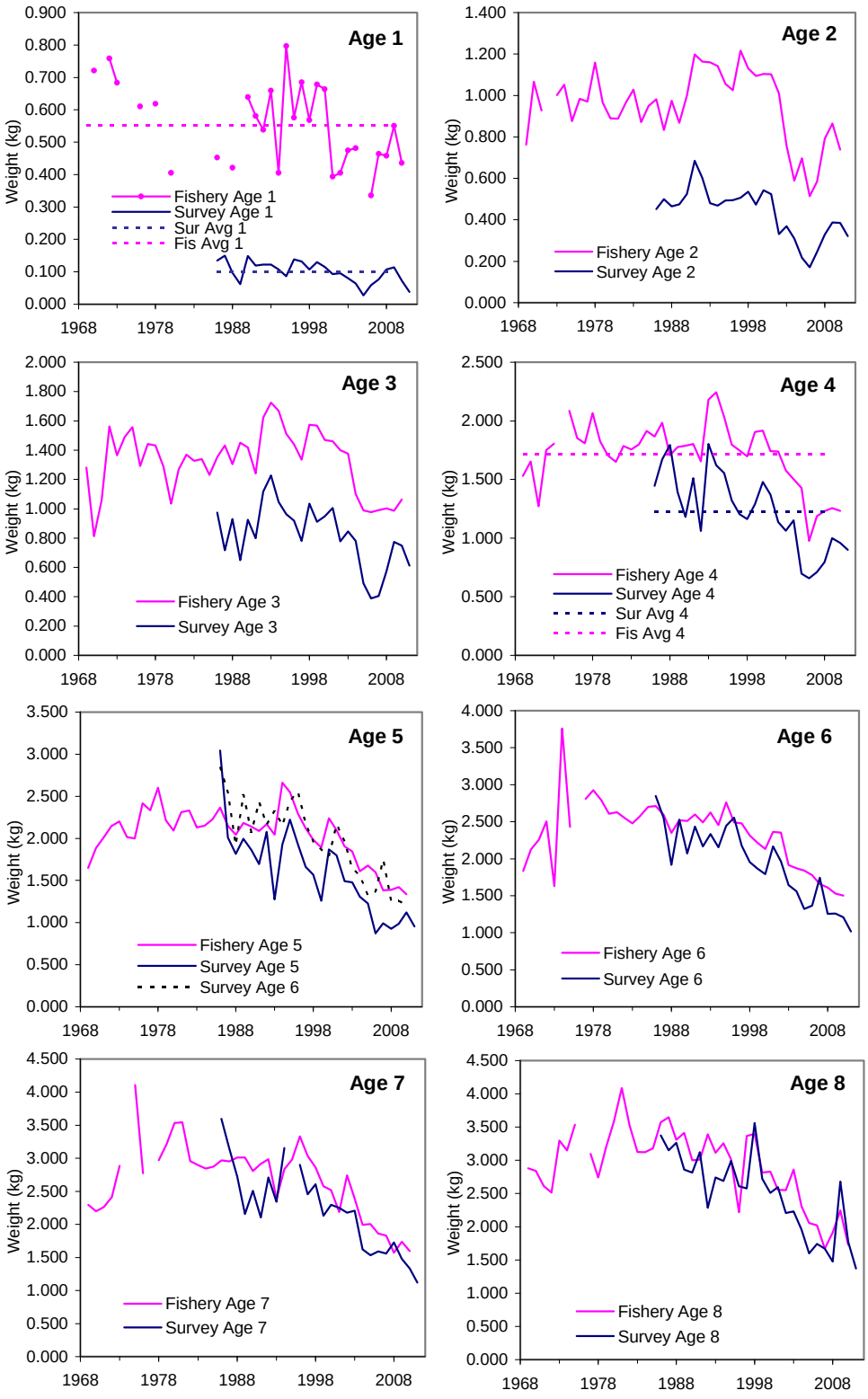


Figure 38. Average weights at age for eastern Georges Bank haddock from the Canadian commercial groundfish fishery during 1969-2010 and from the Canadian Department of Fisheries and Oceans survey during 1986-2011.

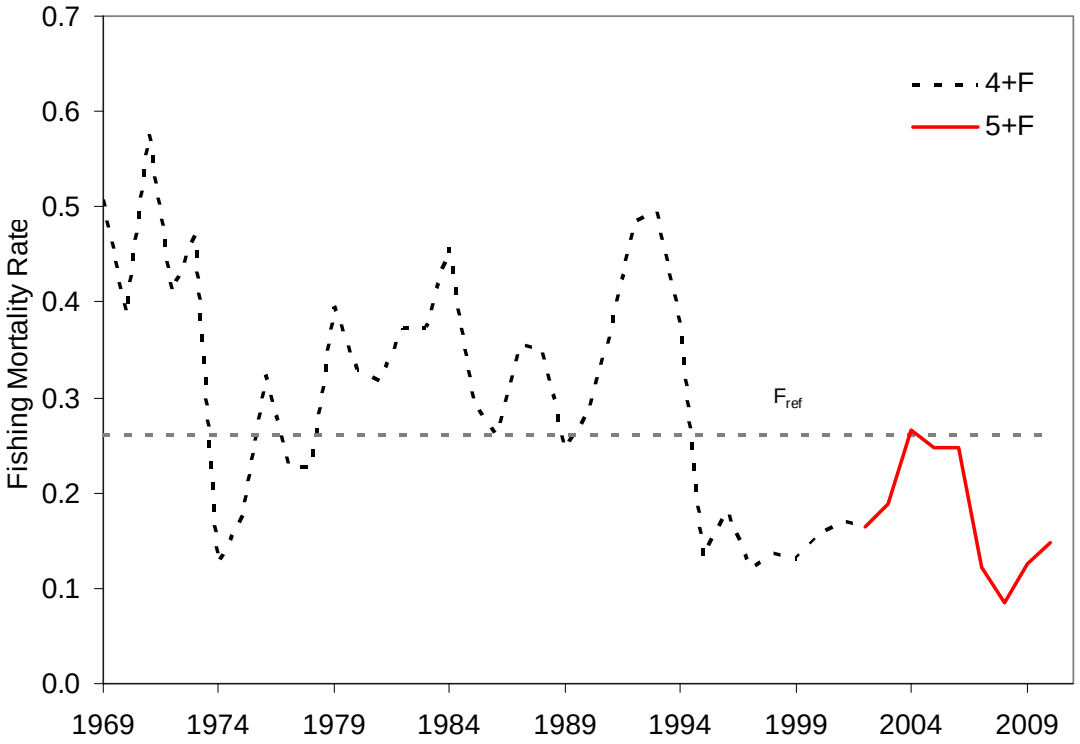


Figure 39. Fishing mortality rate (weighted by population) for eastern Georges Bank haddock ages 4+ and 5+ during 1969-2010 and the fishing mortality threshold reference established at F_{ref} = 0.26.

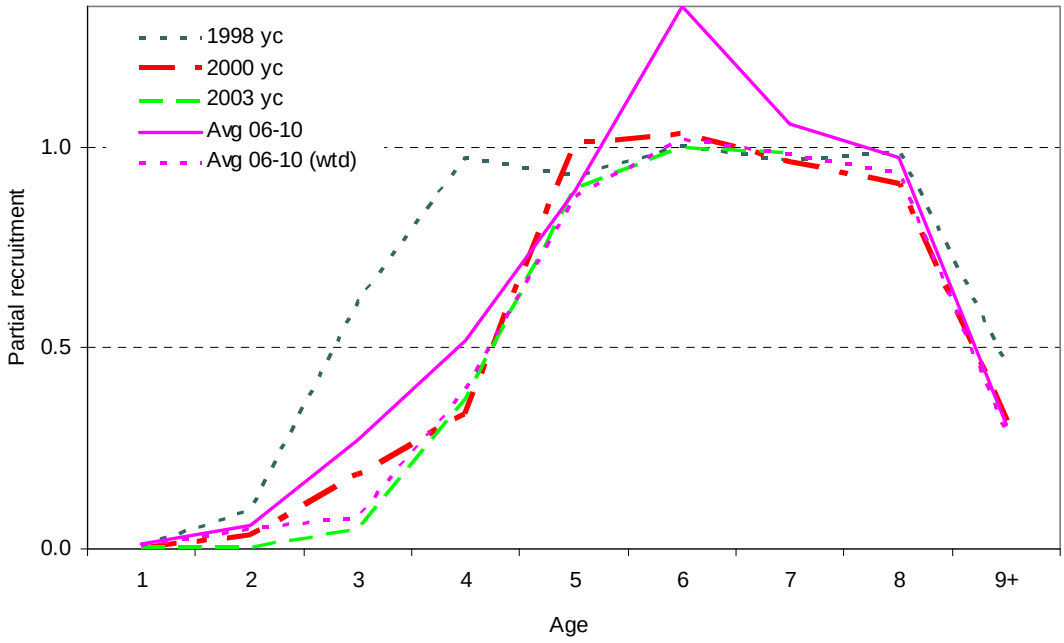


Figure 40. Partial recruitment of eastern Georges Bank haddock for 3 year classes, 1998, 2000 and 2003 and the average and weighted (by population numbers) average for 2006 to 2010. The partial recruitment is normalized to ages 4-8 for years before 2003 and to ages 5-8 for years after 2002.

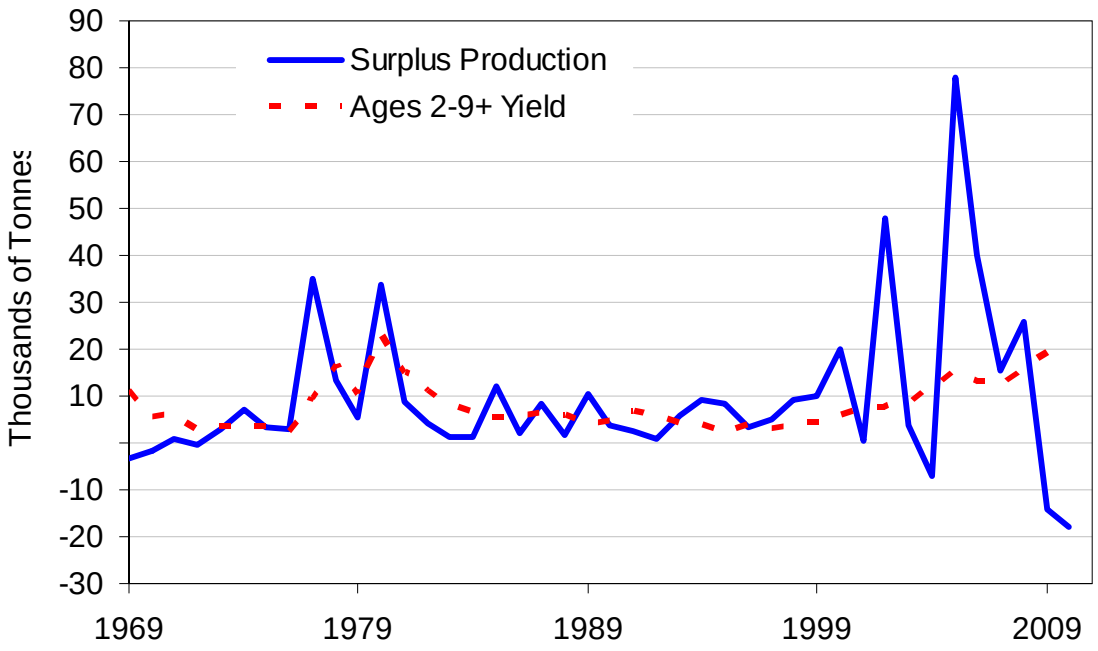


Figure 41. Surplus production of eastern Georges Bank haddock available to the commercial fishery compared to the harvested yield during 1969-2010.

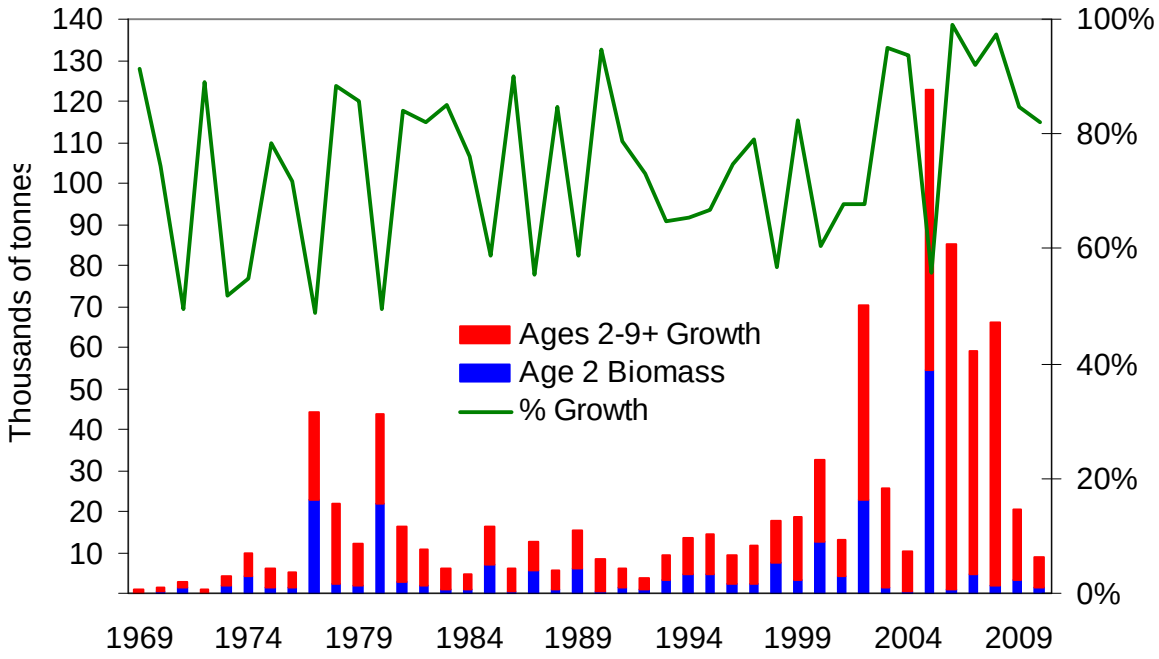


Figure 42. Amount of productivity attributible to growth (ages 2 to 9+) of eastern Georges Bank haddock and the amount contributed by recruitment (age 2) during 1969-2010.

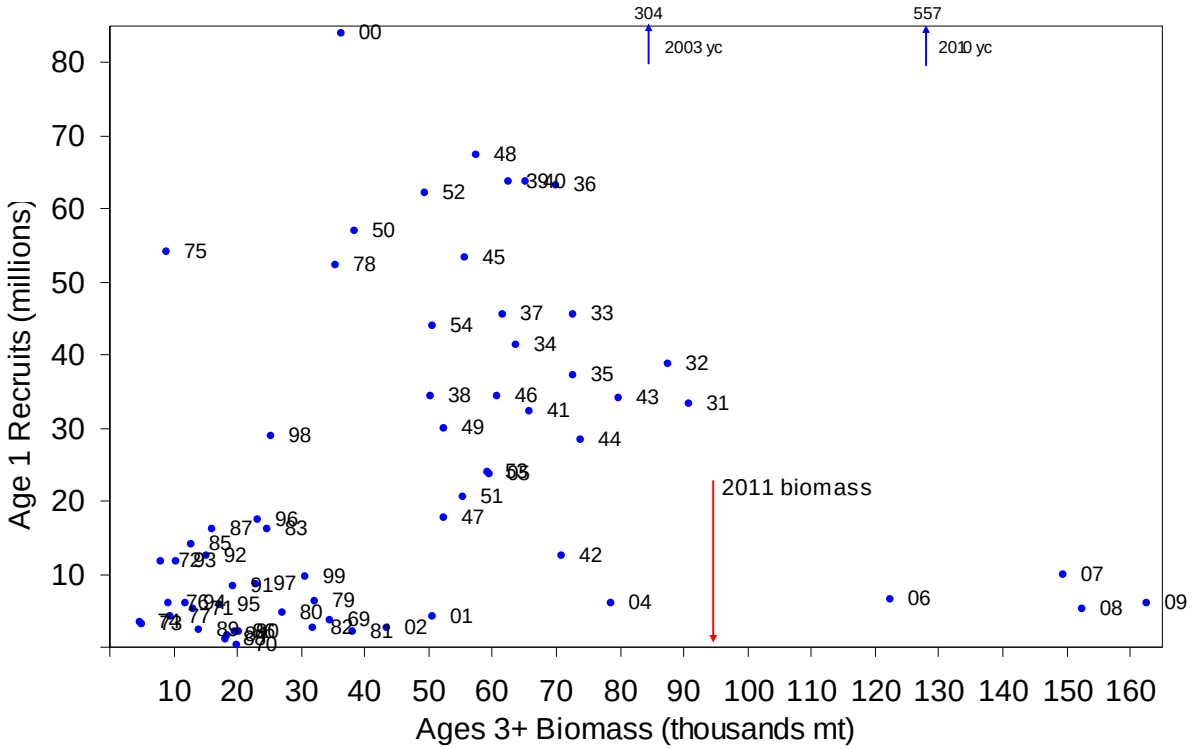


Figure 43. Relationship between eastern Georges Bank adult (ages 3+) haddock biomass and recruits at age 1 during 1931-1955 and 1969-2010.

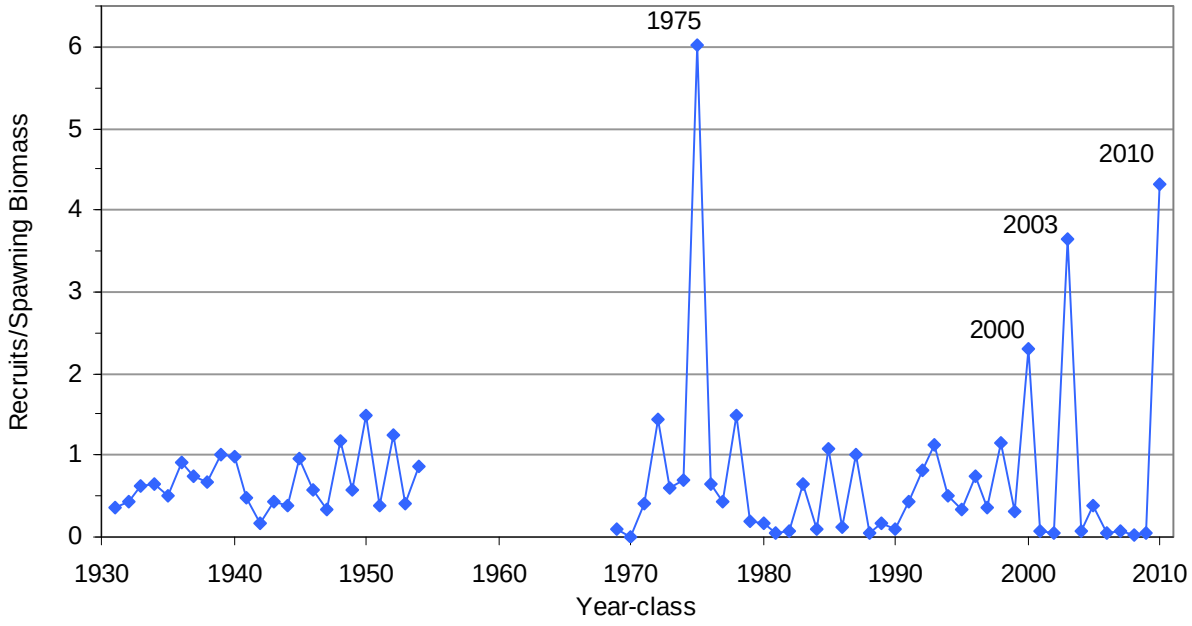


Figure 44. Ratio of recruits (numbers at age 1) to spawning biomass (kg) for eastern Georges Bank haddock during 1931-1955 and during 1969-2010.

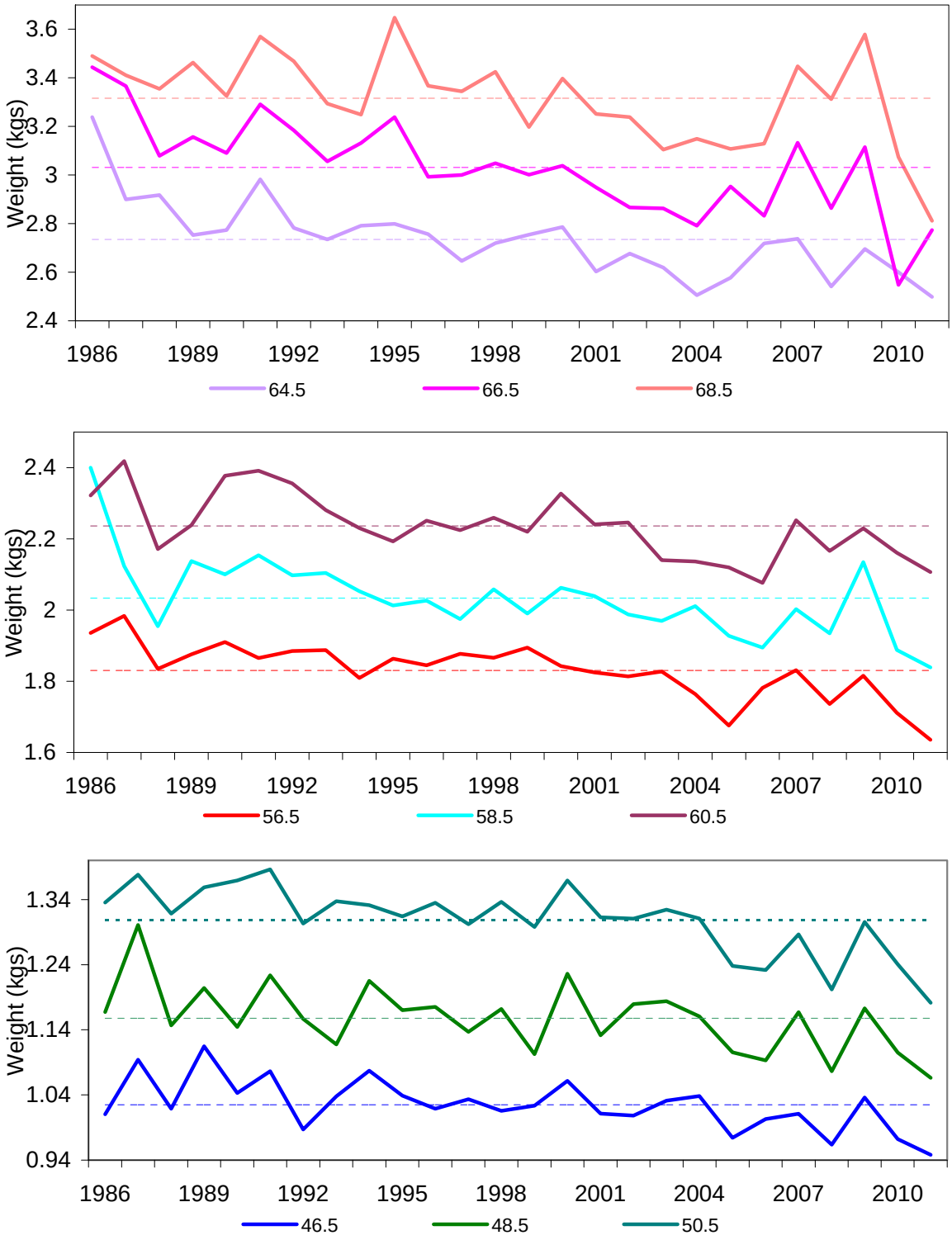


Figure 45. Canadian Department of Fisheries and Oceans survey weights at length for eastern Georges Bank haddock for nine 2 cm length groupings during 1986-2011. The dashed lines represent the average weight over the time series for each length.

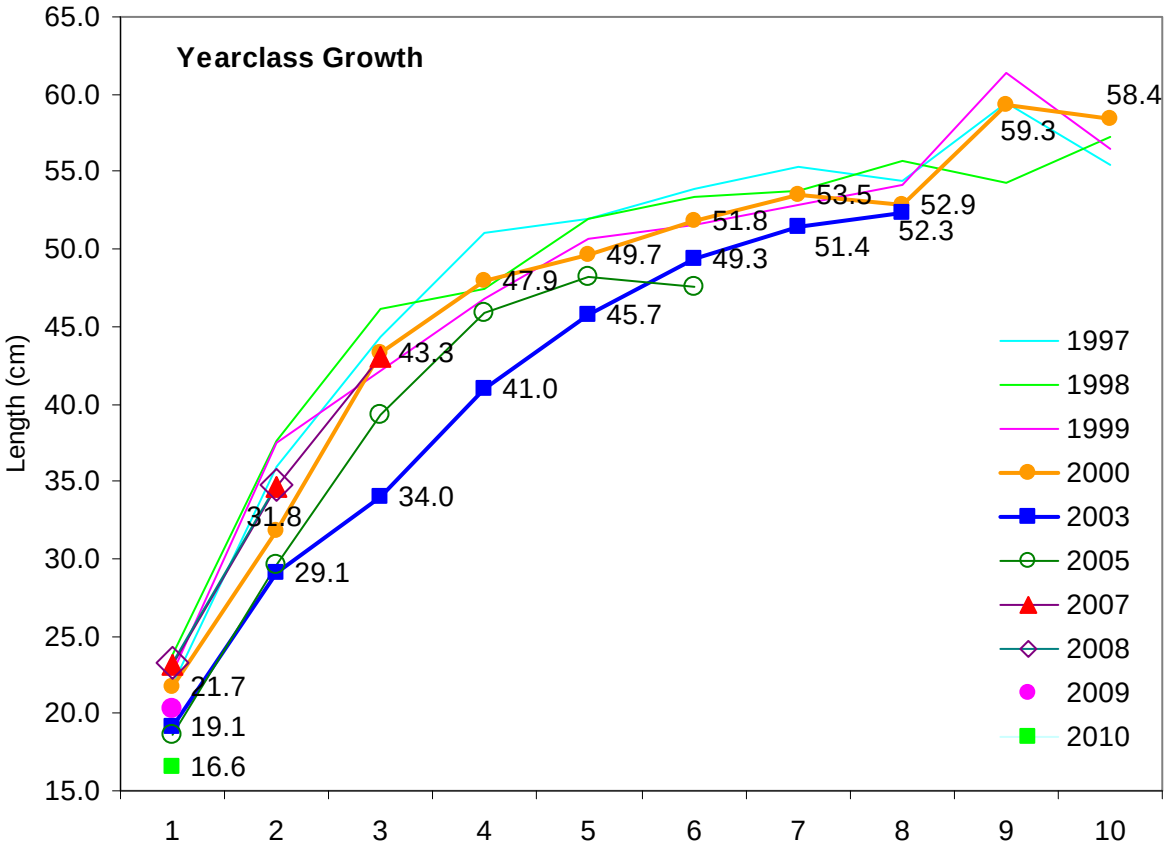


Figure 46. Length at age of eastern Georges Bank haddock year classes from the DFO survey.

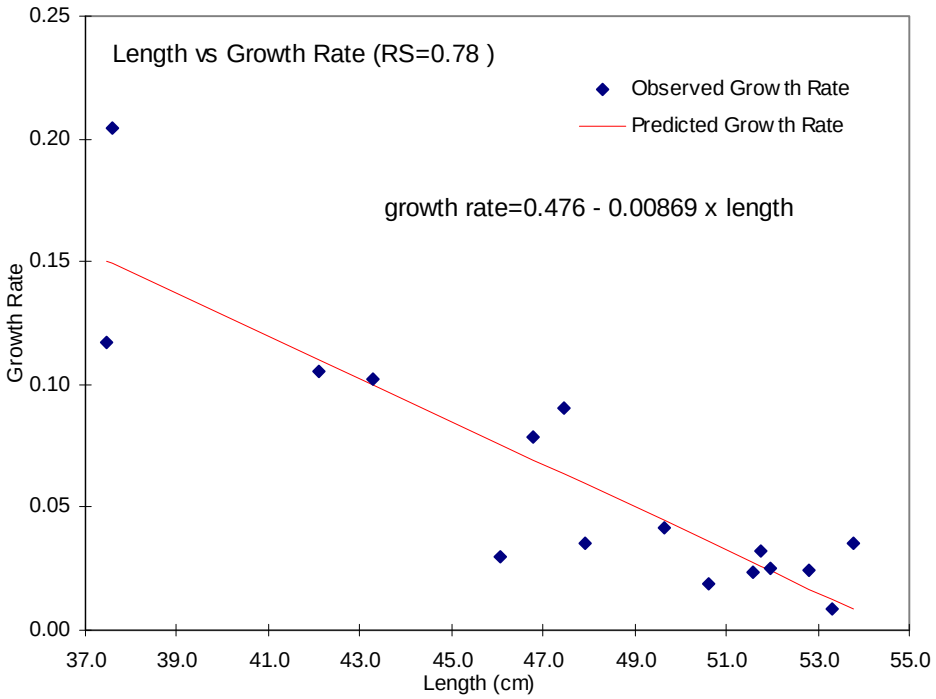


Figure 47. Relationship between length and growth rate derived for eastern Georges Bank haddock using observed growth increments from the 1998, 1999 and 2000 year classes.

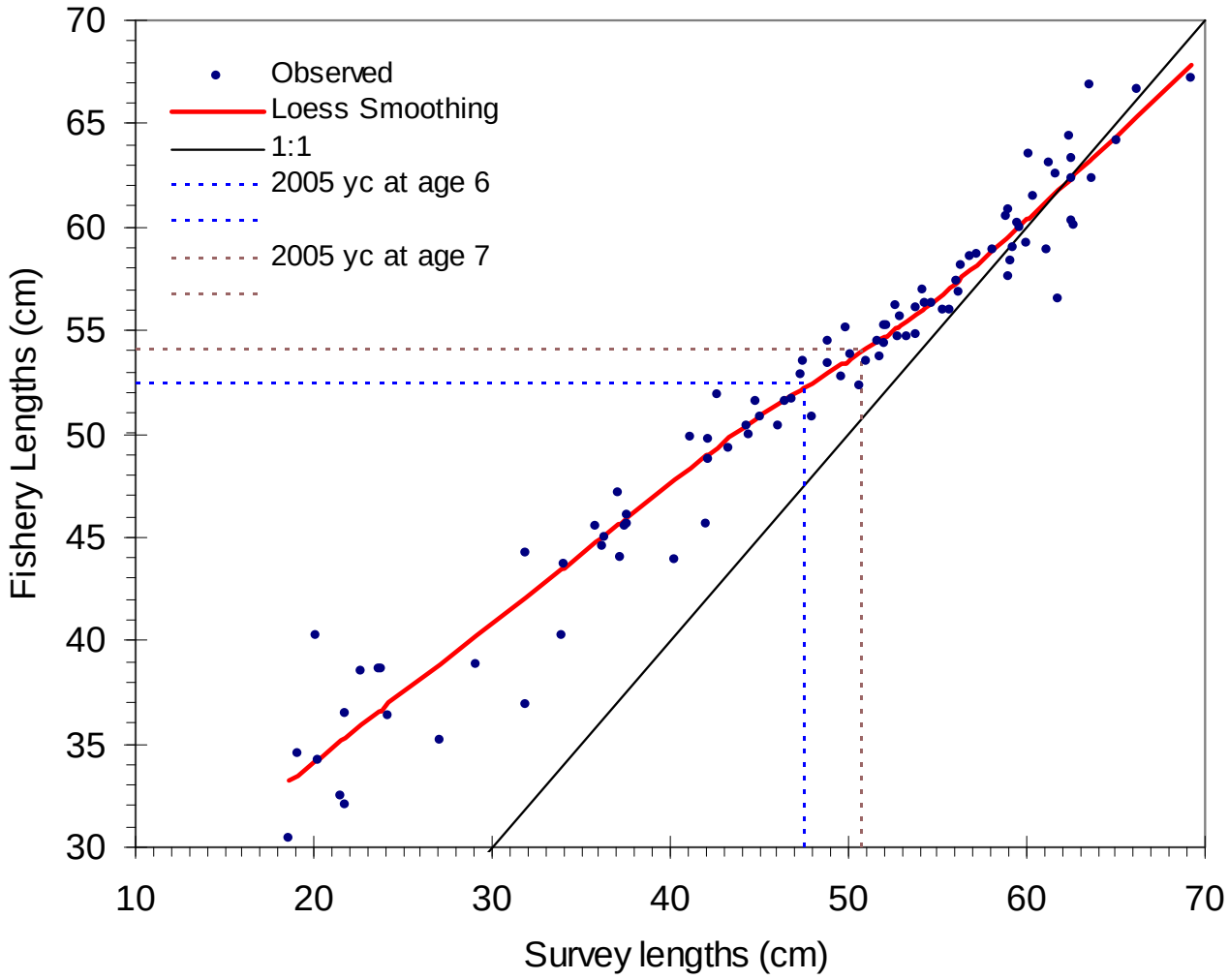


Figure 48. Relationship between eastern Georges Bank haddock beginning of year lengths (Canadian Department of Fisheries and Oceans survey lengths) for 1995 to 2006 to average fishery lengths for the same year smoothed with a Loess smoothing algorithm (Cleveland 1979). The 1:1 line is added for illustrative purposes. The beginning year lengths of the 2005 haddock year class at age 6 (47.6 cm) and age 7 (50.7 cm) with the corresponding fishery lengths, 52.4 cm and 54.0 cm for ages 6 and 7, respectively, are indicated.

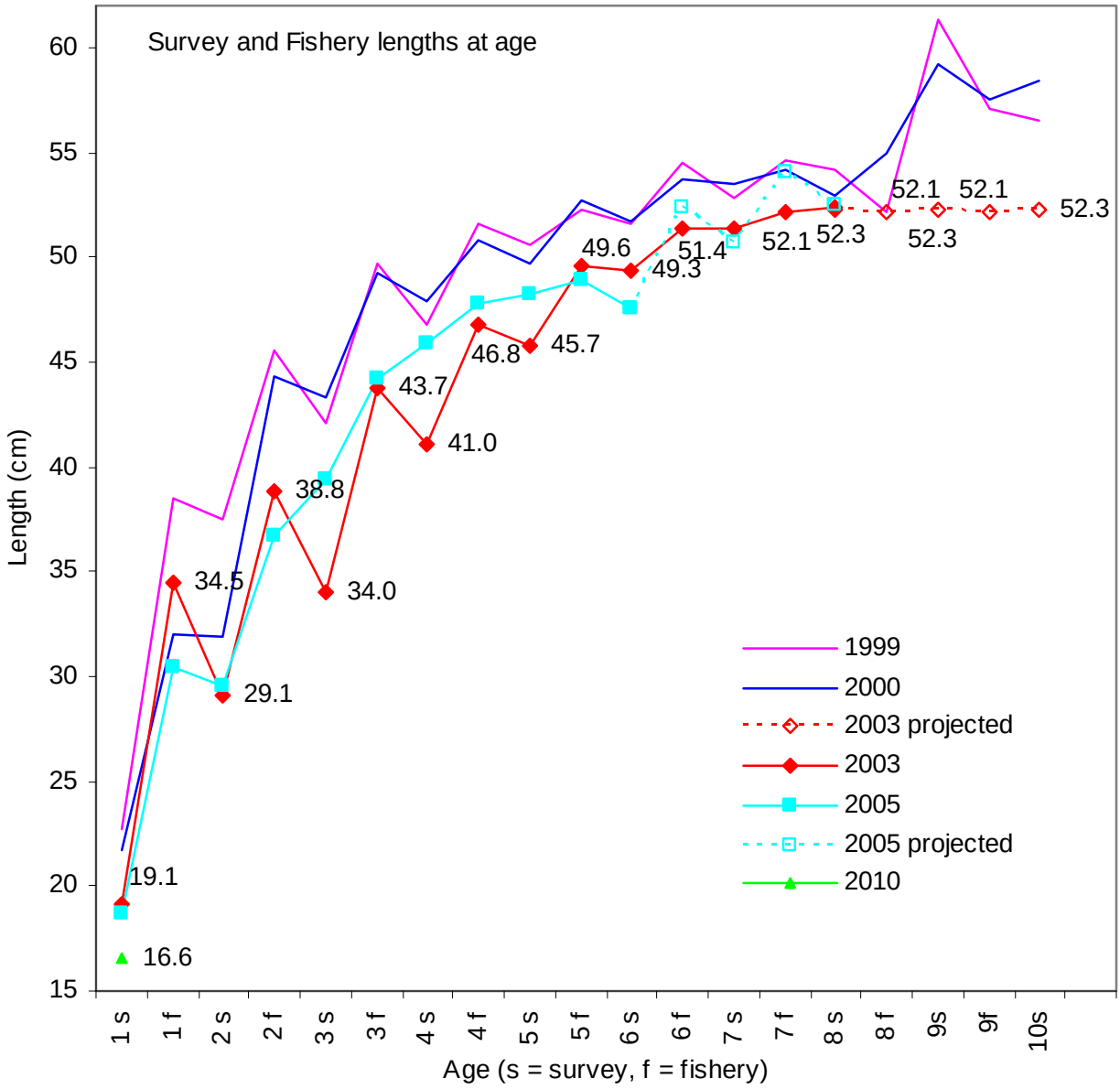


Figure 49. Average population lengths at age and average fishery lengths at age of the 1998, 1999, 2000, 2003, 2005 and 2010 year classes of eastern Georges Bank haddock as observed from the Canadian Department of Fisheries and Oceans survey. Predicted lengths for the 2003 and 2005 year classes are indicated by ◇ and □ respectively. Lengths at ages 2 and 3 for the 2010 year class were predicted to be the same as the 2003 year class.

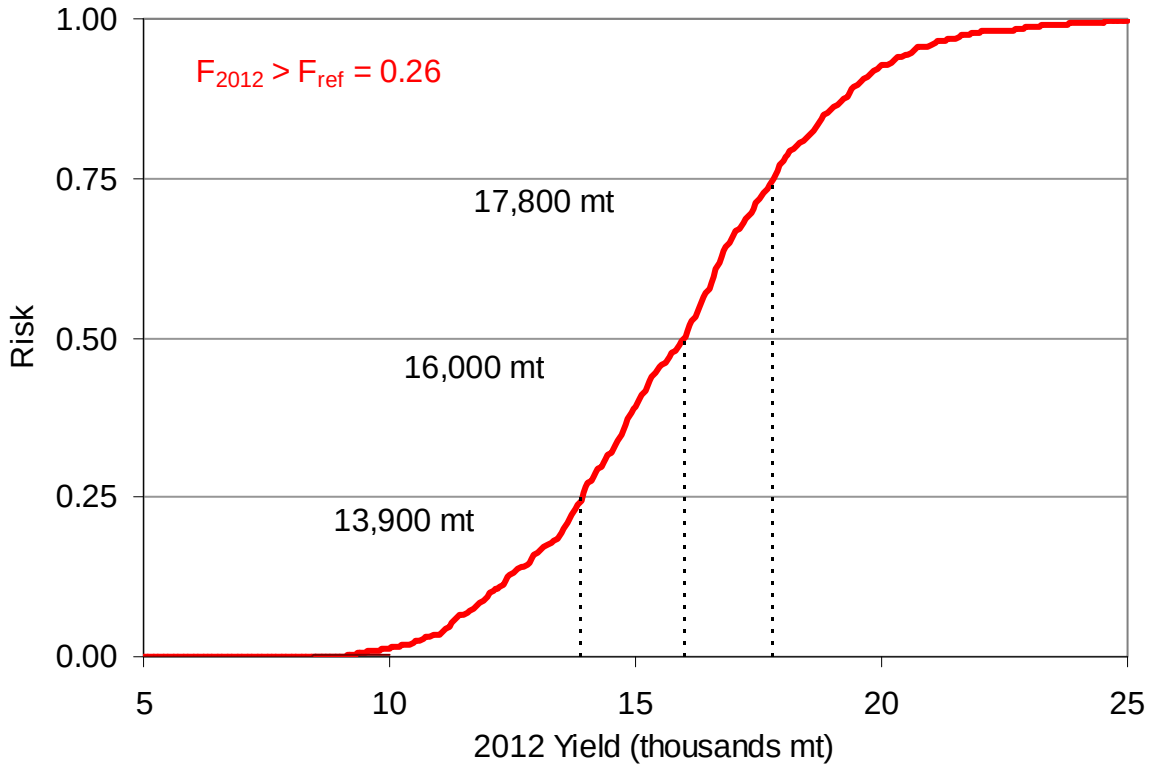


Figure 50. Risk of 2012 fishing mortality exceeding F_{ref} = 0.26 for eastern Georges Bank haddock for increasing catch quotas.

APPENDIX A. EASTERN GEORGES BANK HADDOCK ASSESSMENT MODEL VARIATION WHICH USES THE DFO AND NMFS SPRING SURVEYS AGE 9 INDICES FOR CALIBRATION OF THE VPA.

Introduction:

The 2003 haddock year class will continue to contribute a significant part of the catch when it enters the 9+ group in 2012. At the 2010 TRAC, there was concern that inclusion of age 9 in a plus group may confound the estimation of F and partial recruitment for age 9. Previous assessments have indicated a domed partial recruitment (for age 9+) which would have a significant effect on catch projections. At the 2010 TRAC it was recommended to include age 9 as a tuning index for the DFO and NMFS spring surveys. This would provide a more direct and reliable estimate of age 9 F and partial recruitment from the strong 2000 year class which reached age 9 in 2009. Results should be taken into account for the 2012 projections.

Method:

The benchmark model uses ages 1-8 and a plus group (9+) in the catch at age and calibrates the VPA with ages 1-8 from the DFO and NMFS spring surveys and ages 0 to 5 from the NMFS fall survey. In this model variation, the 9+ group in the catch at age was expanded to age 9 with an age 10+ group, thereby taking the strong 2000 year class at age 9 in 2009 out of the plus group and allowing the use of the age 9 DFO and NMFS spring survey indices to calibrate age 9 abundance. As in the benchmark model, the F on age 8 was calculated from ages 4 to 7 for years before 2003 and from ages 5 to 7 for 2003 to 2010 for this model variant.

Results:

The statistical properties of the estimates of population abundance are shown in Table A1. Beginning of year population abundance, fishing mortality rates and beginning of year biomass are presented in Tables A2 to A4. Table A5 reports partial recruitment normalized to ages 4 to 8 for 1992 to 2002 and for ages 5 to 8 for 2003 to 2010. Survey catchability, residual bubble plots, age 9 residual trends and a comparison of fishing mortality, of population weighted partial recruitment and of biomass between the benchmark model and the variant model are presented in Figures A1 to A6, respectively.

Except for the NMFS Yankee 41 survey, the survey catchabilities for ages 1 to 8 (Table A1) are all slightly higher for the variant model when compared to the benchmark model and population abundance is accordingly reduced for the variant model. For the DFO survey age 9 catchability is lower than the catchabilities for ages 3 to 8. This model has a strong residual pattern for age 9 showing positive residuals in the early part of the time series and nearly all negative residuals for the last 8 (DFO survey) to 12 (NMFS spring survey) years (Figure A3). Residuals for ages 1 to 8 for the variant are similar to the benchmark residuals (Figure A2). In comparison to estimates of population, biomass and F from the benchmark results, the variant estimates reduced population biomass (Table A2, Figure A6) and increased Fs for recent years (Table A3, Figure A4). The model variant 3+ biomass for 2006 to 2011 decreases from 78% to 67%, respectively, relative to the benchmark model biomass (Table A4). Estimates of population weighted partial recruitment are similar to the benchmark results (Figure A5). This model results in a low partial recruitment for the strong 2000 year class at age 9 of 0.36 (Table A5). In comparison, the benchmark model gives a partial recruitment of 0.32 for the age 9+ group in 2009 which would be dominated by the strong 2000 year class.

Discussion:

The variant model results indicate that there is a misspecification of the model to the data as indicated by the age 9 residual pattern for the DFO and NMFS spring survey. This residual pattern indicates that this model is producing more age 9 fish in the population in recent years than the survey is indicating. This interpretation is corroborated by the slightly domed catchability pattern seen for the DFO survey. The domed fishery partial recruitment pattern could be seen as a symptom of a misspecification of the model. It is unlikely that the survey and fishery would have a lower selectivity for age 9 haddock versus fish aged 8 and younger. The residual pattern and the domed fishery partial recruitment could be aliasing increased natural mortality for older fish, emigration of age 9 and older fish outside the survey area or some other unknown mechanism.

The implications for catch projections are significant since the 2003 year class will make up the majority of the age 9+ group and this age group will dominate the catch. Applying a reduced partial recruitment for the catch projection is one way of addressing the model misspecification so as not to advise a catch level that would result in a fishing mortality above the reference level. A sensitivity analysis for the catch projection using a reduced partial recruitment of at least 0.5 for the 9+ age group is recommended to address the uncertainty that is evidenced by the inability to explain the domed partial recruitment pattern in the survey and fishery and the survey residual pattern for age 9 and older haddock.

The exceptional 2003 year class may provide more conclusive evidence to determine the cause of the undesirable patterns seen in the benchmark and variant model when its fate in the fishery and survey is documented as it reaches age 9 and older.

Table A1. Statistical properties of estimates of population abundance (numbers in 000's) at beginning of year 2011 and survey calibration constants (unitless, survey:population) for eastern Georges Bank haddock obtained from a bootstrap with 1000 replications for the model variation of the benchmark.

Age	Estimate	Standard Error	Relative Error	Bias	Relative Bias
		Population Abundance (000's)			
1	626348	369968	0.591	92128	0.147
2	4817	1873	0.389	262	0.054
3	3316	1064	0.321	209	0.063
4	4855	1344	0.277	184	0.038
5	2388	624	0.261	35	0.015
6	6734	1677	0.249	301	0.045
7	986	305	0.309	36	0.036
8	28555	6796	0.238	196	0.007
9	207	68	0.329	8	0.039
		Survey Calibration Constants			
Canadian Department of Fisheries and Oceans Survey					
1	0.249	0.045	0.179	0.002	0.010
2	0.423	0.075	0.178	0.007	0.017
3	0.816	0.145	0.178	0.003	0.004
4	0.873	0.162	0.185	0.019	0.022
5	0.920	0.169	0.184	0.015	0.017
6	0.797	0.137	0.172	0.007	0.008
7	0.925	0.171	0.184	0.014	0.015
8	0.871	0.154	0.177	0.015	0.017
9	0.762	0.137	0.180	0.013	0.017
National Marine Fisheries Service (NMFS) Spring Survey – Yankee 36 – 1969-72/1982-2011					
1	0.134	0.020	0.153	0.000	0.004
2	0.335	0.056	0.166	0.005	0.014
3	0.436	0.068	0.156	0.004	0.010
4	0.406	0.059	0.146	0.005	0.013
5	0.466	0.073	0.157	0.009	0.020
6	0.405	0.063	0.156	0.004	0.010
7	0.410	0.062	0.151	0.005	0.012
8	0.441	0.071	0.161	0.006	0.014
9	0.451	0.089	0.196	0.009	0.019
NMFS Spring Survey – Yankee 41 – 1973-81					
1	0.228	0.074	0.323	0.014	0.062
2	0.534	0.168	0.314	0.026	0.048
3	0.652	0.216	0.331	0.035	0.053
4	0.806	0.249	0.309	0.044	0.054
5	0.895	0.281	0.314	0.046	0.051
6	0.811	0.298	0.367	0.050	0.061
7	1.488	0.534	0.359	0.085	0.057
8	0.724	0.250	0.345	0.032	0.044
9	0.680	0.396	0.582	0.097	0.143
NMFS Fall Survey					
0	0.142	0.020	0.144	0.001	0.010
1	0.313	0.044	0.142	0.003	0.010
2	0.253	0.035	0.137	0.001	0.002
3	0.249	0.035	0.142	0.001	0.005
4	0.208	0.031	0.148	0.004	0.017
5	0.173	0.024	0.140	0.001	0.008

Table A2. Beginning of year population abundance (numbers in 000's) for eastern Georges Bank haddock during 1969-2011 from a virtual population analysis using the bootstrap bias adjusted population abundance at the beginning of 2011 for the model variation of the benchmark. Highlighted cells follow two recent large year classes, the 2000 and 2003.

Year	Age Group												
	1	2	3	4	5	6	7	8	9	10+	1+	2+	3+
1969	804	193	3639	872	911	7650	2497	250	473	304	17592	16789	16596
1970	3593	658	141	1681	479	447	3659	1299	123	383	12080	8488	7830
1971	235	2881	463	109	1061	256	249	1961	729	242	7945	7710	4829
1972	5303	192	1285	155	62	642	69	61	913	427	8682	3379	3187
1973	11637	4029	157	702	63	32	441	21	36	693	17118	5481	1451
1974	3082	8519	1728	123	251	18	17	327	10	445	14073	10991	2472
1975	3448	2489	4947	1166	100	176	12	14	241	316	12594	9146	6657
1976	54074	2807	1787	2701	761	78	112	8	9	428	62336	8262	5455
1977	6038	43909	2157	1307	1463	501	64	74	7	342	55519	49481	5572
1978	4057	4942	28725	1706	906	922	263	52	47	272	41621	37564	32621
1979	52343	3317	3784	14595	1249	587	480	144	34	253	76531	24188	20872
1980	6238	42663	2700	2910	8084	695	300	199	79	222	63868	57630	14967
1981	4616	5078	19098	1901	2111	4442	396	130	117	235	37888	33273	28195
1982	2096	3730	3533	9568	1197	1281	2521	217	76	281	24219	22123	18394
1983	2553	1714	2396	1944	5278	796	708	1409	122	234	16919	14367	12653
1984	16097	2080	1269	1367	1094	2838	465	486	787	260	26482	10385	8305
1985	1639	13114	1613	806	804	652	1311	214	250	573	20403	18764	5650
1986	13903	1334	8804	974	496	480	419	731	127	568	27268	13365	12032
1987	2184	11302	1057	4887	639	278	282	237	442	532	21308	19124	7821
1988	16031	1788	7381	747	2624	434	176	156	131	697	29467	13436	11648
1989	1021	13078	1417	4069	500	1346	255	109	86	588	21881	20860	7782
1990	2379	834	9559	1082	2633	281	791	178	68	510	17804	15426	14592
1991	2061	1920	676	6614	766	1465	164	496	107	436	14268	12207	10288
1992	8076	1667	1153	471	3553	547	848	70	275	394	16660	8584	6916
1993	12088	6568	1141	653	270	1597	367	408	34	469	23125	11037	4470
1994	11357	9824	5121	614	275	139	711	263	193	347	28498	17141	7317
1995	5677	9266	7662	3410	336	159	25	412	136	398	27082	21406	12140
1996	5598	4640	7515	5791	2419	227	108	18	290	423	26607	21009	16368
1997	16655	4580	3770	5711	3964	1604	132	72	12	521	36500	19845	15265
1998	8118	13610	3665	3021	4193	2809	1137	97	52	406	36701	28583	14973
1999	26867	6630	10967	2738	2239	2946	1896	828	68	344	55180	28312	21682
2000	8594	21973	5389	8301	1954	1609	2099	1322	589	315	51829	43235	21263
2001	73840	7031	17701	4007	5654	1362	1126	1524	915	679	113158	39318	32287
2002	3540	60435	5697	12929	2800	3866	879	738	1038	1122	91922	88383	27948
2003	2320	2897	49179	4468	8882	1951	2561	616	505	1508	73379	71060	68163
2004	227563	1893	2363	38612	3398	5934	1214	1666	405	1437	283048	55485	53592
2005	5802	186013	1527	1867	28325	2238	3513	530	986	1272	230799	224998	38984
2006	21554	4738	152077	1224	1326	16998	1359	2136	319	1706	201731	180177	175439
2007	6224	17629	3865	122235	962	826	9835	902	1254	1520	163732	157508	139880
2008	9325	5094	14398	3001	93462	655	526	6766	617	2104	133844	124519	119425
2009	4729	7631	4143	11543	2215	67763	444	354	4902	2142	103723	98994	91363
2010	5597	3857	6135	3220	8786	1579	45458	298	238	5430	75168	69571	65714
2011	534220	4554	3107	4670	2353	6433	950	28359	199	4451	584846	50626	46071

Table A3. Fishing mortality rates for eastern Georges Bank haddock during 1969-2010 from a virtual population analysis using the bootstrap bias adjusted population abundance at the beginning of 2011 for the model variation of the benchmark. The aggregated rates are weighted by population numbers. The rates for ages 4+ and 5+ are also shown as exploitation rate (%).

Year	Age Group													
	1	2	3	4	5	6	7	8	9	10+	4+	4+(%)	5+	5+(%)
1969	0.000	0.111	0.572	0.399	0.512	0.538	0.453	0.508	0.508	0.508	0.508	36.4	0.516	36.8
1970	0.021	0.152	0.057	0.261	0.425	0.383	0.424	0.377	1.027	0.419	0.389	29.4	0.423	31.5
1971	0.000	0.608	0.892	0.369	0.302	1.114	1.202	0.564	0.527	0.979	0.580	40.3	0.585	40.5
1972	0.075	0.005	0.404	0.705	0.468	0.175	0.973	0.342	0.460	0.458	0.410	30.7	0.389	29.4
1973	0.112	0.647	0.045	0.830	1.056	0.410	0.101	0.571	0.306	0.293	0.469	34.2	0.272	21.7
1974	0.013	0.343	0.193	0.000	0.154	0.181	0.015	0.103	0.073	0.166	0.126	10.8	0.141	11.9
1975	0.006	0.132	0.405	0.227	0.051	0.255	0.218	0.218	0.021	0.096	0.176	14.7	0.106	9.1
1976	0.008	0.064	0.113	0.413	0.217	0.000	0.208	0.000	0.851	0.034	0.324	25.2	0.151	12.7
1977	0.000	0.224	0.035	0.166	0.262	0.444	0.000	0.247	0.000	0.049	0.228	18.6	0.261	20.9
1978	0.002	0.067	0.477	0.112	0.235	0.452	0.405	0.244	0.039	0.032	0.228	18.5	0.308	24.2
1979	0.004	0.006	0.062	0.391	0.385	0.471	0.679	0.401	0.199	0.038	0.396	29.8	0.421	31.4
1980	0.006	0.604	0.151	0.121	0.399	0.363	0.639	0.335	0.179	0.003	0.328	25.5	0.391	29.5
1981	0.013	0.163	0.491	0.263	0.299	0.366	0.401	0.330	0.038	0.016	0.318	24.8	0.332	25.8
1982	0.001	0.242	0.398	0.395	0.208	0.393	0.382	0.377	0.803	0.110	0.374	28.5	0.339	26.2
1983	0.005	0.101	0.361	0.375	0.420	0.338	0.176	0.383	0.264	0.043	0.374	28.5	0.374	28.4
1984	0.005	0.054	0.254	0.330	0.317	0.572	0.577	0.467	0.513	0.131	0.460	33.7	0.490	35.4
1985	0.006	0.198	0.305	0.285	0.316	0.242	0.384	0.320	0.162	0.173	0.293	23.2	0.295	23.3
1986	0.007	0.033	0.389	0.221	0.379	0.333	0.372	0.303	0.199	0.041	0.261	20.9	0.275	21.9
1987	0.000	0.226	0.147	0.422	0.189	0.259	0.391	0.389	0.199	0.083	0.355	27.2	0.219	17.9
1988	0.004	0.033	0.395	0.201	0.467	0.331	0.277	0.394	0.247	0.124	0.352	27.1	0.379	28.8
1989	0.002	0.113	0.070	0.235	0.378	0.332	0.158	0.265	0.153	0.069	0.247	19.9	0.263	21.1
1990	0.014	0.010	0.168	0.145	0.387	0.335	0.266	0.309	0.259	0.060	0.286	22.6	0.320	24.9
1991	0.012	0.310	0.161	0.421	0.137	0.347	0.647	0.389	0.208	0.100	0.375	28.5	0.285	22.6
1992	0.007	0.180	0.368	0.356	0.599	0.199	0.532	0.527	0.299	0.069	0.488	35.3	0.499	35.9
1993	0.007	0.049	0.420	0.667	0.462	0.609	0.132	0.547	0.942	0.133	0.500	36.0	0.465	34.0
1994	0.004	0.049	0.207	0.402	0.346	1.512	0.347	0.460	0.182	0.062	0.384	29.1	0.379	28.7
1995	0.002	0.009	0.080	0.143	0.191	0.192	0.120	0.149	0.046	0.030	0.137	11.6	0.121	10.4
1996	0.001	0.008	0.074	0.179	0.211	0.344	0.202	0.193	0.232	0.041	0.187	15.5	0.200	16.5
1997	0.002	0.023	0.022	0.109	0.144	0.144	0.112	0.126	0.101	0.072	0.124	10.6	0.137	11.7
1998	0.002	0.016	0.092	0.100	0.153	0.193	0.117	0.145	0.187	0.074	0.143	12.1	0.158	13.3
1999	0.001	0.007	0.079	0.137	0.130	0.139	0.161	0.141	0.169	0.052	0.138	11.7	0.138	11.7
2000	0.001	0.016	0.096	0.184	0.161	0.157	0.121	0.168	0.107	0.045	0.163	13.7	0.142	12.0
2001	0.000	0.010	0.114	0.158	0.180	0.238	0.222	0.183	0.153	0.149	0.180	15.0	0.188	15.6
2002	0.000	0.006	0.043	0.175	0.161	0.212	0.155	0.179	0.188	0.134	0.178	14.8	0.180	15.0
2003	0.003	0.004	0.042	0.073	0.203	0.274	0.230	0.219	0.211	0.113	0.179	14.9	0.208	17.1
2004	0.002	0.015	0.036	0.109	0.217	0.324	0.627	0.324	0.294	0.138	0.161	13.6	0.304	23.9
2005	0.003	0.001	0.021	0.141	0.309	0.297	0.296	0.307	0.140	0.035	0.286	22.6	0.293	23.1
2006	0.001	0.004	0.018	0.040	0.271	0.344	0.208	0.330	0.310	0.050	0.296	23.4	0.310	24.3
2007	0.000	0.002	0.052	0.067	0.180	0.249	0.172	0.178	0.122	0.039	0.078	6.8	0.159	13.4
2008	0.000	0.006	0.020	0.100	0.119	0.181	0.193	0.120	0.047	0.037	0.117	10.1	0.118	10.1
2009	0.004	0.017	0.050	0.070	0.132	0.194	0.187	0.192	0.069	0.037	0.166	13.9	0.180	15.0
2010	0.005	0.015	0.068	0.107	0.106	0.287	0.260	0.186	0.161	0.036	0.213	17.4	0.218	17.8

Table A4. Beginning of year biomass (mt) for eastern Georges Bank haddock during 1969-2011 from a virtual population analysis using the bootstrap bias adjusted population abundance at the beginning of 2011 for the model variation of the benchmark. Highlighted cells follow two recent large year classes, the 2000 and 2003.

Year	Age Group												
	1	2	3	4	5	6	7	8	9	10+	1+	2+	3+
1969	92	99	3402	1311	1816	17938	6702	733	1457	1105	34655	34562	34463
1970	413	339	132	2528	954	1048	9823	3805	380	1391	20812	20399	20061
1971	27	1483	433	164	2113	600	670	5745	2248	880	14363	14336	12853
1972	610	99	1201	234	123	1506	185	180	2815	1553	8504	7895	7796
1973	1338	2073	146	1056	125	74	1185	62	110	2520	8690	7352	5279
1974	354	4383	1615	184	499	42	46	956	30	1617	9729	9374	4991
1975	396	1281	4626	1754	200	412	33	41	743	1149	10634	10238	8957
1976	6216	1444	1670	4062	1516	183	299	24	28	1558	17001	10785	9340
1977	694	22592	2016	1965	2915	1175	171	217	20	1244	33011	32317	9725
1978	466	2543	26856	2565	1805	2162	706	153	146	990	38393	37927	35384
1979	6017	1706	3537	21949	2489	1375	1289	421	103	921	39808	33791	32084
1980	717	21951	2524	4376	16106	1631	805	584	243	807	49745	49028	27077
1981	531	2613	17856	2859	4205	10416	1063	380	360	855	41137	40607	37994
1982	241	1919	3303	14389	2385	3004	6768	636	235	1023	33904	33663	31744
1983	293	882	2240	2923	10517	1865	1902	4126	376	852	25976	25683	24801
1984	1850	1070	1186	2055	2179	6655	1247	1424	2424	947	21039	19188	18118
1985	188	6747	1508	1212	1602	1530	3520	625	770	2082	19785	19597	12849
1986	1872	602	8578	1407	1510	1367	1509	2469	334	2459	22106	20234	19632
1987	328	5646	757	8173	1286	709	886	746	1568	1984	22084	21756	16110
1988	1559	831	6868	1340	4765	832	479	509	456	2805	20443	18884	18053
1989	63	6201	920	5666	998	3402	550	312	322	1774	20207	20144	13943
1990	354	437	8835	1278	4904	582	1983	502	219	1800	20892	20538	20101
1991	246	1314	540	9997	1298	3565	346	1549	315	1661	20832	20586	19271
1992	988	1004	1288	499	7384	1183	2297	161	924	1522	17251	16263	15258
1993	1475	3160	1400	1178	344	3725	860	1117	71	1600	14929	13454	10295
1994	1212	4609	5361	995	529	300	2244	708	586	1175	17718	16507	11898
1995	489	4572	7379	5307	747	389	60	1232	387	1298	21859	21370	16798
1996	776	2297	6906	7645	4673	581	312	48	997	1786	26020	25244	22947
1997	2201	2320	2947	6884	6595	3490	324	185	41	1642	26629	24428	22108
1998	871	7286	3794	3509	6582	5489	2967	344	165	1462	32468	31596	24310
1999	3483	3140	9989	3530	2818	5506	4041	2254	200	1055	36016	32533	29392
2000	995	11939	5112	12272	3655	2879	4825	3316	1638	1106	47736	46741	34802
2001	6893	3681	17795	5493	10164	2949	2533	3951	2511	2252	58222	51329	47647
2002	339	20039	4432	14710	4184	7596	1913	1628	2715	3115	60669	60331	40292
2003	187	1070	41609	4749	13120	3209	5656	1374	1126	4002	76101	75914	74844
2004	14541	587	1846	44451	4438	9246	1970	3258	1061	3044	84443	69902	69315
2005	162	40505	752	1300	34729	2956	5377	848	2259	3540	92428	92267	51762
2006	1264	811	59137	804	1154	23220	2162	3721	614	4600	97486	96222	95412
2007	476	4328	1565	86670	954	1442	15338	1507	2239	3107	117626	117149	112821
2008	998	1676	8254	2385	86667	821	909	9984	1520	3914	117128	116130	114454
2009	539	2953	3211	11530	2186	85254	658	948	10926	4760	122965	122426	119473
2010	406	1485	4595	3090	9843	1907	60581	528	560	11150	94143	93738	92253
2011	20535	1466	1903	4201	2243	6550	1064	38875	409	7606	84850	64315	62849

Table A5. Partial recruitment of haddock from the eastern Georges Bank commercial fishery during 1992-2010 for the model variation of the benchmark. Partial recruitment was normalized to ages 4 to 8 for 1992 to 2002 and to ages 5 to 8 for 2003 to 2010 (indicated by shading). Highlighted cells follow two recent large year classes, the 2000 and 2003. Missing values are due to zero catch.

	Age Group									
Year	1	2	3	4	5	6	7	8	9	10+
1969	0.00	0.22	1.13	0.79	1.01	1.06	0.89	1.00	1.00	1.00
1970	0.05	0.40	0.15	0.69	1.13	1.02	1.12	1.00	2.72	1.11
1971		1.08	1.58	0.65	0.53	1.97	2.13	1.00	0.93	1.74
1972	0.22	0.01	1.18	2.06	1.37	0.51	2.84	1.00	1.34	1.34
1973	0.20	1.13	0.08	1.45	1.85	0.72	0.18	1.00	0.54	0.51
1974	0.11	2.78	1.56		1.24	1.46	0.12	0.83	0.59	1.34
1975	0.03	0.60	1.85	1.04	0.24	1.17	1.00	1.00	0.10	0.44
1976	0.02	0.17	0.31	1.13	0.59		0.57		2.33	0.09
1977	0.00	0.91	0.14	0.67	1.06	1.80	0.00	1.00		0.20
1978	0.01	0.28	1.95	0.46	0.96	1.85	1.66	1.00	0.16	0.13
1979	0.01	0.01	0.16	0.97	0.96	1.17	1.69	1.00	0.50	0.09
1980	0.02	1.80	0.45	0.36	1.19	1.08	1.91	1.00	0.53	0.01
1981	0.04	0.49	1.49	0.80	0.91	1.11	1.22	1.00	0.12	0.05
1982	0.00	0.64	1.05	1.05	0.55	1.04	1.01	1.00	2.13	0.29
1983	0.01	0.26	0.94	0.98	1.10	0.88	0.46	1.00	0.69	0.11
1984	0.01	0.12	0.54	0.71	0.68	1.23	1.24	1.00	1.10	0.28
1985	0.02	0.62	0.95	0.89	0.99	0.75	1.20	1.00	0.51	0.54
1986	0.02	0.11	1.28	0.73	1.25	1.10	1.23	1.00	0.66	0.14
1987	0.00	0.58	0.38	1.09	0.49	0.67	1.01	1.00	0.51	0.21
1988	0.01	0.08	1.00	0.51	1.19	0.84	0.70	1.00	0.63	0.32
1989	0.01	0.43	0.26	0.89	1.43	1.25	0.60	1.00	0.58	0.26
1990	0.05	0.03	0.54	0.47	1.25	1.08	0.86	1.00	0.84	0.20
1991	0.03	0.80	0.41	1.08	0.35	0.89	1.66	1.00	0.53	0.26
1992	0.01	0.34	0.70	0.67	1.14	0.38	1.01	1.00	0.57	0.13
1993	0.01	0.09	0.77	1.22	0.84	1.11	0.24	1.00	1.72	0.24
1994	0.01	0.11	0.45	0.88	0.75	3.29	0.75	1.00	0.40	0.14
1995	0.01	0.06	0.53	0.96	1.28	1.28	0.80	1.00	0.31	0.20
1996	0.00	0.04	0.39	0.93	1.09	1.78	1.05	1.00	1.20	0.21
1997	0.01	0.18	0.17	0.86	1.14	1.14	0.89	1.00	0.80	0.57
1998	0.02	0.11	0.63	0.69	1.06	1.33	0.81	1.00	1.29	0.51
1999	0.01	0.05	0.56	0.98	0.93	0.99	1.14	1.00	1.20	0.37
2000	0.00	0.10	0.57	1.09	0.96	0.93	0.72	1.00	0.64	0.27
2001	0.00	0.06	0.62	0.86	0.98	1.30	1.21	1.00	0.84	0.81
2002	0.00	0.03	0.24	0.98	0.90	1.18	0.86	1.00	1.05	0.75
2003	0.02	0.02	0.23	0.40	1.11	1.49	1.25	1.19	1.15	0.62
2004	0.01	0.09	0.22	0.68	1.35	2.01	3.89	2.01	1.82	0.86
2005	0.01	0.00	0.07	0.47	1.04	1.00	0.99	1.03	0.47	0.12
2006	0.00	0.01	0.06	0.13	0.86	1.09	0.66	1.05	0.99	0.16
2007	0.00	0.03	0.66	0.87	2.32	3.22	2.21	2.30	1.57	0.50
2008	0.00	0.05	0.17	0.84	1.00	1.52	1.62	1.01	0.39	0.31
2009	0.02	0.10	0.28	0.40	0.76	1.11	1.07	1.10	0.39	0.21
2010	0.02	0.06	0.30	0.47	0.46	1.25	1.13	0.81	0.71	0.16
Avg 1998-02[1]	0.00	0.06	0.54	0.97	0.94	1.11	0.94	1.01	0.88	0.61
Avg 2003-10[1]	0.01	0.01	0.10	0.38	0.95	1.03	1.08	1.00	0.50	0.23
Avg 2008-10[1]	0.01	0.07	0.21	0.46	0.94	1.02	1.10	0.99	0.37	0.19

[1]Weighted by population numbers

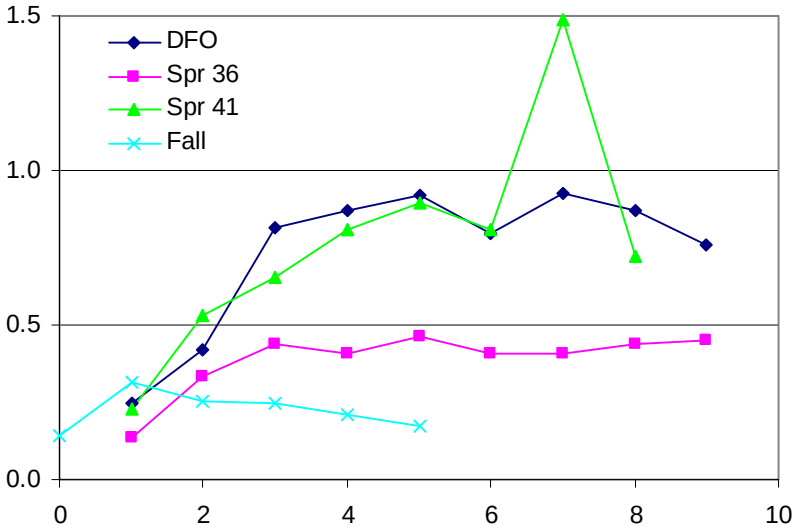


Figure A1. Survey catchability for EGB haddock for the DFO, NMFS spring and fall surveys for the model variation of the benchmark.

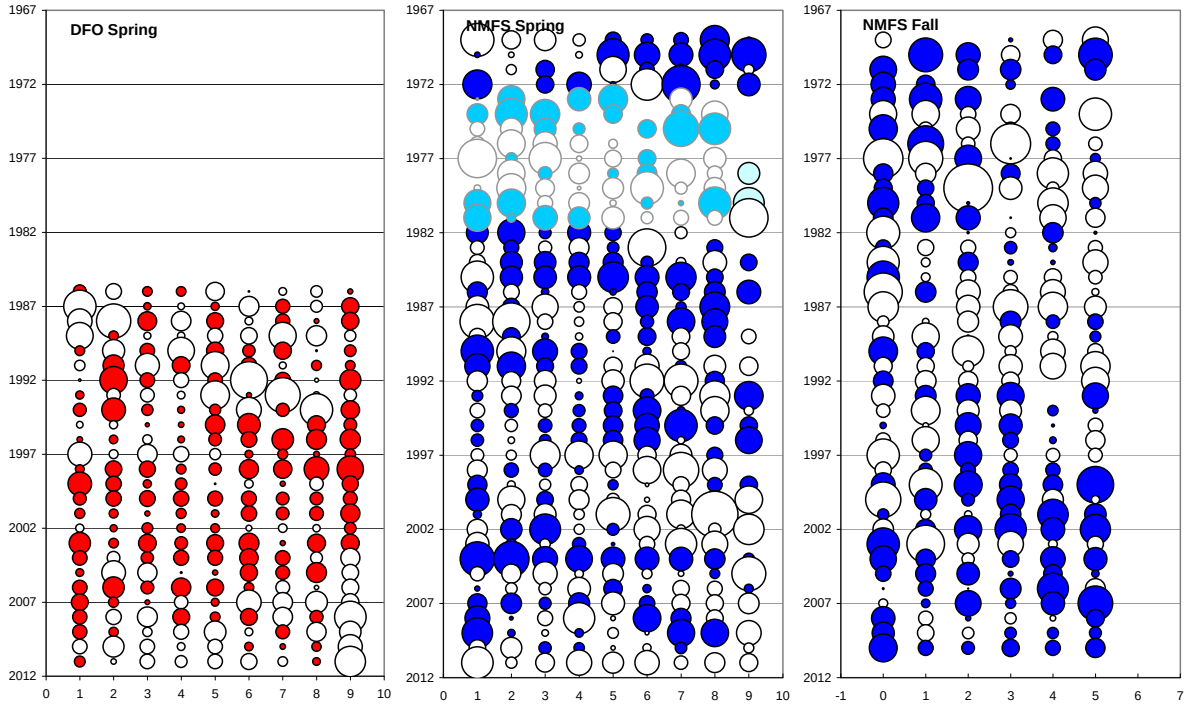


Figure A2. Residuals survey abundance indices by year and age group for the Canadian Department of Fisheries and Oceans (DFO) 1986-2011 surveys, the National Marine Fisheries Service (NMFS) 1969-2011 spring surveys, and for the NMFS fall 1969-2010 surveys for eastern Georges Bank haddock for the model variation of the benchmark. Solid symbols indicate positive values, open symbols indicate negative values. Bubble area is proportional to magnitude. From 1973-81 (light blue circles), a 41 Yankee trawl was used for the NMFS spring survey while a 36 Yankee was used in the other years.

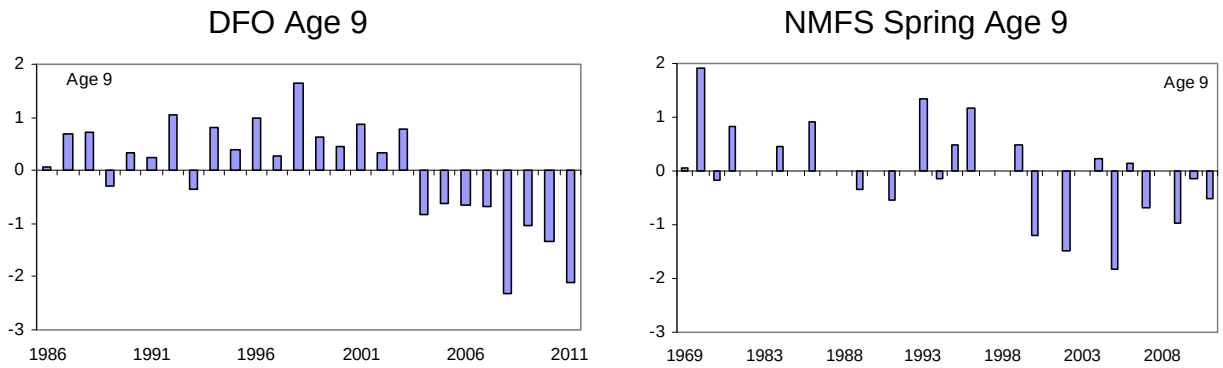


Figure A3. Residuals for age 9 for 1986 to 2011 for the DFO survey and for 1969 to 2011 for the NMFS spring survey for the model variation of the benchmark.

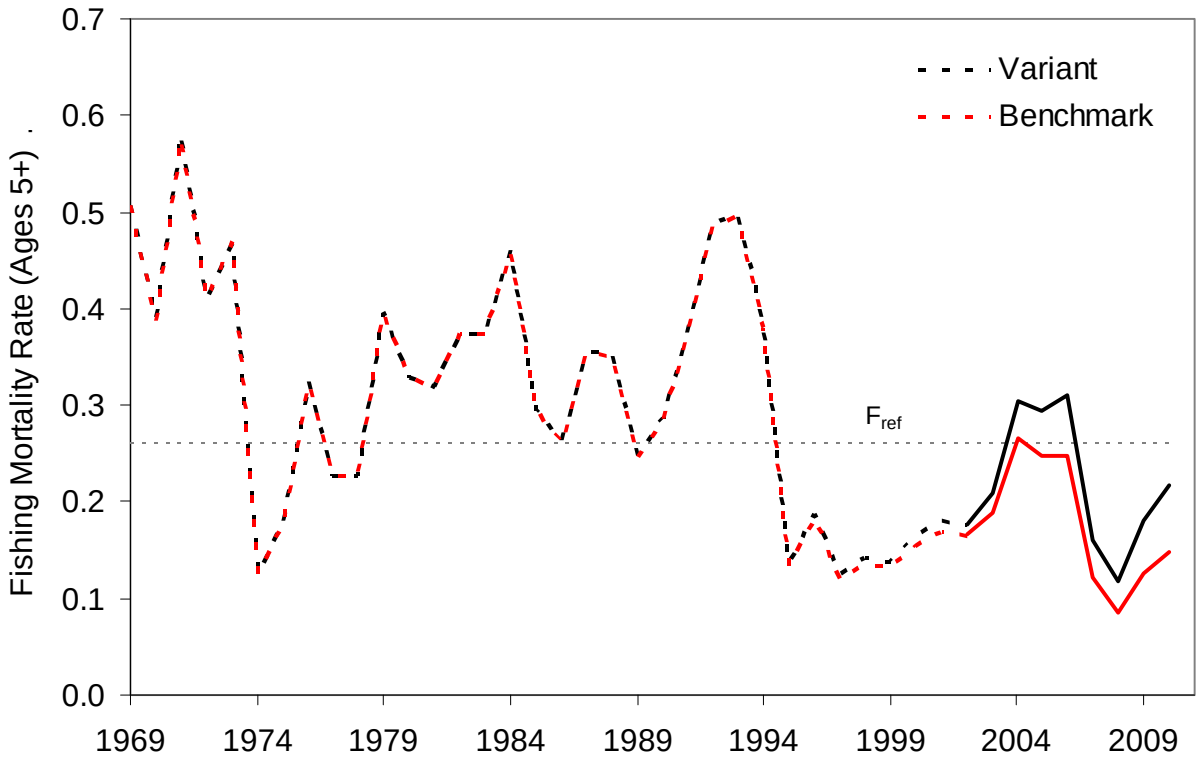


Figure A4. Fishing mortality rate (weighted by population) for eastern Georges Bank haddock ages 4+ (dotted line)/5+ (solid line) during 1969-2010 and the fishing mortality threshold reference established at F_{ref} = 0.26 for the model variation of the benchmark (Variant) and the benchmark (Benchmark).

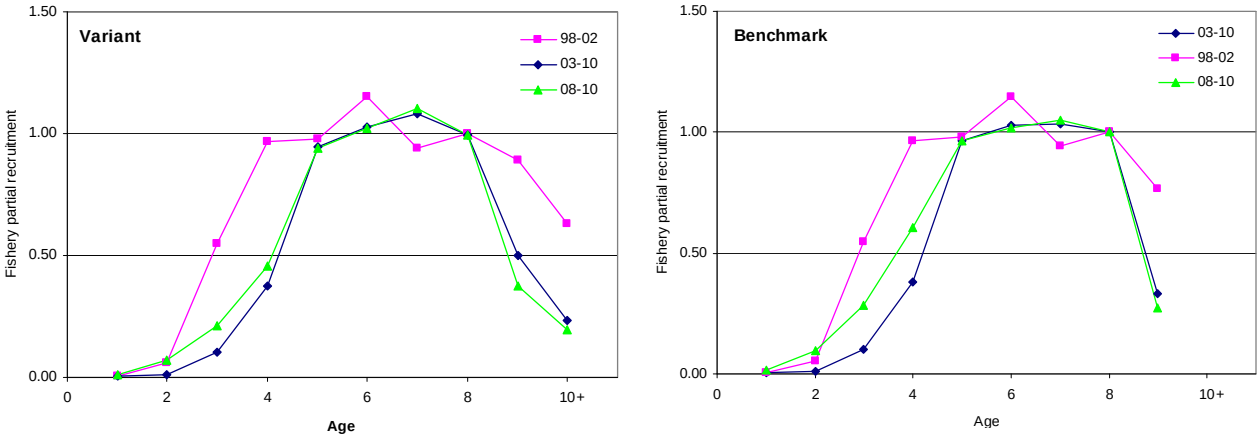


Figure A5. Population weighted average partial recruitment of eastern Georges Bank haddock for 3 time periods, 1998 to 2002, 2003 to 2010 and 2008 to 2010. The partial recruitment is normalized to ages 4-8 for years before 2003 and to ages 5-8 for years after 2002. The figure on the left is from the model variation of the benchmark and on the right from the benchmark assessment model.

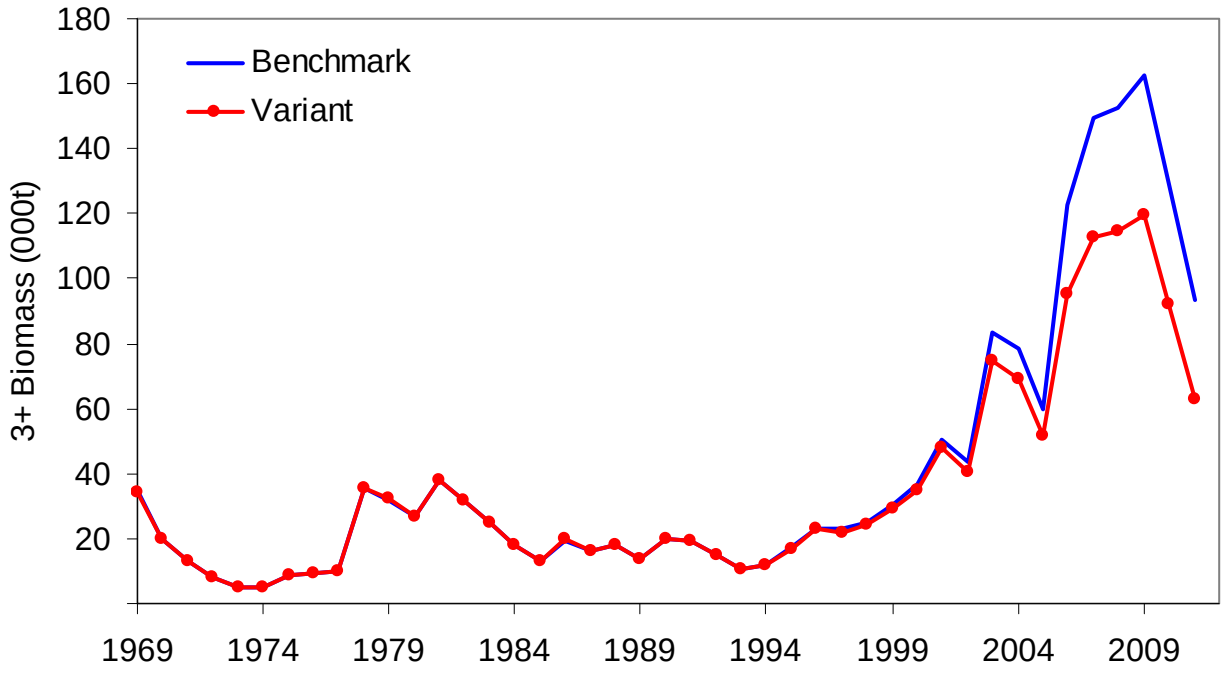


Figure A6. Comparison of beginning of year adult (3+) biomass for the model variation of the benchmark (Variant) and for the model based on the benchmark assessment (Benchmark).

APPENDIX B.

Comparison of EGB haddock TRAC catch advice, TMGC quota decision, actual catch, and 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 2011 assessment. This table was kindly provided by Tom Nies (New England Fisheries Management Council).

TRAC	Catch Year	TRAC Analysis/Recommendation		TMGC Decision		Actual Catch/ Compared to Risk Analysis	Results	Comments[2]
		Amount	Rationale	Amount	Rationale			
1999[1]	1999	6,300 mt	$F_{0.1}$	NA	NA	4,000 mt	*Below $F_{0.1}$*	
2000[1]	2000	8,800 mt	$F_{0.1}$	NA	NA	5,600 mt	*Below $F_{0.1}$*	
2001[1]	2001	9,700 mt	$F_{0.1}$	NA	NA	7,300 mt	*Below $F_{0.1}$*	
2002[1]	2002	10,700 mt	$F_{0.1}$	NA	NA	7,500 mt	*Below Fref = 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%	11,800 mt Low risk of exceeding F_{ref}	*F = 0.17 Age 3+ biomass decreased 27% 04 – 05* F = 0.267 Age 3+ biomass decreased 24% 04 - 05	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	23,000 mt	Low risk of exceeding F_{ref} Adult biomass will increase substantially	15,100 mt Low risk of exceeding F_{ref}	*F = 0.29 Age 3+ biomass increased 142% 05 – 06* F = 0.247 Age 3+ biomass increased 105% 05 - 06	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}	22,000 mt	Neutral risk of exceeding F_{ref}	12,642 mt Low risk of exceeding F_{ref}	*F = 0.36 Age 3+ biomass increased 26% 06 – 07* F = 0.247 Age 3+ biomass increased 22% 06 - 07	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}	19,000 mt	Neutral risk of exceeding F_{ref}	12,680 mt Low risk of exceeding F_{ref}	*F = 0.14* *Age 3+ biomass increased 4% 07 – 08* F = 0.122 Age 3+ biomass increased 2% 07 - 08	2003 year class specific values for projection inputs.
2007	2008	26,700 mt/ 23,000 mt	Neutral/low risk of exceeding F_{ref}	23,000 mt	Low risk of exceeding F_{ref}	15,995 mt Low risk of exceeding F_{ref}	*F = 0.09* *Age 3+ biomass increased 7% 08 – 09* F = 0.085 Age 3+ biomass increased 7% 08 - 09	2003 year class specific values for projection inputs.
2008	2009	33,000 mt /28,000 mt	Neutral/low risk of exceeding F_{ref}	30,000 mt	Low to neutral risk of exceeding F_{ref}	19,707 mt Low risk of exceeding F_{ref}	*F = 0.13* *Age 3+ biomass decreased 21% 09 – 10* F = 0.125 Age 3+ biomass decreased 21% 09 - 10	2003 year class specific values for projection inputs.
2009	2010	29,600 mt/ 25,900 mt	Neutral/low risk of exceeding F_{ref}	29,600 mt	Low to neutral risk of exceeding F_{ref}	18,794 mt Low risk of exceeding F_{ref}	*F = 0.148* *Age 3+ biomass decreased 28% 10 - 11*	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}	22,000 mt	Neutral risk of exceeding F_{ref}	N/A	N/A	2003 and 2005 year class specific values for projection inputs.
2011	2012	16,000 mt/ 13,900 mt	Neutral/low risk of exceeding F_{ref} Adult biomass will increase substantially from 2012 to 2013	N/A	N/A	N/A	N/A	2003, 2005 and 2010 year class specific values for projection inputs. PR_{9+} for projection higher than model estimate.

[1] Prior to implementation of US/CA Understanding

[2]Comments by L. Van Eeckhaute